The Nutritional Effects of Subsequent Birth Spacing in Chad

Savita J. K. Diggs

May 4th, 2021

Abstract

Early childhood nutrition has extensive effects on later adult outcomes including those relating to life expectancy, health, cognitive development, educational attainment, and lifetime earnings. This study is an exploration of how the nutrition of four-year-olds is impacted by subsequent birth spacing in the Republic of Chad. A subsequent birth interval is the length of time between a child's birth and the birth of their closest younger sibling, which is an under-explored area of research. The data for this study are from the Chad 2014-2015 Demographic and Health Survey. The analyses are completed by running multivariable linear regressions with weight-for-height z-score or body mass index z-score as the dependent variable. The results show that subsequent birth intervals affect the nutritional status of four-year-olds on both the extensive and intensive margins. That is, children with subsequent birth intervals of fewer than 36 months are nutritionally worse off, and among children who experience a short interval, an additional month of space is beneficial. These findings have implications for the global fight against early childhood malnutrition as well as for several goals in developing countries relating to improving health, education, income, and life expectancy.

The Nutritional Effects of Subsequent Birth Spacing in Chad

By Savita J. K. Diggs
under the direction of Professor Sarah Adelman

A Thesis
Submitted to the Faculty of Mount Holyoke College
in partial fulfillment of the requirements for the degree of
Bachelor of Arts with Honors

Department of Economics
Mount Holyoke College
South Hadley, Massachusetts

May, 2021

Acknowledgments

This thesis was written in less than a year but it is the product of formative work and learning throughout my life until now. I have had a multitude of phenomenal teachers and experiences that have formed my academic being. Thank you to the teachers who encouraged me to always ask questions and enjoy the process of learning and creating. In particular, thank you Jim Cox, Gary Huggett, Linda Laderach, Frank Newton, and Mike Pfeiffer. Additionally, thank you Professor Margaret Robinson for reigniting my love of quantitative analysis, for expanding my understanding of using math in the world, and for consistently supporting and guiding me.

Thank you to the Mount Holyoke Department of Economics for helping me discover my complete love for economics and entertaining every single one of my “this isn't really a question about the homework, but just conceptually, what happens when...” questions. Especially, thank you to Professor Johannes Norling for being my very first economics professor and for organizing the thesis process. Thank you to Professor Rachel Fink for always lending advice and supporting me in all ways, and to both Rachel and Professor Norling for serving on my thesis committee. Thank you to the Hedley Donovan Fund for supporting some of my research costs.

A truly heartfelt thank you to my thesis advisor, Professor Sarah Adelman. She has introduced me to invaluable people, places, and concepts over the past three years. First, she introduced me to development economics which completely blew my mind, second, to econometrics, third, to some of my best friends, and fourth, to field research and the real effects of economic development research and initiatives. Sarah has changed my understanding of economics and of the world. Thank you for laughing at every thesis meeting, even when nothing seemed to be working, for being my thesis advisor when you had no obligation to do so for the majority of the time, and for pushing me to discover my capabilities. Sarah has guided me not only through my thesis but also through my college experience. Thank you for always welcoming me into your office, even when I was just doing homework for other classes, and for always sharing stories, advice, and seltzer.

I am forever grateful for my friends, who have supported and encouraged me with laughs along the way. Most notably, Emma Coles, Simon Dutton, Maddison Erbabian, Juliet Greenwood, Gabrielle Kerbel, Blythe Schilperoort, Daphne Schneewind, and Yidan Xu. Additionally, thank you to Maddison for guiding me through economics at Mount Holyoke and to Juliet for being my thesis writing pal.

Most of all, thank you to my parents, Anju and John, and my sisters Kimaya and Makeda for being my very first and lifelong teachers and supporters. Along with my brother-in-law Jacob, they listened to my enthusiastic rants about all things economic development and despite my very low-quality explanations, they always had ideas for solving problems or thinking about things in new ways. I love them oh so dearly. Additionally, thank you for the multifaceted support from my extended family, including the Weber and Dennis-Fink families.

In loving memory of my incredible mother,
Anjani Austin Soparkar Diggs, who with her strength was
able to stick around long enough to celebrate my thesis
defense. Her love and support have been absolute.

Table of Contents

List of Tables

List of Figures

1. Introduction

Appropriate nutrition during the first few years of a child's life is essential. Early childhood nutrition has both immediate and long-term impacts. The nutrition of children under three-years-old affects mortality rates and disease susceptibility both in childhood and later as adults. Further, early childhood nutrition contributes to cognitive and structural brain development, both of which have associations with education and adult cognitive ability. Additionally, early nutrition has impacts on the gross domestic product (GDP) of a country and on work productivity. Early childhood malnutrition tends to result in overall poorer adult bodies that are less capable of physical labor, miss work more frequently due to illness, and are more likely to have inhibited cognitive function (Black et al., 2008; Shekar, 2006; Victora et al., 2008, Martorell, 1999, 2017; Fink et al., 2016).

Malnutrition is the predominant cause of childhood mortality, which refers to the death of children under five-years-old. In 2005 it was estimated that over half of global childhood mortality could be attributed to malnutrition, either directly or through causing increased vulnerability to disease, including increasing susceptibility to HIV/AIDS (Bryce et al., 2005, 1150; Shekar, 2006, 15, ix). Malnutrition, particularly under the age of three, is associated with worse fine motor skills, cognitive function, reading comprehension, and attention spans compared to people who were well nourished as young children (Victora et al., 2008, 343; Maluccio et al., 2009, 751; Shekar et al., 2006, 25).

Physical and cognitive development impediments also affect adult work capacity, productivity, and overall earnings. Likely in part due to cognitive and learning deficiencies, early childhood malnutrition leads to lower lifetime educational attainment which is often correlated with adult income (Shekar et al., 2006, 25). However, the impact of early childhood nutrition on income is even stronger than just the connection between nutrition and education (Fink et al., 2016, 106). Better early childhood nutrition leads to adults who are taller, stronger, and have leaner body composition, aspects that improve productivity and ability among adults engaged in physical labor (Martorell, 1999, 288).

A possible contributing factor to the persistence and wide-spread nature of early childhood malnutrition is birth spacing, which theoretically alters resource allocation in a household. For the purposes of this paper, 'birth space' and 'birth interval' are used interchangeably to refer to the length of time between two adjacent births within a family. Birth interval research tends to be split into two categories: previous birth spacing and subsequent birth spacing. A previous birth interval is the length of time between a child's birth and the birth of their nearest older sibling; the space before a child. A subsequent birth interval is the length of time between a child's birth and the birth of their next sibling; the space after a given child.

When the mother of an infant becomes pregnant after a short interval, she is likely to wean the infant off of breast milk prematurely because of the high physical toll of both the pregnancy and producing breast milk. This is particularly likely when the mother herself does not have adequate nourishment (Dewey and Cohen, 2007, 152; Bøhler, 1996, 107). Especially in areas with inconsistent access to uncontaminated food and water, breastfeeding decreases an infant's likelihood of death (Betrán et al. 2001, 304; Briend et al., 1988). Early weaning can cause the infant to experience increased susceptibility to disease, particularly diarrheal diseases which are a central aspect of malnutrition (Betrán et al. 2001, 304). Infants who are not breastfeeding and who are not yet old enough to fully feed and advocate for themselves are at high risk of malnutrition (Mozumder et al., 2000, 297). Resource allocation of the mother's energy and attention as well as of clean food and water are all connected to family demographics, which are fundamentally altered when there is an additional child born. Young children are the most affected by decreases in resources, warranting research into subsequent spacing and its effects.

My study is unusual because I explore nutrition in the context of subsequent rather than previous birth intervals, which is uncommon amongst birth spacing research. In a comprehensive review of the literature on anthropometrics and birth spacing, Dewey and Cohen (2007, 158) found that only 12% of the papers they determined to be reputable were on subsequent birth spacing, compared to 88% on previous birth spacing (7 and 50 respectively). This may be because panel data, data which track children over time, would be the best option for studying subsequent birth spacing since it would be possible to analyze children both before and after their younger sibling is born. Panel data are more difficult to collect and therefore are less common. The majority of the subsequent birth interval studies Dewey and Cohen (2007) found are from the 20th century. It is essential to study birth spacing in the 21st century when there are improved abilities for effective policy interventions.

Despite previous birth intervals being a similar concept to subsequent birth intervals, the challenges resulting from short spacings are fundamentally different. Previous birth spacing centers around the health of the mother and the womb and the feasibility of the mother to have a healthy gestational period, while caring for a young child. Subsequent birth spacing centers around issues of breastfeeding, the difficulties of nurturing two young children, and the distribution of resources between the children when one is more obviously vulnerable and helpless than the other. As such, it is difficult and inaccurate to transfer research done on previous birth spacing over to subsequent birth spacing circumstances.

This paper includes an exploration of birth intervals and how subsequent birth spacing affects early childhood nutrition in Chad. In a broad sense, this paper contributes to literature that examines the impacts of fertility decision-making and contraception access on development. In particular, this topic is important to the research on whether increasing international aid for contraception supply and related resources should be a priority or not. If subsequent birth spacing impacts nutritional outcomes, and contraception access allows increased agency in parental fertility, aid for contraception supply and education could be imperative. Since early childhood nutrition has lifelong consequences, further studies on possible influences of early nutrition and potential solutions to the wide-spread nature of malnutrition are essential.

In the following pages Chapter 2 expands on the importance of early childhood nutrition. Chapter 3 includes the existing literature on previous and subsequent birth spacing and how they relate to nutrition, followed by Chapter 4 which provides a background on Chad, the country of study. Chapter 5 is on the data source, the Demographic and Health Survey. In Chapter 6, I explain my empirical model, and then in Chapter 7, I present the results. Robustness checks are in Chapter 8. Chapters 9 and 10 discuss the implications of the research and conclude, and Chapter 11 is the bibliography.

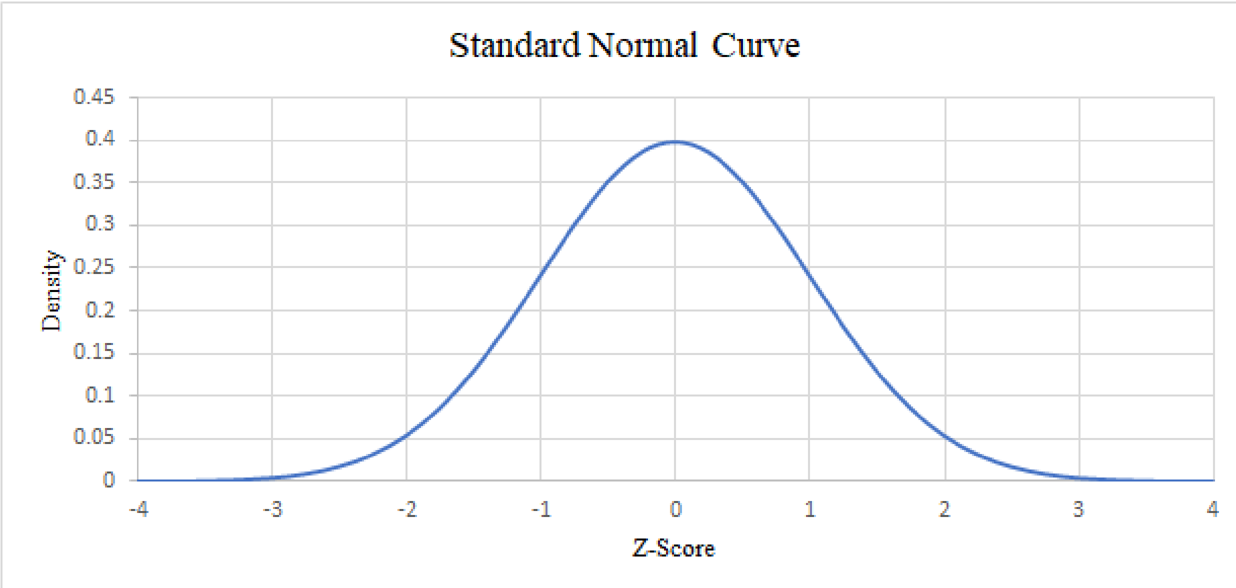
2. Early Childhood Nutrition

Nutrition affects a multitude of aspects of life. In exploring the literature, it is important to first understand the tools used to quantify nutrition. The nutritional research cited in this paper utilize anthropometric measures such as weight and height to estimate nutritional inputs without having to track every moment of consumption over a long period of time. These anthropometric measures take the weight, height, age, and sex of an individual into account. Using these measures it is possible to compare the growth of a population of interest to a healthy reference population in both the long-run (height-related measures) and the short-run (weight-related measures).

The reference population data come from the World Health Organization (WHO) Multicentre Growth Reference Study which was conducted from 1997 to 2003. The study involved collecting data during 21 home visits for each eligible infant starting at birth and continuing periodically until the child was 24-months-old. One-time data were collected on children 18 to 71 months. Thus, this study resulted in both panel data of the children followed for 24 months, and cross-sectional data of the children who were visited only once. Overall, about 8,500 children are included in the sample from the United States, Brazil, Ghana, Norway, Oman, and India. This diversity of geography allows the outcomes from the data to be globally applied as an international reference population. The children were selected based on the likelihood of them developing in circumstances which would promote healthy growth in the given locality. The areas chosen for the study had average socioeconomic statuses which would not inhibit growth. Additionally, mothers were required to follow recommendations regarding breastfeeding and other habits such as not smoking, in order to allow for ideal infant growth. These circumstances are thought to be favorable for the growth of children, so these data create what is considered to be a reasonable and accurate international reference population (de Onis et al., 2004).

Typically, the comparison between the reference population and a population of interest is represented by z-scores. For anthropometrics these are height-for-age z-score (HAZ), weight-for-age z-score (WAZ), weight-for-height z-score (WHZ) and body mass index z-score (BMIZ). The reference population data are standardized to a mean of zero. This creates a standard normal curve as seen in Figure I. In this graph 68.3% of the data points are between -1 and 1 which is within one standard deviation from the mean of zero. Then, 95.5% of the data points are between -2 and 2 which is within two standard deviations from the zero, and 99.7% are between -3 and 3 which is within three standard deviations from the mean. Data points beyond three standard deviations are extremely rare. In considering a population, the z-score of an individual is the number of standard deviations away from the reference population mean of zero that their given anthropometric measure lies. Z-scores are helpful tools in understanding the growth patterns of populations and how they relate to an individual's surroundings and resources.

Figure I



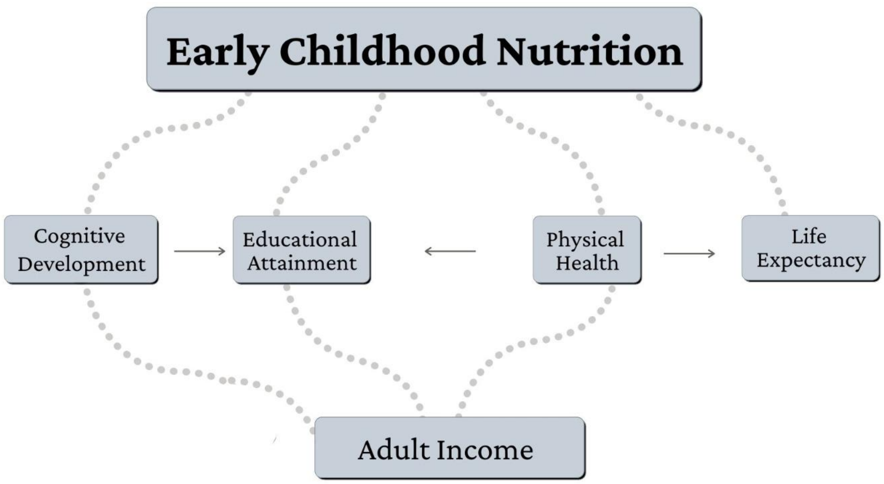
Early childhood malnutrition is detrimental from the start of a child's life. Childhood malnutrition as well as malnutrition passed from a mother to her fetus is the most common cause of childhood mortality. In 2005 it was estimated that 53% of world-wide child mortality could be attributed to malnutrition (Bryce et al., 2005, 1150). Further, undernutrition is the cause of “35% of the disease burden in children younger than 5 years” (Black et al., 2008, 253; 243). Specifically in situations of extreme deficiencies in vitamins and minerals, undernourishment can cause blindness and dwarfism, and for pregnant women can result in a newborn with severe brain and spine birth defects (Shekar, 2006, 24).

Undernutrition in children can cause structural brain damage as well as stunt cognitive functions including the development of infant motor skills and “exploratory behaviour,” particularly when undernutrition is perpetual (Victora et al., 2008, 343). These developmental hurdles can cause children to have impaired behavioural, social, attention, and learning skills. Thus, it is unsurprising that children who are malnourished perform worse in school than their nutrient-rich peers. Yamauchi (2008) finds that a lower HAZ score as a young child (the sample includes children ages one through four) correlates with starting school at a later age, repeating more grades, and attaining a lower level of education. Additional correlations between HAZ scores and educational outcomes suggest that HAZ scores at five-years-old and particularly those below four-years-old are the most predictive of later outcomes, and are therefore critical stages of nutrition (Yamauchi, 2008, 674).

HAZ is used to categorize stunting, which is when someone is significantly too short for their age (*"Stunting Policy Brief,*" 2014). This phenomenon causes poor adult outcomes, as is explored in the rest of this chapter. WHZ measures if someone is wasting, which is having a too low weight for a given height. Measures which include weight, such as WHZ tend to be more reflective of recent nutrition than those only relating to height, since weight is more responsive to changes in nutrition. Because of this, WHZ is a useful marker for short-term nutrition while HAZ represents longer-term nutrition. Most of the causal relationships mentioned in this chapter relate to HAZ, but wasting makes stunting more likely, thus a low WHZ contributes to a poor HAZ, which leads to substandard outcomes (Victora et al., 2021, 1392).

Early childhood malnutrition causes damage at the time of undernutrition as well as later in life, for it increases vulnerability to mortality, disease, and physical and cognitive disadvantages. The most influential effects are shown in Figure II. Early childhood malnutrition is correlated with increased adult risk of diet-related chronic diseases including cardiovascular disease, osteoporosis, and adult-onset diabetes. One way to understand the long-term effects of nutrition is by analyzing data from a randomly-controlled study in Guatemala of infants from six months to seven years in which all treatment group children were consistently given a nutritious drink, while the control group was given a low-nutrient drink. In later years, data were collected on adult outcomes of these children (Martorell, 2017, 7-8). Adults who had been given the nutritious drink as children tended to be taller, stronger, and have leaner body mass than the control group. These outcomes result in improved work capacity and productivity as physical laborers, as well as lower-risk baby deliveries for women (Martorell, 1999, 288).

Figure II



Muluccio et al. (2009) also consider data from the Guatemala study and find that women who had the nutritious drink as children completed 1.17 more grades of school by adulthood than the control group, although no statistically significant effect was found amongst men (749). Additionally, adult reading comprehension of the treatment group was higher by 0.28 standard deviations, and non-verbal cognitive skills similarly improved (Maluccio et al., 2009, 751).

Early malnourishment also has implications for adult wages. Fink et al. (2016, 106) estimate that early childhood malnutrition has caused the loss of hundreds of billions of purchasing power parity-adjusted potential dollars in developing countries, which directly affects those countries' GDP and development indexes. Specifically, in 2016, it was estimated that for children born in 2010, malnutrition would be the cause of a future loss in income of about 616.5 billion purchasing power parity adjusted dollars (Fink et al., 2016, 107). Again, using data from the Guatemala study, nutritional supplements from birth to 24-months-old correlate with a 46%

increase in adult men's mean wages, with no significant difference for women, possibly due to low female work-force participation (Hoddinott et al., 2008, 415). The relationship between early nutrition and income is likely due in part to the cognitive and educational losses stemming from undernutrition. Further, early malnutrition leads to shorter adults, which is a crucial issue because there tends to be an association between height and income, even after adjusting for educational attainment (Victora et al., 2008, 345).

In a comprehensive study Hoddinott et al. (2013, 1174) find that HAZ at 24 months has highly significant effects on adult outcomes including height, educational attainment, cognitive development test scores, age at leaving school, and age at marriage. There is also a correlation with the characteristics of a person's spouse, such as the spouse's age, height, and educational attainment. Additionally, a girl's HAZ at 24 months positively correlates with her age when she first gives birth and negatively correlates with her number of children overall. Children with a one unit increase in HAZ grow up to be adults in households with 21% higher per capita expenditures, which implies overall improved well-being (Hoddinott et al., 2013, 1176). Much larger and extreme coefficients are found when the binary variable of stunting is used instead of the continuous variable of HAZ to complete the same analyses determining the results above. Further, the analyses were replicated with significant coefficients when considering HAZ at 36 months or 72 months rather than 24 months (Hoddinott et al., 2013, 1176). These findings present that the nutrition of children between birth and five-years-old is essential to their later outcomes.

It is clear that early childhood nutrition has enormous effects on a child's health, developmental, educational, and occupational outcomes. The detrimental impacts of malnutrition occur both during childhood and as adults. These areas are especially important in the context of improving welfare in developing countries. Both for the sake of children and for the societies they create it is essential to determine the underlying causes of childhood undernutrition. In the next chapter I introduce what may be an important aspect of malnutrition in developing countries.

3. Birth Spacing

There is no consensus defining the length of a 'short' birth interval, despite the fact that birth spacing studies have been conducted for over 50 years. For example, Molitoris et al. (2019) focus on 36 months as a critical marker, while many studies focus either on 24 months or 1000 days, which is the approximate length of time between conception and 24 months. These researchers find that the period before age two is the most critical stage of development and therefore most clearly predict later outcomes (Martorell, 2017). Others consider much different lengths of time, such as van Eijck and de Graaf (1995, 284) who define a short birth interval as anything within six years. Overall, the vast majority of studies define a short birth space as somewhere within 18 to 36 months ("*Report of a WHO Technical Consultation,"* 2005, 2).

The WHO recommends a period of at least 24 months after a live birth before attempting to conceive again so as to "reduce the risk of adverse maternal, perinatal and infant outcomes" (*"Report of a WHO Technical Consultation,*" 2005, 18). In regards to this paper, it is important to note that the WHO report is based on previous birth spacing rather than subsequent spacing. Nonetheless, taking this recommendation into account, if at 24 months the mother becomes immediately pregnant and has a 9-month gestational period, the birth interval between the two children is 33 months. Therefore, according to the WHO, birth spacing of less than 33 months increases the risk of adverse pregnancy outcomes. In this study I define a short birth interval as anything less than 36 months, based on data availability for my variables of interest.

Previous Birth Interval

The majority of birth spacing research has focused on analyses of how a child is affected by the interval preceding their birth. This topic of discussion centers around the mother's health and the viability of a healthy pregnancy soon after a previous pregnancy. While some researchers consider the impact of back-to-back pregnancies on the mother, most research looks at the infant's health outcomes (Dewey and Cohen, 2007, 157).

Most studies on previous birth spacing consider birth intervals rather than pregnancy intervals. These studies may find false correlations between short previous birth spaces and adverse outcomes, that are in reality due to abridged gestational periods in the second pregnancy (Dewey and Cohen, 2007, 170). For example, de Jonge et al. (2014, 4) find that compared to infants with previous birth intervals of at least 45 months, a previous birth interval of less than 21 months is associated with twice the likelihood of an adverse pregnancy outcome such as a stillbirth or neonatal death. The researchers assumed nine-month-long gestational periods despite having difficulty in distinguishing exact gestation length after about seven months. This could be resulting in inflated coefficients because pregnancy outcomes are attributed to short birth intervals rather than possible premature deliveries. Additionally, there is some evidence that a short birth-to-pregnancy interval correlates with a short gestation period for the pregnancy, which may muddle the relationships between these variables (de Jonge et al., 2014).

An adverse outcome of a previous pregnancy is a strong predictor for having a short birth space before a future child, since a high rate of infant mortality increases a woman's total lifetime fertility, which necessitates shorter birth intervals. Yet, short previous birth intervals increase the likelihood of infant mortality, creating a cycle of short birth intervals and adverse pregnancy outcomes (de Jonge et al., 2014, 6; van Soest and Saha, 2018). Lengthening previous birth intervals is only significant in impacting infant mortality in some situations. Molitoris et al. (2019, 1365) find that spacing of less than 36 months significantly heightens the risk of infant mortality, while an interval of more than 60 months has little to no effect. Further, the relationship is much stronger and more significant in developing countries than in developed, high-income countries. Lastly, van Soest and Saha (2018, 17) are among several researchers who claim an association between the survival of each of two adjacent siblings in the presence of short birth spacing. However, whether the previous child dying or staying alive makes it more likely for the subsequent child to survive is disputed.

Birth interval research reaches beyond that of infant mortality to also consider nutrition. Mozumder et al. (2000, 259) find that previous birth spacing has no significant correlation to moderate or severe malnutrition. Contrarily, a study looking at children in Bangladesh found that 52.8% of children born with a previous birth space of up to 23 months were stunted, while only 37.6% of children born 48 or more months after their sibling were stunted (Rayhan and Khan, 2006, 560). These associations suggest that longer previous birth intervals increase nourishment. Whether this effect is also evident in subsequent birth spacing will be explored in this paper. Overall, Mozumder et al. (2000, 290) say that “longer spacing between two births allows for the optimum use of the parent time inputs and resources for each child, which, in turn, improves child health,” referring to both previous and subsequent spacing.

Subsequent Birth Interval

Similarly to previous birth spacing, much of the research on subsequent birth spacing centers around resource allocations relating to the mother. The difference is that while mothers have little control over the effect of a short birth interval on the younger child, some of the effects on the older child are due to maternal choices. In particular, subsequent spacing research largely surrounds the issue of breastfeeding.

There is some evidence supporting a correlation between lower infant growth rates and being weaned off of the breast milk of a pregnant woman, compared to the growth rates of infants weaned off of nonpregnant women (Bøhler, 1996). Further, children with close younger siblings may not gain all of the advantages of breast milk, either due to early weaning or a lack of quantity. It is common for a mother to wean her infant off of breast milk if she becomes pregnant, because pregnancy drains a woman's energy, protein, vitamins, and minerals. In fact, pregnant women require 13% more energy and 54% more protein than non-pregnant non-lactating women. Lactation raises protein needs by 54% and requires 25% more energy. Thus, women who are both pregnant and lactating simultaneously need an enormous increase in nutrients. By weaning the baby and therefore stopping the production of breast milk, more of a mother's resources can go towards the pregnancy rather than the breastfeeding child (Dewey and Cohen, 2007, 152). This practice is particularly common in developing countries in which a mother may not have access to a comprehensive and nutritious diet, thereby limiting her energy stores (Bøhler, 1996, 107). Additionally, pregnancy may cause lactation to decrease and breast milk taste to change, both of which can result in infant-initiated premature weaning (Jayachandran and Kuziemko, 2011, 1489).

There are several factors involved in a mother deciding when to wean a child off of breast milk that are separate from an infant's demonstrated readiness to wean. One factor is that lactation is a natural contraceptive. The hormones related to consistent lactation cease a woman's menstruation, a phenomenon known as amenorrhea. Using breastfeeding as a type of contraception is known as the lactational amenorrhea method (LAM). Additionally, breastfeeding may lead to a natural biological contraceptive through a malnutrition-based stop to ovulation if lactation depletes a mother of necessary nutrients and she does not consume an adequate diet to replenish herself. Thus, while it is common in developing countries for women to stop breastfeeding when they become pregnant, there is also a biological effect preventing pregnancy from occurring very soon after a previous birth, as long as breastfeeding is consistent enough (Jayachandran and Kuziemko, 2011, 1488). Therefore, extremely close birth spacing may be avoided if the older child of a pair is consistently breastfed, however, once the mother starts ovulating again, if she becomes pregnant — which could still create a short birth interval — the older child is likely to be quickly weaned.

The length of time between birth and when LAM becomes ineffective varies by country. Maintaining the hormones required for lactational amenorrhea requires high frequency of breastfeeding and rigor of suckling. This is why mothers are most likely to be lactationally amenorrheic if they are exclusively breastfeeding their infant rather than providing any other food source. The intensity of breastfeeding can come from culture, which explains the geographic differences in length of postpartum amenorrhea (Brown, 2006, 499). For example, based on data from 2003 in Ghana, women breastfed for a median of 23 months but were only amenorrheic for a median of 10.8 months. In contrast, data from 1999 in Zimbabwe found that women breastfed for a median of 19.8 months, 12.4 of which they were amenorrheic. This implies that Ghanaian women tend to wean their children for more than a year, while Zimbabwean mothers tend to breastfeed more intensely, and then wean over about seven months (Brown, 2006, 498). There is also evidence that in son-preference cultures, women who know about lactational amenorrhea purposely wean girl babies early, in order to quickly become pregnant again, hopefully with a boy. This is particularly common when there have yet to be any sons in the family or when the mother has not reached her optimal number of children (Jayachandran and Kuziemko, 2011, 1516). All of these factors play into lactation decisions that then affect the infant and the likelihood of a short subsequent birth interval.

Breast milk has numerous and tremendous positive effects on a child, particularly in developing countries, so the premature weaning of an infant due to becoming pregnant or desiring a new pregnancy could present concerns for weaned children in resource-poor areas. Breast milk contains important antimicrobial elements that become effective as they interact with matter in the infant's intestines and hence stimulate immunological growth of probiotics (Isaacs, 2005, 1287; Marrow et al., 2005, 1305). Another advantage of breast milk is that the glycans in the chemical makeup of breast milk act as “anti-adhesion agents” that inhibit pathogens from binding to their hosts (Morrow et al., 2005, 1304). This is particularly crucial for babies in areas lacking access to potable water and uncontaminated food, for this means that regardless of what the mother ingests, the breast milk will not have active pathogens. This essential reaction relates to child mortality due to food- and water-borne diseases, particularly diarrheal diseases.

Exclusive breastfeeding significantly decreases the chance of under-three-months-old mortality due to diarrheal disease or acute respiratory infection. A smaller but still statistically significant effect was found for partial breastfeeding and for breastfeeding up to eleven months (Betrán et al. 2001, 304). Even for children 18 to 36 months there is a negative association between breastfeeding and mortality; according to Briend et al. (1988), non-breastfeeding babies in this age range are three times more likely to die within a month of a given interview compared to their exclusively or partially breastfeeding peers.

Beyond the issue of contaminated food and water, an additional concern to early weaning is the quantity of non-breast-milk food and water that an infant consumes. Mozumder et al. (2000, 295) present that "it is common for children to compete for parental resources, which include nurturing and food...This competition results in a negative effect on the health of a child, who is neither old enough to compete with his older siblings, nor breast-fed, due to the presence of younger, breast-fed siblings." Even if the child is able to effectively compete for a substantial quantity of food, children 12- to 23-months-old are especially vulnerable to malnutrition due to their inability to feed themselves adequately while their mother is preoccupied with their younger sibling. This leads to the claim that children under one year old are significantly less likely to be malnourished than children between one- and two-years-old, when there are two children under the age of two. Female children are particularly vulnerable (Mozumder et al. 2000, 297, 293).

4. Chad

The location studied in this research is the Republic of Chad, herein referred to as “Chad.” Chad is a land-locked country in northern-central Africa. It is the fifth largest country on the continent and is bordered by Libya, Niger, Nigeria, Cameroon, the Central African Republic, and Sudan. The capital of Chad is N'Djaména which is located in the southwestern area of the country, quite close to the Cameroon border. The northern half of Chad is in the Sahara Desert and has very little rainfall, while most of the rest of the country experiences a three-month rainy season. There are two main rivers and four large lakes which allow for prosperous fishing (“*Demographic, Health, and Multiple Indicators,*” 1-2). There are over 100 languages and dialects spoken in Chad which can be categorized into 12 types of language. The official languages of the country are French and Arabic (Grove and Jones, 2021).

A Brief Political History

Chad was ruled by several different battling kingdoms and empires from the 11th through the 19th centuries. In 1891, France began to colonize Chad, a process which was completed around 1913. Chad remained a French colony until its independence on August 11, 1960. Following independence, there were decades of conflict over power and civil rights in the form of civil war, guerrilla operations, coups d'état, and human rights violations that led to mass civilian deaths. Violence and power-changes were quite common during this period until the free and democratic election of Idriss Déby under a multi-party system in 1996. Déby was reelected in 2001 as well as in all subsequent elections and is still the president, although there has been consistent controversy regarding the accuracy of the elections, including opposition boycotts. The parliament has voted multiple times to broaden Déby's powers as president and to allow him to run for additional terms. ("*History of Chad,*" 2021; *BBC News*, 2018; Grove and Jones, 2021)

Throughout Déby's presidency there has continued to be revolts and violence, including a full-scale rebellion, due to issues of government corruption and human rights abuses. Additionally, conflict erupted in 2003 in the Darfur region of Sudan, which caused hundreds of thousands of Sudanese people to take refuge in Chad. Violence was rife at the Sudan-Chad border for several years, leading to the death of Chadian civilians and Sudanese refugees. UN peacekeeping groups became involved even as international aid organizations removed their workers from the area due to abductions and murders. This conflict was mostly resolved by 2010. Meanwhile, internal conflict has continued, particularly due to the terrorist organization Boko Haram.

In 2018 Chad adopted a new constitution which is still in use today. This constitution outlines the roles of the president and National Assembly, both of which are elected by Chadians. Presidents are limited to two six-year terms while National Assembly members have five-year terms. The judicial system is made up of a Supreme Court and several criminal and civil courts. The term limit for the presidency will not be enforced retroactively, so Déby will be able to start the first of his 'counted' terms if he is elected following his current term. Based on the consistent and rampant accusations of poll corruption, he is likely to be elected and remain president for an additional 12 years (*BBC News*, 2018; Grove and Jones, 2021).

Chad in 2014 and 2015

In this study I use data that were collected in 2014 and 2015. The population in Chad in 2015 was about 14.11 million people, with children under 15-years-old making up almost half of the population. There was a close-to-even sex split implying a lack of sex-preference culture. Around 77% of the population lived in rural areas, a decrease over the previous 55 years from 93%. About 40% of the land is cultivated for agricultural uses ("*Chad*" The World Bank). Chad produces cotton, livestock for slaughter, and fish. Additionally, there are several natural resources in Chad including the mineral salt natron, gold, uranium, and titanium. Most importantly, in 2003 Chad started mining oil, at which point Chad's GDP growth rate increased significantly (Grove and Jones, 2021). Chad's GDP peaked in 2014 at $13.94 billion in current US dollars, before decreasing to $10.95 billion in 2015. If the GDP were evenly split amongst the population, that is, GDP per capita, each person would have had $776.02 for the year of 2015 ("*Chad*").

Family Demographics and Fertility Decisions

The total fertility rate (TFR) of a country is the average number of births per woman. Chad has among the highest TFRs in the world. The rate continues to be well above the global mean despite the fact that Chad's TFR has been falling since a 1996 high of 7.4 births per woman

(“*Chad*"). In rural areas women have on average 6.8 children each, while the fertility rate in urban areas is 5.4. Overall, the mean household size is 5.8 people (“*Demographic, Health, and Multiple Indicators*”).

There are several factors that contribute to Chad's high TFR. First, women tend to begin having children as adolescents. In 2015, 68% of a sample of women ages 20 to 49 reported that they had given birth to at least one baby by the time they were 20-years-old, while 13% said they had given birth before age 15. A second factor that leads to the high TFR is a high level of desired fertility. When the sample was asked their ideal number of children, the average for women was eight while the average for men was eleven. The averages among married adults and among people who already had children were even higher. Thirdly, women tend to have short birth intervals in between their children. About two-thirds of children are born within three years of their closest older sibling. Of married women who want to have an additional child, 24% want to become pregnant immediately, while 43% report wanting to wait at least two years before an additional child. These numbers suggest that there is some interest in birth spacing that may even be understated since these measures do not take into account timing of the previous birth. Yet, despite possible interest in spacing, close birth intervals are more common than not (“*Demographic, Health, and Multiple Indicators,*”).

Lasty, lack of access to contraception and low use of modern or traditional contraceptives may contribute to Chad's high TFR. The Demographic and Health Survey organization (DHS), which will be expanded upon in the following chapter, considers modern methods of contraception to be sterilization, pills, injections, condoms, LAM, and 'other.' Traditional methods recognized are the rhythm method — also known as periodic abstinence — , withdrawal, and 'other.' Overall, 5.4% of women reported using contraception, the majority of whom were using modern methods. The most common modern method was injection, followed by implants and LAM. Periodic abstinence was the most often implemented traditional method ("*Demographic, Health, and Multiple Indicators,*" 97). Most modern contraceptives were acquired at public hospitals or clinics. Of married women who were not using contraception, 60% planned never to use contraceptives while 17% were unsure if they ever would. Independent of these percentages, of the same category of women, 19% wished to use contraception in order to space out their children ("*Demographic, Health, and Multiple Indicators,*" 110, 104). It is likely that lack of knowledge is not the primary inhibitor to contraception use, for in 2015 about 63% of adolescent and adult women and 76% of men knew at least one method of modern contraception. Overall, contraception is not common in Chad but whether this is due to a lack of desire for contraceptives or a lack of access is unclear.

5. Demographic and Health Survey Data

Data Source

The data analyzed in this study come from the Demographic and Health Survey (DHS). The DHS Program is based in the United States and periodically surveys people in 92 developing countries to create nationally representative cross-sectional datasets ("*Country List*"). To create this type of dataset the DHS Program interviews several thousand people throughout a given country, all within about a year. Eligible household members are interviewed and asked questions relating to health, consumption, material possessions, resources, and household decision-making. People are eligible if they have stayed in the sampled household the night before the interview and meet the age restrictions. Interviewed women must be aged 15 to 49 while men must be aged 15 to 59 ("*Demographic, Health, and Multiple Indicators*"). The DHS splits up the survey questions into multiple datasets. In this analysis I will be using the Children's Recode dataset which has one entry for every child who is 59 months or younger and whose mother participated in the Chad 2014-2015 DHS. These data include detailed information about each child and mother as well as some aggregate information about the family ("*Dataset Types*").

In this study I utilize data from the DHS conducted in Chad in 2014 and 2015. This was the third and most recent DHS in Chad. The first was in 1996 and 1997 and the second was in

2004 (“*Country Main: Chad*”). The data for the 2014-2015 survey were collected by the Chad National Institute of Statistics, Economic Studies, and Demographic Studies, with technical help from ICF International. The project was funded by the Government of Chad, the United States Agency for International Development (USAID), the United Nations Population Fund, the United Nations Children's Fund (UNICEF), the French Agency for Development, the Swiss Confederation, and the World Bank (“*Demographic, Health, and Multiple Indicators,*” ii).

Almost half of Chad's 2015 population was under 15-years-old, which is common in countries with high TFRs (“*Chad*”). This bottom-heavy age distribution is reflected in the 2014-2015 survey data. The largest number of respondents were ages 15 through 19, at 22% of all female interviewees (“*Demographic, Health, and Multiple Indicators,*” 476). Specifically in the Children's Recode dataset, about 70% of respondents were ages 20 through 34, with the largest age cluster of respondents at ages 25 through 29. Considering that this dataset only includes women who have a child under 60-months-old, this age distribution is reasonable and expected. Overall, 96.5% of sampled women were actually interviewed for the DHS.

Sample

This study examines the impact of subsequent birth spacing on the nutritional health of 4-year-olds. This group of children ages 48- to 59-months-old are referred to as the index children in this research. Based on previous literature and data availability, I define short birth spacing as an interval of less than 36 months. The focus on 4-year-olds in this study allows time for the effects of short subsequent birth spacing to develop for at least a year. Index children are split into two categories: treatment and control. Children are 'treated' with short subsequent birth spacing if they have a sibling who is less than 36 months younger. Index children without younger siblings or with siblings born 36 or more months after their own birth are in the control group.

The base DHS Children's Recode dataset is restricted by the eligibility criteria for this study. The base dataset includes 3,609 four-year-olds. The restrictions are displayed in Table I. First, because this study centers around birth intervals, all index children for whom they or a younger sibling has missing age-in-months data are excluded. This restriction has the largest effect on the sample size at a decrease of 44.39%. Second, index children missing anthropometric data for WHZ or BMIZ are excluded. Third, index children who are twins or who have younger siblings who are twins are dropped from the sample since multiple children from one pregnancy alter family dynamics differently than a single child. Fourth, all respondents with missing observations for control variables or who have inconsistent demographic observations such as unexplained changes in the number of children in the household, are excluded.

The final criteria for exclusion from the sample is parental contraception use. People who intentionally space out children may be fundamentally different as parents and in resource distribution than those who do not control their fertility. In order to pick up the direct relationship between nutrition and subsequent birth spacing rather than the relationship between nutrition and parental fertility decisions, it is best to only include children whose parents were not controlling the timing of births. Ideally, children whose parents had used contraception at any point from 2010 to 2015 would be excluded, however, with these data it is only possible to know who had been using contraceptives at the time of their interview in either 2014 or 2015. Overall contraception use was quite low in 2014 and 2015 but there were some people implementing contraceptive methods. Since it is impossible to know exactly which parents were using contraception during this period, I assume that mothers using contraception at the time of their interview may have been the ones who had access throughout the years. As such, all children whose mother reports using contraception in the 2014-2015 data are excluded from the sample. While this assumption may seem extreme, only 4.54% of the sample is dropped due to this provision, disregarding that some of these children are excluded for other reasons as well. Contraception use is so rare that removing these children from the sample is inconsequential.

Table I

Index Sample Exclusion Statistics

	Numeral Decrease in Base Set	% Decrease in Base Set
Second Four-Year-Old[1]	30	0.83
Missing Age-in-Months (Index Child)	1,385	38.38
Missing Age-in-Months (Sibling)	1,559	43.20
Missing WHZ	1,582	43.83
Missing BMIZ	1,582	43.83
Mother Currently Using Contraception	164	4.54
Missing Diarrhea Information	77	2.13
Missing Mother's Education	4	0.01
Inconsistent Family Demographic Data	157	4.35
Twins in the Family (Under 5-Years-Old)	109	3.02
Total Excluded 1,872 (51.87%)		
Total Included 1,737 (48.13%)		
Total Base Set 3,609 (100.00%)		

Notes: The base set is all known four-year-olds. This excludes any potential four-year-olds who have no age data. The majority of dropped observations are due to missing age-in-months data. After the index children and their siblings with no age-in-months data are excluded, the other criteria decrease the index sample size by only an additional 7.48 percentage points. Many of the ineligible children are excluded due to multiple factors; all of the children missing anthropometric data are missing both WHZ and BMIZ. There is also immense overlap between inconsistent family demographic data and the missing data. These confounding exclusions suggest incomplete or lower quality data collection in excluded households.

[1]There are some pairs of siblings in these data who have such close birth spacing that they are both four-years-old. The older of the two is categorized as an index child while the younger is excluded from the index group but is included as a sibling of an index child.

The index children are not the only part of the sample for this study. All treated children have at least one younger sibling. The younger sibling closest in age to the treated index child is kept in the dataset. Most of these children range from 12- through 47-months-old, although there is one child who is 48-months-old because their older sibling who is the index child is 59-months-old, thus both are 4-years-old. Additionally, 439 control children have younger siblings who were born after the short subsequent birth interval threshold of this study. These children were born more than 36 months after the index child. The closest younger sibling of each control child is kept in the dataset. These siblings are 0- through 23-months-old.

6. Empirical Model

In this study I develop a simple linear model with an interaction to determine the effects of short subsequent birth spacing on nutrition. By using this model it is possible to determine how each aspect on the right-hand side of an equation individually affects the left-hand side outcome. The interaction term allows for additionally understanding how variables jointly affect the outcome. The model includes control variables which means that it takes into account other factors which may affect nutrition beyond the effects of the birth interval. Holding the control variables constant shows how a change in birth spacing causes a change in nutrition amongst index children. This process is called a regression. The exact inputs into the model will be described in this chapter following the assumptions of this study.

Assumptions

The identification of the nutritional effect of short birth spacing is based on the assumption that the length of each child's birth interval is exogenous. This means that whether or not an index child is treated is independent of the child's health and nutritional inputs, except for the effects of the treatment itself. Since parents are often the distributors of resources for young children, including resources relating to health, the foundational assumption used in this empirical strategy is that parents are limited in their ability to control birth spacing. This assumption is supported by the very low usage rate of contraception and other family planning strategies in Chad. At the time of the 2014-2015 DHS data collection, only 5.4% of all women surveyed were using contraception ("*Demographic, Health, and Multiple Indicators,*" 91). Once the other exclusionary factors are accounted for, in the sample otherwise eligible for this study, only 3.77% of women were using contraception. The types of contraception used by this group of women are displayed in Table II. Overall, in the sample analyzed in this study 83.42% of women reported that they did not intend to use contraceptives in the future.

Table II

Contraception Use by Type

	Number Using	% Using
Injections	25	35.71
Implants	15	21.43
Lactational Amenorrhea (LAM)	12	17.14
Periodic Abstinence (Rhythm)	7	10.00
Condoms	5	7.14
Other	4	5.71
Pills	2	2.86
Total Using Contraception	70 (100%)	

Notes: This sample is of the mothers using contraception whose children would otherwise be eligible for this study. This group of 70 women would make up 3.77% of the study sample if they had not been using contraception. There are also 52 women with missing data for this variable who are also dropped at this stage due to uncertainty regarding their contraception use.

The assumption that parents do not control birth intervals in this sample is further supported by stated preferences for a high level of fertility; men and women, both with and without children, and both married and unmarried, desire to have between eight and sixteen children ("*Demographic, Health, and Multiple Indicators,*" 88). The index children are on average only the fourth or fifth child in their family, so their parents likely want to continue having additional children. Preferences for large numbers of children add legitimacy to the idea that parents are not using contraception, including period abstinence, which in turn inhibits parents from controlling the spacing of their children. Additionally, on average treated children have a previous birth interval of 28.4 months while control children have a previous interval of 30.4 months. This disparity may be due to a difference in parity between the two groups, which is mentioned in Table III. Regardless of the difference, these lengths of previous birth spaces lend support to the assumption that parents were not controlling fertility, particularly not in regards to birth spacing, since both of these means are under the threshold of 36 months. Lastly, This study also depends on assuming the accuracy of the data collection. This is particularly important for the variables of age-in-months, weight, and height. Concerns relating to data collection and age are discussed in Chapter 9.

Model

The base model for estimation is:

$$y_i = \beta_0 + \beta_1 treatment + \beta_2 interval + \beta_3 interaction + \beta_4 X_i + \beta_5 \Gamma_i + \beta_6 \Theta_i + \epsilon_i$$

where the subscript *i* represents the unique values for each index child i. The dependent variable y_i is one of two anthropometric variables: weight-for-height z-score (WHZ) or body mass index z-score (BMIZ). These outcomes depend upon the inputs on the right-hand side of the equation, which are called the independent variables since their values are not influenced by the left-hand side. The variables with coefficients β_1, β_2, and β_3 are those relating to birth spacing. X , Γ , and Θ represent various household characteristics. All of these parts of the equation will be explored further in the following sections. The error term ϵ_i absorbs mistakes in the model creation and in data collection. If all of these aspects were to equal zero, y_i would equal the constant, β_0, however, in this situation it is impractical and in fact impossible for every other part of the right-hand-side to equal zero, so the constant means very little in this model.

Measuring the Impact of Birth Spacing

The coefficients of particular interest in this model are β_1, β_2, and β_3. The variable *treatment* is a binary variable that equals 1 if the index child has a short subsequent birth interval and equals 0 otherwise. The coefficient of β_1 in the multivariable regressions represents the impact of a child being treated on the child's anthropometrics, holding all other variables constant. I expect to see a negative value, which would show that having a short subsequent birth interval is correlated with worse anthropometric outcomes.

The variable *interval* is a continuous measure of birth space in months. For each child, this variable is the number of months between their birth and their closest younger sibling's birth. Any child who had no younger sibling at the time of the data collection has a value equal to their age-in-months for this variable, since that is the longest subsequent birth interval that can be guaranteed. Although the spacing for many control children likely continued to grow larger beyond the dates of these data, this measurement takes into account that some mothers may have given birth to a new sibling quite soon after the data collection. The mothers of 12% of the control children were pregnant at the time of the data collection.

The coefficient on *interval* is β_2 which represents the effect of birth interval on the dependent variable for children in the control group. The impact of birth interval on the treatment group is captured by the coefficient on *interaction*, which will be described in the next paragraph. I expect β_2 to be positive but statistically insignificant from zero. This is because I expect that longer subsequent birth intervals are always better than short intervals, particularly when the range is between 36 and 59 months, as it is for the control children. Yet, control children have had less time to be impacted by having a younger sibling than treatment children, and about 45% of the control children still had no younger sibling at the time of the data collection. Therefore, I expect that in this sample, beyond 36 months, additional months of spacing make little to no difference in short-term nutrition markers.

The variable *interaction* is the product of *treatment* and *interval*. This is called an interaction term and it measures the difference in the slope of the impact of birth spacing on treatment children versus control children. Effectively, assuming that treatment children would appear like control children if they had not had a short subsequent space, the coefficient on *interaction*, β_3, portrays the impact of birth spacing for only the treatment group. I expect that β_3, will be positive. This would reflect that holding all other variables constant, the treated children with longer birth intervals have better anthropometrics than the treated children with shorter intervals. Thus, I expect to see that amongst treated children, longer birth intervals are advantageous.

In addition to the variables of particular interest, the model includes control variables. This makes it possible to take into account other variables that may impact a child's anthropometrics beyond the effects of subsequent birth spacing, and to individually separate the effect of each variable. Thus, the model does not erroneously portray the effects of other variables as the direct effect of subsequent birth interval. The control variables are split into three groups: X_i, Γ_i, and Θ_i. The vector X_i is composed of characteristics of the index child such as their sex, their birth order, and whether they had diarrhea in the two weeks preceding the data collection. Γ_i is a vector of a set of characteristics belonging to the index child's mother such as her height, age, total number of children, and her years of education. The vector Θ_i is a combination of household characteristics including the wealth index, region, and whether the house is in a rural or urban area. The model error term is represented by ϵ_i.

Dependent Variables

The dependent variable in the model is either weight-for-height z-score (WHZ) or body mass index z-score (BMIZ) depending on the particular regression. As mentioned in Chapter 2, these measures compare each index child's weight and height to those of a healthy reference population. Other commonly analyzed anthropometric variables are height-for-age z-score (HAZ) and weight-for-age z-score (WAZ), both of which are less reactive in the short-term to changes in nutritional input than WHZ and BMIZ. HAZ is not included as a dependent variable because it tends to represent nutrition and growth in the first two years of a child's life more than any other period. HAZ is a measure that can be used to determine if someone is stunted, that is, if they are too short for their age. Stunting is due to poor growth up until about 2-years-old, after which HAZ does not seem to strongly reflect recent nutrition (Martorell, 2017, 4). Many of the index children with short subsequent intervals were past this threshold or quite close to it by the time their younger sibling was born. This means that HAZ is not a responsive measure to short subsequent birth spacing, particularly when a short interval is defined as within 36 months.

The anthropometric measures show short-term nutrition, long-term nutrition, or a combination of both. HAZ is considered a long-term nutrition marker because it continues to reflect very early childhood nutrition throughout a person's life, since it focuses on the slow-to-change factors of height and age. WHZ and BMIZ are short-term nutrition markers for they take weight into account which is responsive to recent nutrition changes. WAZ reflects both short- and long-term nutrition by relating to weight and age. WAZ is not included as a dependent variable because it may reflect nutritional status from before the treatment period rather than only showing the anthropometric outcomes which are due to having a short subsequent birth interval, or due to the control variables.

Control Variables

A few of the independent variables in this research warrant explanations. All of the control variables are listed in Table III. A few of the variables warrant explanations. The *Wealth Index* is an estimation of a household's living standard relative to other surveyed households. It is composed of several variables about resources including source of water, the materials of which the house is constructed, the size of the house and land, type of toilet, and type of cooking heat. Additionally, the index takes into account whether a household has particular possessions including livestock, a radio, a refrigerator, a motorcycle, a bicycle, a telephone, a clock, and various pieces of household furniture ("*Wealth Index Construction*"). The measure is computed as numerals one through five, where lower numbers represent lower standards of living.

The variable *Mother's Height* includes nine mothers who do not have a listed height. These mothers are given the mean height of the entire index sample, 5.31 feet. *Parity* is the number of births preceding and including the index child that the child's mother has had. In 2014 and 2015, the years the data were collected, the DHS recognized 21 regions in Chad. The *Region* variable lists the regions in the following order: Batha, Borkou/Tibesti, Chari Baguirmi, Guéra, Hadjer-Lamis, Kanem, Lac, Logone Occidental, Logone Oriental, Mandoul, Mayo Kebbi Est, Mayo Kebbi Ouest, Moyen Chari, Ouaddaï, Salamat, Tndjilé, Wadi Fira, N'Djaména, Barh el Gazal, Ennedi, and Sila. Lastly, there are three dummy control variables that each equal one when their name is true and zero otherwise. These are *Male*, *Urban* — as opposed to rural —, and *Diarrhea in the Last 2 Weeks*, specifically the two weeks preceding the data collection.

As displayed in Table III, the difference between the control and treatment groups is not statistically significant for most of the control variables. Statistical significance portrays the percentage chance that an estimation is wrong and that the effect is actually no different from zero. The significance of each estimation is the p-value and is indicated by stars. In Table III the significance test determines if the difference between the treatment and control groups is significantly different from zero or not. The findings show that for most of the variables, the difference between the two groups is indistinguishable from zero. This supports that the populations are similar and that the treatment of some index children experiencing short subsequent spacing is random. By definition, the *Birth Interval* variable is significantly different. Additionally, on average the control children are 0.42 months older, tend to be 0.87 higher in parity, and have mothers about 2.22 years older.

Table III

Summary Statistics

	Control Mean	Treatment Mean	Ctrl-Trmt	Std Error	Obs
Birth Interval	48.553	24.170	24.3828***	0.3154	1737
Male	0.479	0.505	-0.0261	0.0241	1737
Age in Months	53.999	53.575	0.4235**	0.1544	1737
Parity	4.746	3.868	0.8786***	0.1221	1737
Diarrhea in the Last 2 Weeks	0.102	0.088	0.0150	0.0141	1737
Mother's Total Children	4.737	4.758	-0.0202	0.1069	1737
Mother's Age	31.065	28.819	2.2464***	0.3183	1737
Mother's Height (ft.)	5.312	5.300	0.0119	0.0106	1737
Mother's Years of Education	1.194	1.142	0.0518	0.1271	1737
Wealth Index	3.022	3.080	-0.0575	0.0642	1737
Urban	0.186	0.194	-0.0080	0.0189	1737
Region	11.159	11.003	0.1555	0.2873	1737
Total Participants	800	937			1737

Notes: Control-treatment is the difference in means of the control and treatment groups. The entire sample is of index children. *p<0.5, **p<0.01, ***p<0.001.

7. Results

The models I analyze have either WHZ or BMIZ as the dependent variable. In all of the models the results are clustered by region, and a dummy variable for each of the 21 regions is included as a control. The reference region is Batha. In other words, the model takes into account that nutrition may vary by region and separates regional effects from the effect of subsequent birth spacing. All models include variables for whether an index child is treated, their birth interval, the interaction term between treatment and birth interval, the child's sex and parity, and the mother's age and height.

Weight-for-Height Outcomes

The first models of consideration are those with weight-for-height z-score as the dependent variable. Table IV displays four models which each include different control variables. Across all of them I expected to find that short spacing led to worse WHZ. Model (1) includes only the basic control variables. In this model, having a close younger sibling decreases a child's WHZ by 0.633 at the 5% significance level. Additionally, for treated children, a one month longer interval increases their WHZ by 0.0160, also at the 5% significance level. These results follow my expectations and show that spacing correlates with a statistically significant fall in nutritional status.

The only significant control variable in Table IV and Model (1) is recent diarrhea at 5% significance. As expected, children who had diarrhea in the two weeks preceding the data collection are likely to have worse WHZs by 0.176. This is reasonable since diarrhea can cause weight loss due to rapid depletion of liquids, and WHZ is based on weight.

The majority of the control variables are not significantly different from zero, yet the signs of the coefficients can be considered. Most of the signs of the coefficients support the expectations in this study. The *Male* variable has a positive coefficient that reflects the often-found outcome of boys having better nutrition than girls. *Parity* also has a positive coefficient. This could be due to positive effects of care from old siblings up to a particular parity. The coefficient on *Mother's Age* is negative which could be because older mothers are likely to have more children overall which could lead to worse nutrition due to additional divisions in resources. The *Mother's Height* coefficient is positive as expected, since taller mothers pass on genetics that are likely to result in taller children. Again, this coefficient is insignificant, which may be because growth potential before 3-years-old is fairly universal rather than being based on genetics (Martorell, 2017, 3).

Table IV

Regressions on Weight-for-Height Z-Score

	(1)	(2)	(3)	(4)
Treatment	-0.654*	-0.694*	-0.698*	-0.698*
	(-2.69)	(-2.75)	(-2.75)	(-2.77)
Birth Interval	-0.0104	-0.0125*	-0.0127*	-0.0127*
	(-2.00)	(-2.25)	(-2.24)	(-2.24)
Treatment*Interval	0.0166*	0.0175*	0.0176*	0.0176*
	(2.49)	(2.56)	(2.61)	(2.62)
Male	0.0303	0.0310	0.0312	0.0309
	(0.53)	(0.53)	(0.53)	(0.53)
Diarrhea in the Last 2 Weeks	-0.182*	-0.184*	-0.186*	-0.188*
	(-2.22)	(-2.26)	(-2.26)	(-2.33)
Parity	0.0311	0.0643	0.0679	0.0679
	(1.54)	(1.99)	(2.05)	(2.06)
Mother's Age	-0.00284	-0.00209	-0.00205	-0.00201
	(-0.38)	(-0.27)	(-0.27)	(-0.27)
Mother's Height (ft.)	0.0151	0.0177	0.0135	0.0127
	(0.08)	(0.10)	(0.07)	(0.07)
Mother's Total Children		-0.0433	-0.0449	-0.0443
		(-1.33)	(-1.36)	(-1.34)
Mother's Years of Education			0.0124	0.0133
			(1.32)	(1.38)
Urban			0.0644	0.0824
			(0.61)	(0.80)
Wealth Index				-0.0148
				(-0.50)
R^2	0.215	0.216	0.217	0.217
Observations	1737	1737	1737	1737

Notes: The dependent variable is weight-for-height z-score. The sample is all index children. The variable Treatment*Interval is the interaction term of the two variables. All four of these models are estimated with clusters at the region-level and dummy variables for each region. T-statistics are in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

In Model (2) the variable *Mother's Total Children* is added to the regression. Despite being insignificant, this variable changes the overall results. In Model (2) The coefficients on *Treatment*, the interaction term, and *Birth Interval* all become larger in magnitude compared to Model (1). This change and the slight increase in the R^2 value suggest that Model (1) had omitted variable bias due to a lack of the *Mother's Total Children* variable.

In Model (2) *Birth Interval* becomes significant at the 5% level but has a negative coefficient. This coefficient captures the effect of birth interval on the nutrition of control children, so it may be that after some length of time, increased birth spacing is disadvantageous, perhaps due to a loss of resource pooling between siblings. Another possibility is that the effect of birth interval on control children is skewed because about 45% of control children had no younger sibling at the time of the data collection. The spacing of these children is then assumed to be their age since that is the longest interval they definitely did not have a younger sibling, however, for the majority of the control children their subsequent space continued to lengthen past the data collection. Only 94 (12%) of the control children's mothers were pregnant at the time and even they likely did not all give birth immediately after the data collection. Thus, due to limitations in determining the full length of each control child's subsequent space, the true effect of subsequent spacing on the nutrition of control children is not captured in this study.

Models (3) and (4) have very similar results for the coefficients of interest. Control variables for each mother's years of education and whether an index child's household is in a rural or urban area are included in Models (3) and (4), as well as a control for household wealth in Model (4). None of these controls are significant. Regardless, the coefficients on *Urban* and *Mother's Years of Education* are both positive. Positive signs were expected because urban households may have access to more resources relating to health and nutrition than rural households. Additionally, mothers with more education may be more equipped in allocating resources and therefore improving the nutrition of index children.

Unexpectedly, in Model (4) the coefficient on the *Wealth Index* is negative, which means that children in families with better standards of living are worse off anthropometrically. One possible reason for this is that families with better wealth indexes may have more members who are outside of the household working, which may result in less oversight of young children, such as the index children, who need assistance in consumption. More likely, this is a case of WHZ masking the presence of stunting. Children in the poorest wealth index category tend to be stunted. By being short for their age, these children require fewer calories making it easier to achieve a healthier WHZ, despite this level being unhealthy when age is more heavily weighted. Similarly, the richest kids tend to me taller and have a higher caloric demand.

In Models (3) and (4), *Treatment, Birth Interval*, the interaction term, and recent diarrhea are all significant at the 5% level. Notably, treated children have 0.698 worse WHZs on average, and treated children with one additional month of birth spacing tend to have 0.0176 improved WHZs. Among control children, an additional month of spacing actually decreases WHZ. This again suggests either a threshold after which birth spacing becomes disadvantageous, somewhere between 36 months and 59 months, or that the data are biased since almost half of the control children have no younger sibling in the dataset. The *Treatment,* interaction term, and *Birth Interval* coefficients are constant across both Model (3) and Model (4), which suggests that the wealth index control variable does not affect nutrition in the index children.

All of the WHZ models are estimated with region clusters and include region dummy variables, although these are not listed in Table IV. Across all four models the majority of the region dummy variables are significant at the 0.1% level. The exceptions are as follows: the coefficients on Lac and Wadi Fira are insignificant in all four models, Ouaddaï is significant at 1% for all models, Ennedi is significant at the 5% level for Models (1), (2), and (3) but insignificant in Model (4), and the coefficient on Borkou/Tibesti is significant at 5% in Models (1) and (2) while insignificant in Models (3) and (4). The coefficients on Borkou/Tibesti, Ouaddaï, and Ennedi are negative in all the models, while all of the other region coefficients are consistently positive. This means that it is nutritionally better to live in almost any other region rather than in the reference region of Batha.

Despite differing control variables, the *Treatment* and interaction coefficients of interest are fairly consistent across Models (2), (3), and (4). By taking into account the controls, which may impact anthropometric outcomes, these multivariable regressions show a clear relationship between improved WHZ and longer subsequent birth spacing. This is true on the extensive margin in that a short subsequent interval causes worse a WHZ outcome than intervals 36 months or larger, as well as on the intensive margin that among treated children, shorter intervals cause more harm than longer intervals.

Body Mass Index Outcomes

The models with BMIZ as the dependent variable present similar results as the WHZ models, although the BMIZ results have greater magnitudes and stronger statistical significance. The similarity between the models on WHZ and BMIZ is unsurprising since body mass index takes both weight and height into account, so BMIZ and WHZ have similar inputs. Each of the BMIZ models have respectively the same variables as the WHZ models. Like the WHZ models, there is a large jump between the coefficients of interest in Model (1) and the rest of the models. Again, this indicates that controlling *Mother's Total Children* is imperative to the estimation. The models are shown in Table V.

Across all four models a short subsequent birth space decreases a child's BMIZ. The coefficients on treatment are all significant at the 1% level. In Model (4), which has the highest R^2 value, experiencing a short subsequent interval results in a BMIZ 0.909 lower than the control children. Additionally, the interaction term is positive and significant at the 1% level in all four of the models, which shows that for children with short subsequent birth spaces, longer intervals correlate with improved BMIZs. In Model (4) a one month increase in spacing results in a 0.0222 improvement in BMIZ. In terms of the effect of birth spacing for control children, in all four models the coefficient on *Birth Interval* is negative and significant at 5%. Again, this may be due to a loss of resource pooling or the uncertainty relating to the subsequent birth intervals of 45% of the control children.

The significance of the control variables is slightly different in the BMIZ models compared to the WHZ models. In the BMIZ models recent diarrhea is never significant, but *Male* is significant at the 5% level and has a consistent coefficient across all four models. As expected, boys tend to have higher BMIZs than girls. Almost all of the signs of the coefficients on the control variables match those of the controls in the WHZ models. The exception is that in the BMIZ models the coefficient on *Mother's Height* is negative. Genetics do not play a large role in the growth potential of children under three-years-old, therefore an insignificant negative coefficient is not concerning (Martorell, 2017, 3).

Table V

Regressions on Body Mass Index Z-Score

	(1)	(2)	(3)	(4)
Treatment	-0.870**	-0.905**	-0.908**	-0.909**
	(-3.66)	(-3.65)	(-3.67)	(-3.72)
Birth Interval	-0.0116*	-0.0134*	-0.0135*	-0.0136*
	(-2.37)	(-2.54)	(-2.52)	(-2.55)
Treatment*Interval	0.0213**	0.0220**	0.0221**	0.0222**
	(3.06)	(3.09)	(3.13)	(3.17)
Male	0.134*	0.134*	0.134*	0.134*
	(2.23)	(2.22)	(2.21)	(2.21)
Diarrhea in the Last 2 Weeks	-0.119	-0.121	-0.122	-0.126
	(-1.50)	(-1.54)	(-1.58)	(-1.63)
Parity	0.0293	0.0578	0.0605	0.0606
	(1.51)	(1.79)	(1.85)	(1.85)
Mother's Age	-0.00297	-0.00232	-0.00230	-0.00222
	(-0.41)	(-0.32)	(-0.32)	(-0.31)
Mother's Height (ft.)	-0.0434	-0.0412	-0.0456	-0.0470
	(-0.23)	(-0.22)	(-0.24)	(-0.25)
Mother's Total Children		-0.0372	-0.0383	-0.0371
		(-1.15)	(-1.18)	(-1.14)
Mother's Years of Education			0.0104	0.0122
			(1.29)	(1.48)
Urban			0.0339	0.0689
			(0.33)	(0.69)
Wealth Index				-0.0287
				(-0.98)
R^2	0.208	0.209	0.209	0.210
Observations	1737	1737	1737	1737

Notes: the dependent variable is body mass index z-score. The sample is all index children. The variable Treatment*Interval is the interaction term of the two variables. All four of these models are estimated with clusters at the region-level and dummy variables for each region. T-statistics are in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The vast majority of the region dummy variables have positive coefficients; across all four models Borkou/Tibest, Ouaddaï, and Ennedi are the only regions with negative coefficients.

Most of the coefficients are significant at the 0.1% level. The exceptions are that the coefficient on Wadi Fira is never significant, Borkou/Tibesti is significant at 1% for Models (1) and (2) and insignificant for (3) and (4), Lac is significant at 1% for Model (1) and at 5% for the others, and Ennedi is insignificant in Model (4) but significant at 1% in the other models. Overall, the region variables have fairly similar signs and significance in the BMIZ models as those in the WHZ models.

All of the models, regardless of whether WHZ or BMIZ is the dependent variable, show that when the control variables are taken into account, short subsequent birth spacing causes worse anthropometric outcomes than spacing of 36 months or more. The models also exhibit that among treated children, shorter intervals are worse than longer intervals. These results match the expectations of this study and the findings of previous research. The models also show that among control children, longer intervals result in worse anthropometric outcomes, but again, the full nature of this result requires further research in that specific area with more comprehensive data.

8. Robustness Checks

In this chapter I will discuss the sensitivity of the results in this study to the specific parameters and assumptions of the models. This will include an exploration of what happens in the results if the age range of the index children is changed or if the definition of a short birth interval is adjusted. Further, this chapter considers if these results could be replicated in alternative countries. The central issues are the sign, magnitude, and significance of the coefficients on the treatment and interaction variables.

Alterations to the Index Children Group

The first change to the model parameters is considering a different or larger age range for the index children. For all of these estimations I will be using the mixture of control variables used in Models (4). These are listed in the notes of Tables VI. For ease in comparison, the original Models (4) are the first two rows of the table while the varying index child age ranges are in the following rows for estimations on WHZ and BMIZ.

If index children are those aged three-and-a-half through four-years-old, instead of only four-years-old, the sample size of index children increases to about 1.5 times as large as the original sample. One aspect of note is that in this expanded sample there is a 5% significance difference in mean children who have recently had diarrhea. This dummy variable equals one if the child has had diarrhea in the last two weeks before the data collection and in this sample the control mean is 0.025 higher than the treatment mean. The results on both *Treatment* and the interaction term are statistically significant at the 0.1% level across all the models, both WHZ and BMIZ. This is a stronger significance than in the original models. With this larger group of index children the coefficients of interest are the same signs as in the original models but both have larger in magnitudes, which mean that having a short subsequent birth space is even more damaging.

The index group can be expanded even further to include all three- and four-year-olds. With this estimation, the coefficients on *Treatment* and the interaction maintain the expected signs, are smaller in magnitude than the original models, and have the same or weaker significance levels. In this sample more control children than treatment children had recent diarrhea, at a 0.1% significant difference between the groups. The decrease in magnitude and significance in this model is likely because the youngest of the index children, those who are within the first few months of 3-years-old, may not have experienced the full effects of having a short subsequent birth interval, since their younger sibling may have been born quite recently. A final adjustment to the index child age range is to look at children three-and-a-half to four-and-a-half. These models result in the largest magnitudes.

Table VI

Age Ranges for the Index Children

Age-in-months (age-in-years)	Dependent Variable	Treatment Coefficient	Interaction Coefficient	Treatment Obs	Control Obs	Total Obs
48-59 (4-4.9)	WHZ	-0.698* (0.252)	0.0176* (0.00673)	937 (54%)	800 (46%)	1737
48-59 (4-4.9)	BMIZ	-0.909** (0.244)	0.0222** (0.00699)	937 (54%)	800 (46%)	1737
42-59 (3.5-4.9)	WHZ	-0.866*** (0.166)	0.0212*** (0.00501)	1294 (50%)	1300 (50%)	2594
42-59 (3.5-4.9)	BMIZ	-1.272*** (0.160)	0.0305*** (0.00526)	1294 (50%)	1300 (50%)	2596
36-59 (3-4.9)	WHZ	-0.310 (0.255)	0.0102 (0.00559)	1689 (51%)	1647 (49%)	3336
36-59 (3-4.9)	BMIZ	-0.770** (0.213)	0.0214** (0.00586)	1689 (51%)	1647 (49%)	3336
42-53 (3.5-4.5)	WHZ	-0.991** (0.269)	0.0263** (0.00747)	834 (49%)	866 (51%)	1700
42-53 (3.5-4.5)	BMIZ	-1.573*** (0.585)	0.0408*** (0.0126)	834 (49%)	866 (51%)	1700

Notes: The first two rows are the results from the original Model (4)s of this study, for comparison purposes. All of the results are estimated with clusters at the region-level and dummy variables for each region. The other control variables are *Male, Diarrhea in the Last 2 Weeks, Parity, Mother's Age, Mother's Height, Mother's Total Children, Mother's Years of Education, Urban,* and *Wealth Index*. Standard errors are in parentheses.
*p<0.05, **p<0.01, ***p<0.001.

All of these results suggest that children who are close in age to the short-spacing cutoff have not yet fully responded to the negative effects of short birth spacing, possibly because their younger sibling may not have been out of the womb for very long. As in the original results, BMIZ tends to have stronger responses than WHZ. Overall, the exact ages of the index children do not appear to change the general takeaway that a short interval has negative anthropometric effects and that among treated children, an additional month of space is advantageous.

Variations to the 'Short Interval' Definition

Based on the literature and the results in this study, shorter birth spaces are expected to have larger adverse impacts. Yet, when the threshold definition of a short interval is considered anything less than 30 months rather than 36 months, the coefficients of interest become smaller in magnitude and weaker in significance, except that the magnitude of the treatment coefficient on BMIZ increases. One reason for these results could be that by decreasing what counts as a short interval, the number of eligible index children falls slightly, and the ratio of index children becomes more heavily weighted towards control children and away from treated children. Despite the insignificancies and the smaller magnitudes, the result coefficients still have the expected signs for the treatment and interaction variables. The results discussed in this section are displayed in Table VII. Again, the original Model (4) results are the first two rows for comparison purposes.

Neither of the coefficients of interest are significant in any of the models if a short birth interval is defined as a space of less than 24 months. This is quite likely due to a lack of data on treated children. This effect becomes even more dramatic when a short interval is considered to be 18 or 12 months. Because the sample size of treated children becomes extremely small these results are not included in Table VII. At 18 months the signs of the coefficients are still as expected, however, for estimations with 12 months as the threshold, the coefficient on *Treatment* is still negative, but the coefficient on the interaction term also becomes negative, unlike all of the other models.

The WHO recommends at least 24 months between two pregnancies (*"Report of a WHO Technical Consultation,*" 2005, 18). Assuming a 9-month gestation, this means a 33 month birth space. Similarly to the other decreases in the definition of a short birth space, the significancies are weaker and the magnitudes of the effects are smaller, still, the signs of the coefficients are as expected. Lastly, if the threshold of a short birth interval is increased from the original 36 months to 40 months, the magnitudes of the coefficients of interest are greater than in the original models. The significance is either the same or weaker. This effect is a continuation of the results found with birth spaces of less than 36 months, as mentioned in the previous paragraphs. These are unexpected results which require an additional study to fully understand.

Table VII

Short Interval Definition Variations

Short Interval	Dependent Variable	Treatment Coefficient	Interaction Coefficient	Treatment Obs	Control Obs	Total Obs
< 36	WHZ	-0.698* (0.252)	0.0176* (0.00673)	937 (54%)	800 (46%)	1737
< 36	BMIZ	-0.909** (0.244)	0.0222** (0.00699)	937 (54%)	800 (46%)	1737
< 30	WHZ	-0.410 (0.219)	0.0149 (0.00822)	722 (42%)	1005 (58%)	1727
< 30	BMIZ	-1.513* (0.234)	0.0171 (0.00868)	722 (42%)	1005 (58%)	1727
< 24	WHZ	-0.374 (0.286)	0.0170 (0.0149)	407 (24%)	1275 (76%)	1682
< 24	BMIZ	-0.395 (0.299)	0.0166 (0.0155)	407 (24%)	1275 (76%)	1682
< 33	WHZ	-0.501* (0.217)	0.0132 (0.00727)	830 (48%)	904 (52%)	1734
< 33	BMIZ	-0.651** (0.228)	0.0163* (0.00780)	830 (48%)	904 (52%)	1734
< 40	WHZ	-1.046 (0.586)	0.0270 (0.0125)	982 (58%)	718 (42%)	1700
< 40	BMIZ	-1.851** (0.585)	0.0462** (0.0126)	982 (58%)	718 (42%)	1700

Notes: The first two rows are the results from the original Model (4)s of this study, for comparison purposes. All of the results are estimated with clusters at the region-level and dummy variables for each region. The other control variables are *Male, Diarrhea in the Last 2 Weeks, Parity, Mother's Age, Mother's Height, Mother's Total Children, Mother's Years of Education, Urban,* and *Wealth Index*. Standard errors are in parentheses.

*p<0.05, **p<0.01, ***p<0.001.

9. Discussion and Implications

The findings in this study show a causal relationship between shorter subsequent birth spacing and worse nutrition outcomes. The magnitude and application of this effect as well as the study limitations are laid out in this chapter. Additionally, the importance of this type of research and areas requiring further study are explored.

Wasting: Low Weight-for-Height

Wasting is when a person's weight is significantly too low for their height. The thresholds for wasting are developed according to the WHO Child Growth Standards, which dictate that a WHZ of less than -2 indicates wasting ("*Country Profile Indicators,*" 2010). In this sample, 12.91% of treated children are wasted. However, if these children had not had a short subsequent birth interval, based on WHZ Model (4), only 3.95% of the treated children would be wasting. That is a 8.96 percentage point fall in wasting children if only the children had not experienced short birth spacing.

On the other side, 12.25% of control children in the sample are wasted. If the control children had experienced short subsequent intervals their WHZs would decrease and an additional 15.13% would then 'qualify' as wasting. This means that if the control children had short birth spacing, 27.38% of them would be wasting. This is crucial because persistent short-term malnutrition in the form of low weight increases the risk of long-term malnutrition which causes damage throughout a person's life (Victora et al., 2021, 1392). Wasting is not determined by BMIZ, but the fact that the effects of birth spacing on BMIZ are even more extreme than those on WHZ is indicative of a thoroughly concerning phenomenon.

Limitations and Concerns

One of the central assumptions of this study is the accuracy of the age data. This allows for the calculation of birth intervals and for anthropometric comparisons between children of the same age both within the sample and in regards to the WHO reference population. For the calculation of anthropometric z-scores, the day of birth for each index child is recorded so as to compare them to someone of the exact same age. This is not an infallible method, for all children with unknown days of birth are given the 15th of their birth month (Rutstein and Rojas, 2006, 144).

Another concern is that the exact birthday of each child is used only for finding z-scores. Otherwise, birth data is limited to month and year. Age-in-months is calculated by subtracting each child's birth from the month of the interview. This means that age-in-months may be over- or under-estimated depending on if the child's birth or the interview are closer to the beginning or end of a given month. These errors should be equally overstated and understated across the sample, but this does create concerns for the birth interval data, since sibling pairs may not be biased in the same direction ("*Calculating the Age of Children*"). This measurement error is independent from the model error term since the likelihood of an individual household being interviewed closer to the beginning versus closer to the end of a given month was random. Thus, while error in the age creates omitted variable bias in the model, it does not create an issue of collinearity.

None of the index children in the sample have missing data for month or year of birth. This means that the DHS did not need to conjecture the month for any index child and that the data is as accurate as the interview respondents were. However, mothers do not always remember the exact month each child was born. This can cause clustering around year values due to approximation (Pallum and Staveteig, 2017, 8). Any estimation of month of birth can cause attenuation bias and affects the birth interval value, which sheds uncertainty on the accuracy of the results found in this study.

Another limitation relates to the data on infant and childhood mortality. The DHS collects data on the month of death for children under 2-years-old, and the year of death for children under 5-years-old, however, there is a lot of error in this variable. This error comes from several places. First, it is common for interviewees to omit reporting children who have died. This means that no matter the accuracy of the data that do exist, there is an unknown number of children who have died and left no trace in the data (Rutstein and Rojas, 2006, 90). Second, there tends to be heaping at 12 months. In other words, a disproportionate number of children are reported to have died at 12-months-old, which is likely due to rounding to the nearest year rather than reporting the actual month of death (Pallum and Staveteig, 2017, 10). Third, the children who are reported as dead but who have incomplete date data are given an approximate date of death by the DHS system, based on the death of children with similar profiles (Rutstein and Rojas, 2006, 91).

It could be that there were children whose nutrition fell so low due to a short subsequent birth space that they passed away. The anthropometrics of these children do not show up in the data. Additionally, control children may have had a short subsequent birth space, but if the younger sibling died, they may not be in the data which makes it appear like the index child has had no younger sibling within 36 months. In this study, the effects of birth spacing include both those while the younger sibling is gestating as well as when they are a newborn. These effects are not separated from each other. This means that an arbitrary control child whose mother became pregnant soon after their own birth with an infant who was either stillborn or died before the data collection, experienced the negative effects of a short pregnancy interval but not of competing with their sibling outside of the womb. Despite experiencing the consequences of a younger sibling gestating soon of their own birth, the child is considered to have not had a short subsequent interval in this study. Because of this and the possible loss of life due to a short birth space among treated children, the effect of short subsequent birth intervals on nutrition may be understated in this study.

Alternative Countries and Time Periods

Each country has a unique set of resources, challenges, and possible solutions. In particular, culture may play a large role in fertility choices in any given country, so it is necessary to do a focused study on each country of interest. The exact control variables which are most important for an estimation may also vary by country. However, it is still possible to do a simple replication of this study in other sub-Saharan countries to determine if this specific setup can be extended with few alterations. The two countries explored are the Democratic Republic of Congo and Ghana. The results are exhibited in Table VIII.

The Democratic Republic of Congo

Similarly to Chad, the Congo is useful to study because there is an unusually low rate of modern contraception use. To look at the Congo I use a DHS from 2013 and 2014. As with the Chad estimations, I assume that the length of a child's subsequent birth space is exogenously determined, perhaps by biology. At the time of the survey, 8.1% of women were using modern contraceptives, while 11.1% were using traditional contraception, the most popular being period abstinence ("*Democratic Republic of Congo,*" 96). This implies that there is some interest in controlling fertility but that there may be a lack of access or interest relating to modern contraceptives. Any child whose mother is using any type of contraception is dropped from the analyses. I use identical models to those used originally in this study for Chad. Across all of the models, the coefficients on *Treatment* and the interaction term are the expected signs, but the coefficients are never significant.

Ghana

Another country to analyze is Ghana, using the 2008 DHS. At the time, Ghana had exogenously-influenced low contraception supply which is why it has been chosen for this section. This was due to the Mexico City Policy which is discussed in the following chapter. Despite a decrease in contraception use compared to previous years, contraception use was still much higher than it is in Chad, at 19.3% of women using either modern or traditional methods ("*Ghana Demographic and Health Survey 2008,*" 86). Similarly to the Congo, the model results using data from Ghana have the expected coefficient signs but are insignificant. The higher level of contraception use implies that Ghanaians may have more resources than Chadians, which could be affecting the estimates. Another aspect of note in the Ghana models is that the sample is extremely small. This means that there may not be enough data to find evidence of a general effect.

Table VIII

Country Extensions

Country	Dependent Variable	Treatment Coefficient	Interaction Coefficient	Treatment Obs	Control Obs	Total Obs
The Congo	WHZ	-0.717 (-1.69)	0.0159 (1.41)	605 (58%)	437 (42%)	1042
The Congo	BMIZ	-0.870 (-2.21)	0.0191 (1.77)	605 (58%)	437 (42%)	1042
Ghana	WHZ	-0.726 (-0.49)	0.0271 (0.76)	97 (29%)	233 (71%)	330
Ghana	BMIZ	-0.707 (-0.50)	0.0254 (0.76)	97 (29%)	233 (71%)	330

Notes: All of these results are estimated with clusters at the region-level and dummy variables for each region. The other control variables are *Male, Diarrhea in the Last 2 Weeks, Parity, Mother's Age, Mother's Height, Mother's Total Children, Mother's Years of Education, Urban,* and *Wealth Index*. T-statistics are in parentheses in the coefficient columns.
*p<0.05, **p<0.01, ***p<0.001.

Development Initiatives and International Aid

Birth spacing affects early childhood nutrition, which affects numerous outcomes throughout a person's life. These outcomes include general welfare, lifetime earnings, and health. These outcomes are intimately intertwined with the concept of development. More specifically, birth intervals could have consequences and effects in areas directly relating to the United Nations' 17 Sustainable Development Goals. These are goals for improving welfare and development with an intersectional approach. Birth spacing could be crucial in meeting goals one through five, eight, ten, and seventeen, and possibly others. These particular goals are to achieve “no poverty,” “zero hunger,” “good health and well-being,” “quality education,” “gender equality,” “decent work and economic growth,” “reduced inequalities,” and “partnerships for the goals” (“*United Nations Department of Economic and Social Affairs*”). These goals refer to some of the most detrimental issues plaguing developing countries.

Birth interval research has the potential to be essential in crafting solutions to these developmental issues. Longer subsequent birth intervals reduce malnutrition which then improves general health, educational attainment, work capacity and economic growth. In areas with sex-preference culture, spacing can reduce the inequality in resource allocation between girls and boys, particularly in regards to length of breastfeeding (Jayachandran and Kuziemko, 2011). All together, birth spacing is a fairly simple concept but has immense reach in affecting many different aspects of development. To increase subsequent birth intervals it is necessary to pinpoint why short spacing happens. It is likely that birth intervals are impacted by contraception and family demographic preferences.

Contraception and Family Size

One way to lengthen birth spacing is to increase the number of people using contraceptives, particularly modern contraceptives which are much more effective at preventing a pregnancy than traditional methods such as withdrawal. Contraception gives parents control over their fertility which allows them to at least make a decision regarding birth spacing. Some contraception just requires knowledge, like LAM. Any mother who knows that consistent and rigorous breastfeeding causes lactational amenorrhea can use this type of contraception without any further outside resources, as long as she has the resources to uphold her own health enough to continue producing breast milk. Most other modern methods require additional supplies.

The US is a leading contributor of international aid and therefore has had strong impacts on the development of foreign countries. The Mexico City Policy (MPC) in the US affects how the US distributes international aid. This policy inhibits non-government organizations which "perform or actively promote abortion as a method of family planning in other nations" from receiving US aid (The White House Office of Policy Development, 1984). The MPC was first enacted in 1984 and has been rescinded and reinstated respectively by Democratic and Republican presidential administrations ever since. Throughout this time, and in fact since 1973, US funds have not been allowed to be used to "pay for the performance of abortions as a method of family planning or to motivate or coerce any person to practice abortions" ("*Legislation on Foreign Relations,*" 40).

The MCP prevents all organizations which have involvement in abortions from receiving any US aid. The largest resulting change in service budget tends to be a decrease in contraception supply funds. There is no change in abortion service funds since the US has not contributed in that area in almost 50 years. Therefore, the MCP has the inadvertent result of decreasing contraception supply in several developing countries (Jones, 2015, 38). The exact effect of the MCP relates to the level of dependency that organizations in a given country have on US aid. In Chad, although there is little data to confirm this, the MCP does not seem to have a large effect, likely because there is extremely low contraception access to begin with, so any decrease affects very few people. Yet, this raises the issue of international aid supplying contraception and how supply can change based on foreign politics. This type of international aid may not be sustainable as a method of increased fertility agency if the supply is volatile. Access to contraception may be an impactful way to increase birth intervals in Chad. In particular, this could be effective in conjunction with research relating to determining the most culturally-appropriate types of contraception, such as in Ashraf et al.'s (2014) paper on hidden contraception use.

Access to contraception gives parents the ability to control the timing of their fertility, but having access does not mean that people will want to use contraceptives. About 60% of married women not using contraception at the time of the Chad DHS data collection planned to never use contraceptives. This could be due to a lack of access, particularly a lack of access to effective methods of contraception which have the least possible damaging side effects. If this is the case, the problem is not easy to solve, but it is the type of issue which can be resolved by 'throwing money at it,' which is an easier type of solution than a change in culture or preferences.

Some people may simply not want to space out their children. There could be any number of reasons why parents may choose not to space their children when they have the ability to do so. In Chad, one reason is that men and women prefer large family sizes. The DHS asks all interviewees their ideal number of children. For people who already have children they are asked to think back to before they had children and say how many children they would have wanted to have. Generally, men report wanting more children than women, people who are married prefer more children than those who are not, and people who already have children have the highest number of child preferences. Across these groupings, the average number of desired children ranges from about eight to sixteen ("*Demographic, Health, and Multiple Indicators,*" 88). This measurement is entirely subjective but it can still provide some information, such that larger families are preferred. Spacing children could make it biologically impossible for people to reach their ideal number of children.

Another reason to not control the timing of fertility is due to religious beliefs. When asked about their ideal number of children, 23% of women and 16% of men gave answers of either not caring or knowing, or that it is up to God ("*Demographic, Health, and Multiple Indicators,*" 87). The exact ratio of those who want to leave fertility decisions up to God is unknown within these percentages, but it is an important aspect in terms of some households having no interest in spacing out children. Thus, while increasing access to contraception may be a somewhat simple way to increase birth intervals, contraception access is irrelevant for people who do not want to use contraceptives or who do not want to space out their children.

Nutritional Supplementation

The central issue at stake is early childhood nutrition. Instead of considering the inputs that affect nutrition, such as subsequent birth spacing, one possibility is to directly target malnutrition by providing nutritional supplements. This is particularly important when there are people who do not want to have birth intervals of at least 36 months between their children. There has been a multitude of research conducted on nutritional supplements in various forms in developing countries.

Additional nutrition inputs can be allocated in several different ways including by providing households with nutrient-rich foods or drinks or feeding children at school. School feeding programs ensure that the additional calories are going directly to the child (Jacoby, 2002). However, school feeding programs are not a substitute for the benefits of birth spacing. This study shows that birth spacing decreases weight which increases the risk for linear growth faltering. Children over three-years-old are less responsive to issues of linear growth than younger children which makes early intervention crucial (Martorell, 2017, 2). Nutritional supplements for school children may be too late to counteract the effects of short subsequent birth spacing. Yet, other programs may be effective, such as nutritional supplements at very early ages (Martorell, 2017; Hoddinott et al., 2008; Mallucio et al., 2009). This type of approach may not be sustainable, particularly since the GDP of a country tends to be highly correlated with the total fertility rate, and nutritional supplements do not directly impact fertility (de Silva and Tenreyro, 2017, 208). Further, potable water is also essential which requires more extensive infrastructure to supply. Thus, while directly improving nutrition rather than diminishing the causes of malnutrition is a sound strategy, the exact benefits and consequences to focusing on nutrition rather than birth spacing are unknown and require further research.

Recommendations for Further Research

To fully understand the relationships between subsequent birth spacing, education, GDP, and general welfare, additional research is necessary. In particular, the field could benefit from research that includes reliable data on infant and childhood death, age-in-months, and contraception access. Further, a study on the long-term effects of birth intervals while controlling for nutrition, and research comparing the effects of subsequent spacing versus nutritional supplements would be advantageous to understanding the full scope of subsequent birth interval effects. and a study on the long-term effects directly relating to birth intervals versus those relating to birth intervals through nutrition. Overall, panel data that follow participants for several years would be extremely beneficial. The findings in this study must be replicated in additional places and time periods to determine if similar effects are found in all developing countries. These factors may be critical in meeting some of the UN Sustainable Development Goals.

Further research is also needed to consider the exogenous forces that impact birth spacing. One such aspect could be the Mexico City Policy which causes periods of decreased contraception access in areas highly dependent on the US for family planning services. This type of study would also contribute to a greater understanding of the reach and domino effects of US aid-related policymaking (Brooks et al., 2019). If the MCP is causing an undesired lack of control over fertility and birth spacing, the US could be inadvertently responsible for malnutrition, and thus indirectly responsible for loss in potential income, health, educational attainment, and even life.

10. Conclusion

This paper has explored how short subsequent birth intervals in Chad affect early childhood nutrition and how this period of nutrition is critical in both the development of an individual and potentially of the entire country. Early childhood nutrition can have long-lasting impacts on cognitive development, physical development, health, longevity, educational attainment, and income (Victora et al., 2008; Martorell, 2017; Maluccio et al., 2009; Fink et al., 2016; Hoddinott et al., 2013). All of these factors contribute towards general welfare and prosperity. Compared to nutritional supplementation, birth spacing could be a longer-term and possibly easier intervention for improving early childhood nutrition.

The women in the sample of this study had little control over their fertility and limited ability to determine the interval between their children. This situation allows for a study of birth spacing separate from the possible fundamental differences between parents who choose to space out their children and those who do not. Further, the data have variables which make it possible to take into account non-birth-interval factors to ensure that the results do not capture effects due to other variables such as having diarrhea in the two weeks preceding the data collection.

The results from this study are found using DHS data and multivariable linear regressions on weight-for-height z-score and body mass index z-score. These dependent variables reflect recent nutritional intake. The models show that experiencing a short subsequent birth interval results in a 0.698 lower average WHZ than the children who did not have a short subsequent space. Further, among the treated children, an additional month of space leads to a 0.0176 increase in WHZ. The results on BMIZ are similar but with greater magnitude in that treated children tend to have a 0.909 lower BMIZ than control children, and that one more month of space correlates with a 0.0222 increase in BMIZ for treated children. These same effects are found with greater magnitudes and stronger significance when the age range for the index children is expanded from only children four-years-old to also including children three-and-half-to four-years-old. Unexpectedly, when the definition of a short birth interval is a decreased length of time, the coefficient magnitudes of interest become smaller. This is an effect which requires further research to understand. The full extent to which these results can be replicated in alternative countries also necessitates additional research, but some of the ideas can still be extrapolated in this study.

Increasing average subsequent birth intervals to at least 36 months could ameliorate several issues plaguing developing countries. These include malnutrition, low life-expectancy, high infant mortality, a lack of formal education, gender inequality, and low adult wages. All of these aspects relate directly to the development of a country and general welfare. Birth spacing is not a magical cure-all, but it does have far-reaching effects in these and many other areas. Overall, providing education or resources for longer birth intervals allows for increased agency and control over fertility amongst the population, which can only be a positive outcome, even if birth spacing and the likely subsequent decrease in total fertility rate is not desired or implemented by everyone. This is an area of study which warrants continued research, for the results of increased subsequent birth intervals have the potential to improve the lives of individuals as well as elevate the development of lower-income countries at a staggering scope.

11. Bibliography

Ashraf, Nava, Erica Field, and Jean Lee. 2014. "Household Bargaining and Excess Fertility: An Experimental Study in Zambia." *American Economic Review* 104 (7): 2210–37. https://doi.org/10.1257/aer.104.7.2210.

BBC News. 2018. "Chad Profile - Timeline," May 8, 2018, sec. Africa. https://www.bbc.com/news/world-africa-13164690.

Betrán, Ana P., Mercedes de Onís, Jeremy A. Lauer, and José Villar. 2020. "Ecological Study Of Effect Of Breast Feeding On Infant Mortality In Latin America," 5.

Black, Robert E, Lindsay H Allen, Zulfiqar A Bhutta, Laura E Caulfield, Mercedes de Onis, Majid Ezzati, Colin Mathers, and Juan Rivera. 2008. "Maternal and Child Undernutrition: Global and Regional Exposures and Health Consequences." *The Lancet* 371 (9608): 243–60. https://doi.org/10.1016/S0140-6736(07)61690-0.

Bøhler, E. 1996. "Child Growth during Weaning Depends on Whether Mother Is Pregnant Again." *Journal of Tropical Pediatrics* 42 (2): 104–9. https://doi.org/10.1093/tropej/42.2.104.

Briend, A., B. Wojtyniak, and M. G M Rowland. 1988. "Breast Feeding, Nutritional State, and Child Survival in Rural Bangladesh." *BMJ* 296 (6626): 879–82. https://doi.org/10.1136/bmj.296.6626.879.

Brooks, Nina, Eran Bendavid, and Grant Miller. 2019. "USA Aid Policy and Induced Abortion in Sub-Saharan Africa: An Analysis of the Mexico City Policy." *The Lancet Global Health* 7 (8): e1046–53. https://doi.org/10.1016/S2214-109X(19)30267-0.

Brown, Mark. 2006. "When Ancient Meets Modern: The Relationship Between Postpartum Non-Susceptibility and Contraception in Sub-Saharan Africa," 23.

Bryce, Jennifer, Cynthia Boschi-Pinto, Kenji Shibuya, and Robert E Black. 2005. "WHO Estimates of the Causes of Death in Children." *The Lancet* 365 (9465): 1147–52. https://doi.org/10.1016/S0140-6736(05)71877-8.

"Calculating the Age of Children More Precisely." n.d. The DHS Program. Accessed May 3, 2021. https://dhsprogram.com/data/calculating-the-age-of-children.cfm.

"Chad." n.d. The World Bank. Accessed April 11, 2021. https://data.worldbank.org/country/chad.

"Country List." n.d. The DHS Program. Accessed November 25, 2020. https://dhsprogram.com/Countries/Country-List.cfm.

"Country Main: Chad." n.d. The DHS Program. Accessed April 19, 2021. https://dhsprogram.com/countries/Country-Main.cfm?ctry_id=59&c=Chad&Country=Chad&cn=&r=1.

"Country Profile Indicators Interpretation Guide." 2010. World Health Organization. https://www.who.int/nutrition/nlis_interpretation_guide.pdf.

"Dataset Types." n.d. The DHS Program. Accessed April 11, 2021. https://dhsprogram.com/data/Dataset-Types.cfm.

"Democratic Republic of Congo Demographic and Health Survey 2013- 2014." 2014. Ministry of Planning and Monitoring of the Revolution of Modernity, the Congo Ministry of Health, and ICF International. https://www.dhsprogram.com/pubs/pdf/FR300/FR300.pdf.

"Demographic, Health, and Multiple Indicators in Chad 2014-2015." 2016. Final Report. Chad National Institute of Statistics, Economic Studies and Demographic Studies and ICF International. https://dhsprogram.com/pubs/pdf/FR317/FR317.pdf.

Dewey, Kathryn G., and Roberta J. Cohen. 2007. "Does Birth Spacing Affect Maternal or Child Nutritional Status? A Systematic Literature Review." *Maternal & Child Nutrition* 3 (3): 151–73. https://doi.org/10.1111/j.1740-8709.2007.00092.x.

Eijck, Koen van, and Paul M. de Graaf. 1995. "The Effects of Family Structure on the Educational Attainment of Siblings in Hungary." *European Sociological Review* 11 (3): 273–92.

Fink, Günther, Evan Peet, Goodarz Danaei, Kathryn Andrews, Dana Charles McCoy, Christopher R Sudfeld, Mary C Smith Fawzi, Majid Ezzati, and Wafaie W Fawzi. 2016. "Schooling and Wage Income Losses Due to Early-Childhood Growth Faltering in

Developing Countries: National, Regional, and Global Estimates." *The American Journal of Clinical Nutrition* 104 (1): 104–12. https://doi.org/10.3945/ajcn.115.123968.

"Ghana Demographic and Health Survey 2008." 2009. Ghana Statistical Service, Ghana Health Service, and ICF Macro. https://dhsprogram.com/pubs/pdf/FR221/FR221[13Aug2012].pdf.

Grove, Alfred Thomas, and Douglas Henry Jones. 2021. "Chad." Encyclopedia Britannica. January 31, 2021. https://www.britannica.com/place/Chad.

"History of Chad." n.d. Chad Embassy in the US. Accessed April 11, 2021. https://www.chadembassy.us/index.php/the-country/history-of-chad.

Hoddinott, John, Jere R Behrman, John A Maluccio, Paul Melgar, Agnes R Quisumbing, Manuel Ramirez-Zea, Aryeh D Stein, Kathryn M Yount, and Reynaldo Martorell. 2013. "Adult Consequences of Growth Failure in Early Childhood." *The American Journal of Clinical Nutrition* 98 (5): 1170–78. https://doi.org/10.3945/ajcn.113.064584.

Hoddinott, John, John A Maluccio, Jere R Behrman, Rafael Flores, and Reynaldo Martorell. 2008. "Effect of a Nutrition Intervention during Early Childhood on Economic Productivity in Guatemalan Adults." *The Lancet* 371 (9610): 411–16. https://doi.org/10.1016/S0140-6736(08)60205-6.

Isaacs, Charles E. 2005. "Human Milk Inactivates Pathogens Individually, Additively, and Synergistically." *The Journal of Nutrition* 135 (5): 1286–88. https://doi.org/10.1093/jn/135.5.1286.

Jacoby, Hanan G. 2002. "Is There an Intrahousehold 'Flypaper Effect'? Evidence from a School Feeding Programme." *The Economic Journal* 112 (476): 196–221.

Jayachandran, S., and I. Kuziemko. 2011. "Why Do Mothers Breastfeed Girls Less than Boys? Evidence and Implications for Child Health in India." *The Quarterly Journal of Economics* 126 (3): 1485–1538. https://doi.org/10.1093/qje/qjr029.

Jones, Kelly M. 2015. "Contraceptive Supply and Fertility Outcomes: Evidence from Ghana." *Economic Development and Cultural Change* 64 (1): 31–69. https://doi.org/10.1086/682981.

Jonge, Hendrik CC de, Kishwar Azad, Nadine Seward, Abdul Kuddus, Sanjit Shaha, James Beard, Anthony Costello, Tanja AJ Houweling, and Ed Fottrell. 2014. "Determinants and

Consequences of Short Birth Interval in Rural Bangladesh: A Cross-Sectional Study." *BMC Pregnancy and Childbirth* 14 (1): 427. https://doi.org/10.1186/s12884-014-0427-6.

Legislation on Foreign Relations Through 2002. n.d. https://www.usaid.gov/sites/default/files/documents/1868/faa.pdf.

Maluccio, John A., John Hoddinott, Jere R. Behrman, Reynaldo Martorell, Agnes R. Quisumbing, and Aryeh D. Stein. 2009. "The Impact of Improving Nutrition During Early Childhood on Education among Guatemalan Adults." *The Economic Journal* 119 (537): 734–63. https://doi.org/10.1111/j.1468-0297.2009.02220.x.

Martorell, Reynaldo. 1999. "The Nature of Child Malnutrition and Its Long-Term Implications." *Food and Nutrition Bulletin* 20 (3): 288–92. https://doi.org/10.1177/156482659902000304.

———. 2017. "Improved Nutrition in the First 1000 Days and Adult Human Capital and Health." *American Journal of Human Biology* 29 (2): e22952. https://doi.org/10.1002/ajhb.22952.

Molitoris, Joseph, Kieron Barclay, and Martin Kolk. 2019. "When and Where Birth Spacing Matters for Child Survival: An International Comparison Using the DHS." *Demography*, no. Journal Article. https://link.springer.com/article/10.1007%2Fs13524-019-00798-y.

Morrow, Ardythe L, Guillermo M Ruiz-Palacios, Xi Jiang, and David S Newburg. 2005. "Human-Milk Glycans That Inhibit Pathogen Binding Protect Breast-Feeding Infants against Infectious Diarrhea1." 5.

Mozumder, A. B. M. Khorshed Alam, Barkat-E- Khuda, Thomas T. Kane, Ann Levin, and Shameem Ahmed. 2000. "The Effect of Birth Interval on Malnutrition in Bangladeshi Infants and Young Children." *Journal of Biosocial Science* 32 (3): 289–300. https://doi.org/10.1017/S0021932000002893.

Onis, Mercedes de, Cutberto Garza, Cesar G. Victora, Adelheid W. Onyango, Edward A. Frongillo, and Jose Martines. 2004. "The Who Multicentre Growth Reference Study: Planning, Study Design, and Methodology." *Food and Nutrition Bulletin* 25 (1_suppl_1): S15–26. https://doi.org/10.1177/15648265040251S104.

Pallum, Thomas, and Sarah Staveteig. 2017. "An Assessment of the Quality and Consistency of Age and Date Reporting in DHS Surveys, 2000-2015." 19. DHS Methodological Reports. ICF.

Rayhan, Md Israt, and M. Sekander Hayat Khan. 2006. "Factors Causing Malnutrition among under Five Children in Bangladesh." *Pakistan Journal of Nutrition* 5 (6): 558–62.

"Report of a WHO Technical Consultation on Birth Spacing." 2005. https://apps.who.int/iris/bitstream/handle/10665/69855/WHO_RHR_07.1_eng.pdf;sequence=1.

Rutstein, Shea Oscar, and Guillermo Rojas. 2006. "Guide to DHS Statistics: Demographic and Health Surveys Methodology," September, 168.

Shekar, Meera, Richard Heaver, and Yi-Kyoung Lee, eds. 2006. *Repositioning Nutrition as Central to Development: A Strategy for Large Scale Action*. Directions in Development. Washington, DC: World Bank.

Silva, Tiloka de, and Silvana Tenreyro. 2017. "Population Control Policies and Fertility Convergence." *Journal of Economic Perspectives* 31 (4): 205–28. https://doi.org/10.1257/jep.31.4.205.

Soest, Arthur van, and Unnati Rani Saha. 2018. "Relationships Between Infant Mortality, Birth Spacing and Fertility in Matlab, Bangladesh." Edited by Bolajoko O. Olusanya. *PLOS ONE* 13 (4): e0195940. https://doi.org/10.1371/journal.pone.0195940.

"Stunting Policy Brief." 2014. Global Nutrition Targets 2025. World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/149019/WHO_NMH_NHD_14.3_eng.pdf?ua=1.

The White House Office of Policy Development. 1984. "US Policy Statement for the International Conference on Population." *Population and Development Review* 10 (3): 7.

"United Nations Department of Economic and Social Affairs - Sustainable Development: The 17 Goals." n.d. https://sdgs.un.org/goals.

Victora, Cesar G, Linda Adair, Caroline Fall, Pedro C Hallal, Reynaldo Martorell, Linda Richter, and Harshpal Singh Sachdev. 2008. "Maternal and Child Undernutrition 2" 371: 18.

Victora, Cesar G, Parul Christian, Luis Paulo Vidaletti, Giovanna Gatica-Domínguez, Purnima Menon, and Robert E Black. 2021. "Revisiting Maternal and Child Undernutrition in Low-Income and Middle-Income Countries: Variable Progress towards an Unfinished Agenda." *The Lancet* 397 (10282): 1388–99. https://doi.org/10.1016/S0140-6736(21)00394-9.

"Wealth Index Construction Principal Component Analysis Chad 2014-2015." n.d. The DHS Program. https://www.dhsprogram.com/programming/wealth%20index/Chad%20DHS%202014-15/Chad%202014%20DHS.pdf.