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Birth Spacing and Child Health Trajectories

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ABSTRACT

Using longitudinal data on a cohort of over 4,000 children from four low- and middle-income countries, we document the association between birth spacing and child growth trajectories. We find decreased height at age 1 among children born less than three years from an older sibling. However, we also observe compensatory (catch-up) growth for closely spaced children as they aged. We find no evidence that catch-up growth was driven by remedial health investments after birth, suggesting substitutability in underlying biological processes. We also find that very widely spaced children (preceding birth interval of more than seven years) were similar in height at age 1 as children spaced three to seven years apart, but outgrew their closer spaced counterparts as they aged. However, further sibling comparisons suggest that the growth premium observed for very widely spaced children may be driven by unobserved confounding factors. JEL classifications: I10, O57

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1 Introduction

The importance of birth spacing for maternal and child health has been of long-standing interest to researchers and policymakers alike. Empirical evidence has consistently found that a markedly short or wide preceding birth interval (length of time since last birth) is associated with increased risk of maternal and child mortality and morbid- ity (Conde-Agudelo et al., 2006; DaVanzo et al., 2004; Winikoff, 1983). On the basis of these findings, the World Health Organization (WHO) has recommended birth-to- pregnancy intervals of at least 24 months, or about three years between births (World Health Organization, 2005). The examined morbidity risks of poor birth spacing have primarily concerned birth and early life outcomes, including pregnancy-related com- plications (high blood pressure, pre-eclampsia), preterm birth, low birthweight, and small for gestational age, while the evidence of birth spacing effects on downstream morbidity and the evolution of child health is scant and either weak or mixed (Dewey and Cohen, 2007; Kozuki et al., 2013). This leaves an important gap in the existing literature, particularly as poor health in childhood has been shown to lead to lower educational attainment (Oreopoulos et al., 2008; Powell and Steelman, 1993), poor la- bor market outcomes (Smith, 2009; Case et al., 2005), lower human capital and social status (Case et al., 2001), and lower earnings in adulthood (Case et al., 2005; Schultz, 2002).

In this study, we document the association between preceding birth interval and child growth trajectories using longitudinal data that was collected on a cohort of children and their siblings in four low- and middle-income countries. We assess whether and how the observed height gap associated with short and wide birth spacing changed for the cohort sample as children aged, documenting patterns from raw data as well as estimates adjusted for a variety of child- and household-level characteristics. We also investigate potential mechanisms behind the observed patterns by (1) examining the relationship between birth spacing and parental investments in child health from conception to early adolescence, and (2) comparing siblings within the same family to analyze the potential influence of unobserved confounding factors on associations between birth spacing and health trajectories in our primary cohort panel.

1.1 Previous Research

The relationship between short or wide preceding birth interval and high infant and child mortality is well established in a wide range of populations (DaVanzo et al., 2004; Molitoris, 2017; Kozuki et al., 2013; Conde-Agudelo et al., 2012). Conversely, there is relatively less empirical evidence that directly assesses the links between birth inter- vals and child morbidity. The closest approximation of child morbidity effects from birth spacing is provided by studies that examine the relationship between indicators of childhood malnutrition (stunting, wasting, underweight) and family formation pat- terns. A systematic review by Dewey and Cohen (2007) assessed the evidence from 52 studies and noted that approximately half found that a previous birth interval of at least 36 months was associated with a 10 to 50 percent reduction in childhood stunt- ing (similar for wasting), whereas the remaining studies found no association or were inconclusive. A study by Rutstein (2008), which pooled birth history data from 52 Demographic and Health Surveys (DHS) that were conducted from 2000 to 2005, ob- served a positive association between birth interval length and child nutritional status outcomes. Similarly, a more recent study by Fink et al. (2014), which pooled 153 DHS surveys across 61 countries conducted between 1990 and 2011, found that birth inter- vals of less than 12 months and between 12 and 23 months were associated with higher risks for stunting (relative risks of 1.09 and 1.06) as compared to a 24 to 35 month inter-pregnancy interval. Due to the cross-sectional nature of the data, however, both the Rutstein (2008) and the Fink et al. (2014) studies were limited in their ability to make inferences on the persistence of these associations in children over time.

More recently, several studies have investigated the health impacts of birth spacing in high-income coun- tries by comparing siblings within the same family who differ in preceding birth interval length. The aim of the "within family" fixed effects approach is to control for unobservable family factors that are cor- related with birth spacing and are also risk factors for the adverse child health outcomes of interest (e.g. shared maternal frailty). Findings from these studies have been mixed, with some finding the association between short interpregnancy intervals and outcomes related to child morbidity (e.g. preterm birth, small for gestational age, etc.) to be neglibile after applying family fixed effects (Ball et al., 2014; Class et al., 2017), while others find such associations remain (Mayo et al., 2017; Shachar et al., 2016). Several recent studies using family fixed effects in low- and middle-income countries have found that short birth intervals are still associated with mortality at lower levels of development; however, the association considerably attenuates with increasing development as well as with socioeconomic status of the family (Molitoris, 2017; Molitoris et al., 2018).

1.2 Potential Mechanisms

The relatively scarce evidence linking birth intervals and child morbidity is surprising considering that the mechanisms through which birth intervals may be associated with child health and well-being have been extensively discussed in the literature (DaVanzo et al., 1983; Miller, 1991; DaVanzo et al., 2004). Broadly, we can group hypothesized mechanisms linking birth spacing to cross-sectional child health into three categories: (1) maternal physiology; (2) behavioral mechanisms; (3) confounding factors. Mater- nal physiology is perhaps the most common argument linking birth spacing to infant and child health outcomes. In particular, the consequences of a short birth interval have often been attributed to the physiological effects related to "maternal depletion syndrome," which postulates that the woman may not have fully recuperated from one pregnancy before supporting the next one (Conde-Agudelo et al., 2012; Dewey and Cohen, 2007). By the same token, especially wide birth intervals have also been hypothesized to adversely influence perinatal outcomes through maternal physiology. Specifically, "physiological regression theory" suggests a long interval may allow for the physiological state of a mother to revert back to the physical state of a woman who has not yet experienced a pregnancy, which would imply that the mother is less physically primed for childbearing (Zhu et al., 1999). This may partially explain why both first-born children and children born after long intervals are more likely to be born preterm (Conde-Agudelo et al., 2012).1

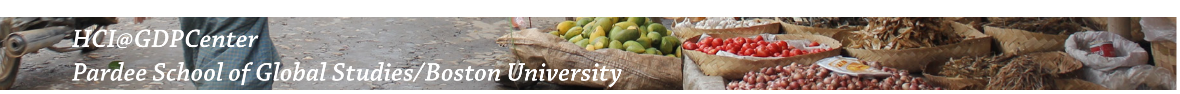
The proposed behavioral mechanisms largely operate through differences in parental health investments associated with birth spacing. As a common example, short in- tervals have been hypothesized to increase competition between siblings for parental financial resources and/or time. Differences in parental investments could also directly stem from depleted household resources that were used for a relatively recent preced- ing birth. This may include a lack of physical resources or even a psychological or emotional inability to provide the later child with adequate attention if its birth came sooner than desired (DaVanzo et al., 2004; Conde-Agudelo et al., 2012).

Finally, observed associations between birth spacing and child health could be driven by a wide range of confounding factors such as socioeconomic status, mother's age at birth, race, and household size, among others. To the extent that relevant confounding variables are observable, they can be controlled for when estimating cor- relations. However, some confounding factors may be unobserved by the researcher, resulting in estimated associations that are not strictly causal in nature (Conde-Agudelo et al., 2012, 2006; DaVanzo et al., 2004; Dewey and Cohen, 2007; Kozuki et al., 2013).

1.3 Birth Spacing and Health Dynamics

One of our key aims is to understand not only cross-sectional associations between birth spacing and child health, but also how these relationships persist or change over stages of child development. Broadly, we can think that these relationships might change due to the interaction between underlying biological processes of child develop- ment and parental investment responses to the evolution of child health. To see this more clearly, we consider the general model of human capital formation proposed by Heckman (2007), which provides a useful framework for understanding the potential influence of parental investment response to birth spacing effects on child health tra- jectories. We consider a stock of child health capital that evolves over time in response to parental health investments:

$$h_{t+1} = f_t\ (h_t, I_t),$$



where h_t is health capital stock at time t, I_t are general investments made in the child when they are t years old, and $f(.)$ is a biologically determined health production function. Health investments are a perfect substitute for the existing health stock when $\partial f_t(h_t, I_t) / \partial h_t \partial I_t = 0$. With perfect substitution and standard preferences over own consumption incentive to compensate and child's health, low health Currie stocks and with Almond additional (2011) show investments that parents ($\partial h_t / \partial I_t < 0$). an In contrast, there is "dynamic complementarity" when the return to health investments are increasing in the stock of existing health capital: $\partial f_t(h_t, I_t) / \partial h_t \partial I_t > 0$. The stronger the complementarity, ($\partial h_t / \partial I_t < 0$). the more incentive parents have to reinforce existing health stocks For example, if a closely spaced child is of poor health at age 1, parents may decide to shift resources to other siblings where marginal returns to health investments are higher.

The model's predicted evolution of health over time depends on the strength of dynamic complementarity. Consider a cohort of children with differing initial health stocks due to differential birth spacing. If complementarity is strong, the theory pre-dicts reinforcing investments and a divergence in health within the cohort over time. If there is substitutability, the theory predicts compensatory investments with the po- tential for converging health over time.

It are is also instead possible equal that for parental all children investments across the do cohort not respond ($\partial h_t / \partial I_t = 0$)the . initial health stock We may expect this to be the case if differences in health stocks are unobservable to the parent or if parents directly value equitable investments, for example, across peers or siblings. With equal investments and strong dynamic complementarity, the model predicts a divergence in health within the cohort. In contrast, if there is adequate substitutability, the initial differences in health will persist but will not grow over time, and may fade away as in the widely used Grossman (1972) model of health capital. Thus, even in the absence of parental investment differences, the shape of the health production function will determine the extent to which there exists persistence in adverse early health outcomes that arise due to, for example, maternal physiology.

1.4 Our Contributions

Our study contributes to the literature in two primary ways. First, we use a longitudi- nal dataset to document changes in the association between birth spacing and health over stages of child development. Existing studies have almost exclusively relied on cross-sectional data. Importantly, the cross-sectional structure of surveys like the DHS does not allow one to adequately control for both age and birth cohort effects when examining health trajectories over childhood. Moreover, the DHS does not include height measures for children after age five. To our knowledge, no other studies have investigated whether adverse early life health outcomes associated with intrapartum spacing persist in a given cohort of children as they aged, especially as they transition into adolescence.

Second, we analyze potential mechanisms driving observed results in two comple- mentary ways. First, we attempt to isolate biological and behavioral mechanisms by examining parental investment patterns on the basis of birth spacing. This provides novel insight into the complementarity or substitutability of the underlying biological processes and how they interact with parental investments. Second, we employ an alter- nate statistical model that relies on within-family sibling comparisons of birth spacing for identification. This approach serves to minimize residual confounding by adjust- ing for all time-invariant factors that remain constant within the family and provides further evidence on the extent to which observed relationships in our cohort analyses may be interpreted as causal estimates of birth spacing effects on health trajectories.

2 Data and Methods

2.1 Data

For our analyses, we used longitudinal data from the Young Lives Study (YLS), which investigates the determinants of childhood poverty and well-being (Oxford Department of International Development, 2017). As part of the YLS, detailed health, nutrition, and other sociodemographic data was collected on a cohort of children born between 2001 and 2002 from four low- and middle-income countries—Ethiopia, India, Peru, and Vietnam. The sampling design included selecting 20 communities in each country and randomly selecting 100 children from each. Data was collected on approximately 8,000 children (2,000 from each country) over five survey waves that were conducted in 2002, 2006, 2009, 2013, and 2016, when children were approximately one, five, eight, twelve, and fifteen years old. The study also collected information on household and child characteristics in each survey wave, including the anthropometric markers height and weight. Beginning in the third survey wave, anthropometric markers were also collected for a sibling of the primary cohort of children.2

In order to calculate proceeding birth interval for our sample children, we used available survey data to estimate the date of birth of each sibling in the family. In each survey wave, child's age in months was collected for the primary cohort and for their siblings with anthropometric data. For remaining siblings, age in years was collected. We first subtracted reported age (in months or years) from the interview date for each of the five survey waves. We then chose the median of these values for each child as their estimated date of birth. A number of household and child characteristics were also used in analyses to help control for demographic and socioeconomic effects on child health outcomes (see Appendix A for outcome and control variable construction details).

As our focus is on proceeding birth intervals, we excluded first-born children from all analyses. For those with an older sibling, we grouped proceeding birth interval into three categories: under three years, three to seven years, and seven years or more apart. We chose these categories primarily based on WHO birth spacing recommendations and to keep groups large enough to maintain statistical precision—particularly for sub-group analyses. However, we also examined robustness of main panel results to defining finer birth spacing groups (see Appendix B).

Excluding first-born children, the YLS consisted of a total of 23,435 observations for the primary cohort of children summed across the five survey waves and four countries in the study. Of this sample, we dropped 0.3 percent of observations due to missing data on birth spacing and another 7.1 percent due to missing household or child char- acteristics (including height). This left a panel sample of 21,701 observations from 4,410 children born between 2001 and 2002. We used this birth cohort as our primary sample to examine the association between birth spacing and child health trajectories. We also used data collected on siblings of the primary birth cohort to compare birth spacing effects across sibling pairs in the same family. As first-born children are again excluded form the sibling pair, the sample for this analysis was restricted to families with at least three children. Of the 4,410 children included in our primary panel sample, 1,262 (29%) were excluded from the sibling sample because they did not have at least two siblings and 849 (19%) were excluded because sibling anthropometric data was unavailable (or data was only available for the first-born sibling in the family). This left a sibling sample of 16,717 observations from 2,299 unique sibling pairs.

2.2 Outcomes

We used height (measured in centimeters) as our primary child health outcome. Height captures a child's restricted growth potential associated with the chronic or long-term effects of health shocks and/or undernourishment and is an important predictor of later-life well-being and productivity (Schultz, 2002; Case et al., 2005; Heckman, 2007). While raw height was used as our main outcome, we also conducted robustness analyses using standardized height-for-age z-scores and the probability of stunting (see Appendix B).In addition to documenting associations between birth spacing and growth trajec- tories, we are also interested in understanding the underlying mechanisms. To this end, we examined the association between birth spacing and additional measures related to parental investments in children. Examined prenatal and birth investments included level of prenatal care (*Prenatal care*) and indicators for place of delivery (*Home birth*), presence of a medical professional at birth (*Pro at birth*), and whether the pregnancy was reportedly wanted (*Wanted*). These outcomes provide insight into how the re- lationship between birth interval and early infant health may be driven by maternal physiology relative to parental investment differences.

In order to understand the parental investment response to birth spacing after birth and over childhood, we also examined child weight-for-height (*WFH*). Weight-for- height—weight in grams divided by height in centimeters—is a measure associated with acute nutrition as it is more sensitive to short-term health inputs and environment. As such, we used weight-for-height measured in each survey wave as a proxy for nutritional investments over childhood. In a series of robustness analyses, we also examined the variety and frequency of meals and parent's perceptions of child health as a means to provide additional insight into parental investment behavior. These analyses provide some suggestive evidence on the extent to which any observed effects of birth spacing on growth trajectories may have been operating through underlying biological channels (e.g. the shape of the health production function) relative to behavioral mechanisms (e.g. competition for resources).

2.3 Panel Model

Our primary objective was to examine the association between birth spacing and longi- tudinal health trajectories. In our main empirical specification, we exploited the panel structure of the YLS by estimating the following model:

$$Y_{is} = \delta_s Space_i + \beta_s X_i + \gamma_s a_{is} + \kappa_s a^2_{is} + \eta_s + \lambda_s \zeta_i + \varepsilon_{is} \qquad (1)$$

where Yis is an outcome for child i measured in survey round s; $Space_i$ is a categorical variable for preceding birth interval (3-7 years is the reference group); X_i is a vector of child-specific characteristics; a_i is age in months at time of measurement; η_s is a survey round intercept; ζ_i is an unobserved child-level random effect; and ε_{is} is a random error term. This approach allowed for comparison of effects at ages one, five, eight, twelve, and fifteen, estimated longitudinally for a single birth cohort. Included in the time invariant characteristics X_i are mother's age and age squared at birth, wealth index, total number of siblings, caregiver's education and dummies for sex, number of older siblings, season of birth[3], and community of residence.

Note that coefficients were allowed to vary by survey wave to capture heterogene- ity in effects over childhood.[4] Identification of coefficients on child random effects λ_s required a normalization, so we set $\lambda_1 = 1$. We also assumed the error term is inde- pendent and identically distributed across individuals and independent across survey waves. As we wanted to examine association changes over time, we included only children without missing height in any of the five survey waves, leaving a total of 4,093 children. This inclusion ensured us that sample composition changes were not influencing results.

The coefficient of interest is that on birth spacing, δ. Interpretation of the coeffi- cient of interest requires careful consideration. Effects estimated from this model can only be interpreted as causal if birth spacing is uncorrelated with any unobserved de- terminants of examined outcomes. It is clearly the case that geographic residence is likely to be correlated with both health outcomes and birth spacing, as access to fam- ily planning and other health services vary considerably across countries and locales. However, effects associated with geographic area were controlled for with the inclusion of community fixed effects. An additional concern is the existence of seasonal patterns of fertility that correlate with our independent variables of interest. If, for example, pregnancies that are associated with shorter birth intervals are correlated with times of the year when food is relatively scarce, then results could be attributed to season of birth as opposed to birth spacing (e.g. Moore et al. 1999, 2004; Rayco-Solon et al. 2005; McEniry 2011; Miller 2017). Moreover, studies have documented seasonal patterns of fertility across a variety of countries (e.g. Rajagopalan et al. 1981; Panter-Brick 1996; Buckles and Munnich 2012). However, the inclusion of month by country of birth dum- mies controlled for seasonal effects that occurred at the country level and that were independent of birth spacing.

2.4 Family Fixed Effects Model

While our main panel analysis controlled for many child- and household-level charac- teristics, it is still conceivable that fertility patterns could correlate with additional unobserved characteristics of children or their families. To explore this possibility, we employed a secondary statistical model that relies on within-family sibling compar- isons of birth spacing for identification. This approach served to minimize residual confounding by adjusting for all time-invariant factors that remain constant within the family. Specifically, we estimated the following family fixed effect model:

$$Y_{ifs} = \delta Space_{if} + \beta X_{if} + \gamma a_{ifs} + \kappa a^2_{ifs} + \eta_s + \zeta_i + \theta_f + \varepsilon_{ifs} \qquad (2)$$

where Y_{ifs} is an outcome for child *i* from family *f* measured in survey round *s*; θ_f is a family fixed effect; and other independent variables are as previously defined. Due to collinearity with the family fixed effect, we dropped the household wealth index, total number of siblings, and caregiver's education from the vector of child-level characteristics, X_{if}. However, we added the child's year of birth to control for cohort effects.

This approach controlled for any remaining permanent unobserved correlation be- tween a child's family and the spacing measures by comparing children within the same family. We used this model to check sensitivity of the overall height and investment gradients in birth spacing. However, there were two primary limitations to this specifi- cation. First, we could not directly observe trends in effects as a cohort aged. However, we also estimated this model with an interaction between birth spacing category and age. This allowed us to compare general age trends in the family fixed effects model with those from our panel model. Second, there was a smaller (non-random) sample for this model as we were limited to including only sibling pairs with anthropometric data in which neither sibling is the first-born child in the family.

3 Results

3.1 Descriptive Statistics

Table 1 presents descriptive statistics for the main panel sample as well as the sibling sample used in the family fixed effects model. Forty percent of the panel sample were spaced less than three years of an older sibling, while 14 percent were spaced seven or more years apart. About half of the panel sample had more than one older sibling with an average of 2.9 total siblings (by the final survey wave). The average maternal age at birth was nearly 28 years, and caregiver's average education was less than four years. The sample was somewhat skewed towards countries with higher overall fertility rates, namely Ethiopia and India (as YLS children were less likely to be first-born in these countries).

Table 1: Descriptive statistics

	Panel sample				Sibling sample			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Height (cm)	118.35	30.13	54.70	183.10	121.59	27.87	54.70	184.00
Preceding birth interval								
<3 years	0.40	0.49	0.00	1.00	0.46	0.50	0.00	1.00
3-7 years	0.46	0.50	0.00	1.00	0.48	0.50	0.00	1.00
7+ years	0.14	0.34	0.00	1.00	0.05	0.22	0.00	1.00
Older siblings								
1	0.51	0.50	0.00	1.00	0.24	0.43	0.00	1.00
2	0.23	0.42	0.00	1.00	0.34	0.47	0.00	1.00
3+	0.26	0.44	0.00	1.00	0.42	0.49	0.00	1.00
Male	0.53	0.50	0.00	1.00	0.51	0.50	0.00	1.00
Mom's age at birth	27.83	5.88	12.00	50.00	28.13	5.66	13.00	49.00
Age (months)	99.33	59.39	5.00	199.00	107.81	57.20	5.00	253.91
Wealth index	0.54	0.21	0.00	0.96	0.46	0.20	0.00	0.95
Total siblings	2.90	1.94	1.00	11.00	3.98	1.87	2.00	11.00
Caregiver's edu.	3.87	4.50	0.00	28.00	2.54	4.05	0.00	28.00
Ethiopia	0.28	0.45	0.00	1.00	0.46	0.50	0.00	1.00
India	0.25	0.44	0.00	1.00	0.23	0.42	0.00	1.00
Vietnam	0.23	0.42	0.00	1.00	0.12	0.33	0.00	1.00
Peru	0.23	0.42	0.00	1.00	0.18	0.39	0.00	1.00
Observations	21701				16717			
Individuals	4410				4598			
Sibling Pairs					2299			

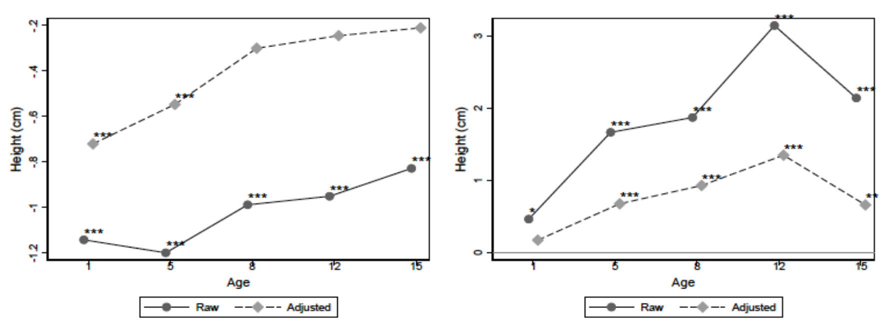
Source: Young Lives Study, young cohort. Sample of observations with non-missing height or covariates, excluding first-born children.

Compared to the panel sample, a somewhat higher 46 percent of the sibling sample were spaced within three years of an older sibling and only five percent were spaced more than seven years. Given this sample included only families with at least three children by construction, the average number of siblings was also higher than the panel sample at nearly four. Socioeconomic status was also lower as measured by wealth or caregiver's education, although mother's average age at birth was similar. The sample was also further skewed towards high fertility countries, particularly Ethiopia.

3.2 Main Panel Results

The associations between birth spacing and child height at each age for the primary YLS birth cohort are presented in Figure 1 (point estimates and standard errors are provided in appendix Table 7). Raw mean differences across spacing groups are pro- vided as well as adjusted results estimated from model (1). Panel (a) plots estimated coefficients for children spaced less than three years from an older sibling relative to those spaced three to seven years. At age one, short spacing was significantly associated with decreased height, even after controlling for confounding variables. Specifically, a preceding birth interval of less than three years was associated with an adjusted de- crease in height of 0.72 cm—or about 15 percent of the standard deviation of age one height in the sample. However, the magnitude of the associations between short birth spacing and child height declined over time. Formally, we can reject the null hypoth- esis—that adjusted model coefficients are equal—at the 5% level between ages 1 and 12 (χ^2 = 5.04) and between ages 1 and 15 (χ^2 = 3.85).5 This observed attenuation of birth spacing effects provides evidence of catch-up growth among more narrowly spaced children over childhood.

FIGURE 1: ASSOCIATION BETWEEN BIRTH SPACING AND CHILD HEIGHT



(a) <3 years to older sibling

(b) 7+ years to older sibling

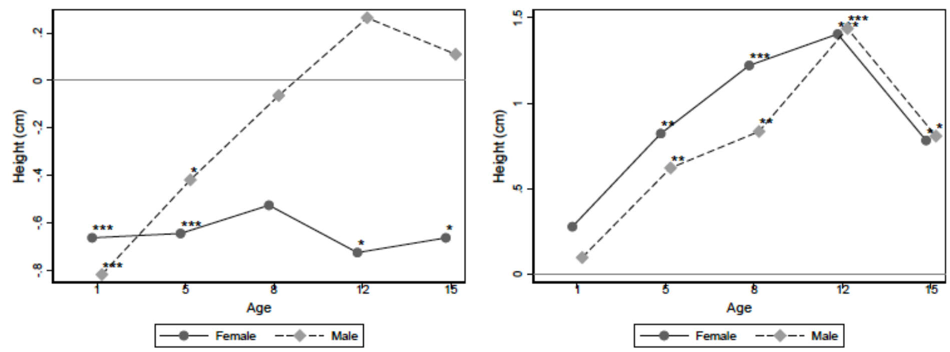
Notes: Figure plots estimated coefficients (raw and adjusted for confounding variables) for those spaced less than three years (panel a) and greater than seven years (panel b) from an older sibling. Estimates are relative to being spaced 3-7 years from a older sibling. Stars indicate p-values— *** p<0.01, **p<0.05, * p<0.1.

Panel (b) in Figure 1 shows results for children spaced more than seven years from an older sibling. In contrast to adjusted results for short spacing, very widely spaced children did not significantly differ in height from children spaced three to seven years at age one. However, very widely spaced children outgrew their more closely spaced counterparts over childhood. Again we can formally reject the null hypothesis of equal adjusted coefficients for widely spaced children at the one percent level between ages 1 and 12 (χ^2 = 18.32) and at the 10 percent level between ages 1 and 15 (χ^2 = 2.78).

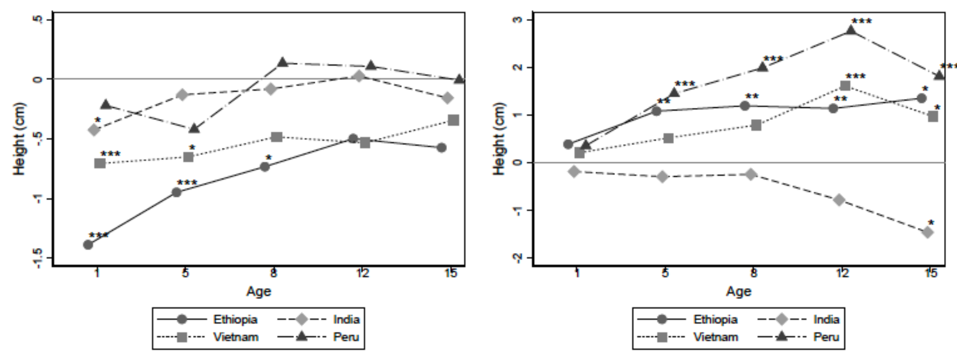
3.3 Heterogeneity

Figure 2 shows results from our main panel model run separately for sex and by country specific sub-samples (point estimates are provided in Appendix tables 8-10). Panel (a) provides adjusted estimates by sex for children spaced less than three years from an older sibling. The point estimates are statically significant and similar in magnitude for both sexes at age 1. However, for closely spaced males, the estimated negative effects of short birth spacing are quantitatively and statistically negated by age 8. In contrast, the magnitude and significance of the impact of short birth spacing persists through age 15 for closely spaced females. Thus, while estimated associations between short birth spacing and height did not worsen over childhood for females, the evidence for catch-up growth that was observed in the aggregate results appears to be driven primarily by catch-up growth in male children in the sample. In contrast, panel (b) provides results by sex for children spaced more than seven years from an older sibling. While widely spaced males may have gained relatively more between ages 8 and 12 than widely spaced females, the overall pattern of results does not differ significantly between sexes.

FIGURE 2: HETEROGENEITY IN ASSOCIATION BETWEEN BIRTH SPACING AND CHILD HEIGHT



(a) <3 years to older sibling by sex (b) 7+ years to older sibling by sex



(c) <3 years to older sibling by country (d) 7+ years to older sibling by country

Notes: Figure plots estimated coefficients (by sex and country) for those spaced less than three years (panels a and c) and greater than seven years (panel b and d) from an older sibling. Estimates are relative to being spaced 3-7 years from a older sibling. Stars indicate p-values—*** p<0.01, **p<0.05, * p<0.1.

Panels (c) and (d) in Figure 2 provide country specific results. Overall, negative associations between short birth spacing and height were most strongly observed in Ethiopia, followed by India and Vietnam; in contrast, the coefficients were smallest and statistically insignificant in Peru. However, a pattern of attenuating point estimates on short birth spacing was observed across all countries as children aged. For widely spaced children, similar patterns were present across all countries except India. In India, the estimated coefficient on wide spacing remained insignificant over most of childhood, with a marginally negative effect appearing at age 15.

3.4 Prenatal and Childhood Investments

Table 2 presents the association between birth spacing and prenatal and birth invest- ments. Children who were closely spaced received less prenatal care, were more likely to be born at home, were less likely to have a medical professional present at birth, and were less likely to be from a reportedly wanted pregnancy. These differences in prenatal care suggest that the health benefits of increased birth spacing observed by age one could be partially driven by differential parental investment behavior. To ex- plore this possibility further, we ran our benchmark specification with and without the inclusion of the prenatal investment variables (results in Appendix Table 11). The available investment variables had a mediating influence on the estimated coefficients of close birth spacing, thereby supporting our hypothesis for a parental investment mechanism. However, the mediation effect was generally small, which suggests that maternal physiological factors may still be the primary mechanism that links birth spacing to perinatal and infant health.

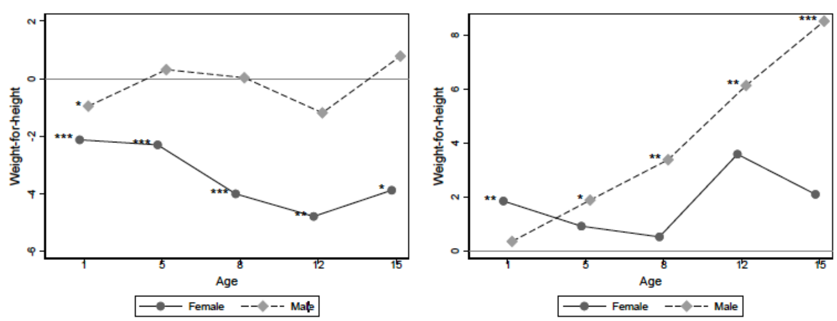
Table 2: Prenatal investments and birth outcomes

	Prenatal care	Wanted	Pro at birth	Home birth
Space <3	0.911**	0.681***	0.825***	1.216***
	(0.039)	(0.041)	(0.050)	(0.068)
Space 7+	1.012	1.205**	1.233**	0.904
	(0.053)	(0.090)	(0.125)	(0.086)
Obs	4192	4163	3394	3970

Odds ratios reported from probit model. Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, **p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

In order to examine the association between birth spacing and nutritional invest- ments after birth and over childhood, Figure 3 presents results from our empirical model with weight-for-height as the outcome (point estimates available in Appendix Table 12). Given the observed differences by sex in height trajectories after age 1, weight-for-height results are reported separately for males and females. As shown in panel (a), weight-for-height at age 1 was marginally lower among males spaced less than three years from an older sibling compared to those males who were spaced three to seven years. However, this difference is insignificant at all older ages, suggest- ing closely spaced males did not receive substantially different nutritional investments than wider spaced males over most of childhood. In contrast, weight-for-height among closely spaced females was significantly lower than wider spaced females at all ages in the panel. This suggests closely spaced females consistently received lower nutritional investments throughout childhood. Panel (b) of Figure 3 provides results compar- ing widely spaced children (seven or more years) to those spaced three to seven years. Starting from age 5, wider spaced males had significantly higher weight-for-height, sug- gesting higher levels of sustained nutritional investment. Similarly, results for widely spaced females were positive at all ages, though generally smaller in magnitude and only statistically significant at age 1.

FIGURE 3: ASSOCIATION BETWEEN BIRTH SPACING AND CHILD WEIGHT-FOR-HEIGHT



(a) <3 years to older sibling (b) 7+ years to older sibling

Notes: Figure plots estimated coefficients (by sex) for those spaced less than three years (panel a) and greater than seven years (panel b) from an older sibling. Estimates are relative to being spaced 3-7 years from a older sibling. Stars indicate p-values—*** p<0.01, ** p<0.05, * p<0.1.

3.5 Comparing Siblings

Results from the family fixed effects model are presented in Table 3. The first column shows the association between birth spacing and height in the pooled sibling sample without the inclusion of a family fixed effect (i.e. model (2) with $\theta_f = 0$). Relative to being spaced three to seven years of an older sibling, being spaced less than three years was associated with a 0.762 cm decrease in a child's height, while being spaced at least seven years apart was associated with a 1.287 cm increase.6 The second column shows results when the family fixed effect was added to the previous model specification. There was a moderate decrease in the coefficient estimate when moving from the simple OLS to the family fixed effect specification for closely spaced children. In contrast, the coefficient on widely spaced children becomes slightly negative and statistically insignificant. This suggests there may be important unobserved confounding variables that are driving the observed patterns for very widely spaced children in our panel model results. However, we also note that the confidence intervals around the fixed effects estimates were wider than those from the standard OLS, particularly for the wide spacing group where there were generally fewer observations.

Table 3: Family fixed effects model

	Height	Height	Height	Height	WFH	WFH	WFH	WFH
Space <3	-0.762***	-0.827***	-1.184***	-1.264***	-3.307***	-2.717**	-4.391***	-4.090**
	(0.223)	(0.265)	(0.226)	(0.343)	(0.746)	(1.331)	(1.139)	(1.721)
Space 7+	1.287***	-0.342	0.089	-1.632*	3.970**	-2.464	-6.881**	-13.823***
	(0.395)	(0.769)	(0.513)	(0.924)	(1.837)	(2.610)	(2.746)	(4.131)
Space <3 x Age			0.004**	0.004*			0.009	0.012
			(0.002)	(0.002)			(0.011)	(0.012)
Space 7+ x Age			0.011***	0.011***			0.097***	0.096***
			(0.003)	(0.003)			(0.026)	(0.029)
Sibling FE	No	Yes	No	Yes	No	Yes	No	Yes
Obs	16717	16717	16717	16717	16655	16655	16655	16655

Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, and dummies for number of older siblings, sex, survey round, year and season of birth. OLS regressions also include wealth index, number of siblings, caregiver's education, and community dummies.

Columns 3 and 4 show results from the same regressions with the addition of an interaction term between birth spacing and child age in months. The interaction was positive and significant for both closely and widely spaced children. This is broadly con- sistent with our panel model results—closely and widely spaced children both outgrew the reference spacing group as they aged. However, we note that the base coefficient on the widely spaced group is negative and marginally significant in the fixed effects spec- ification. This suggests when comparing within a family, very widely spaced children may start out to be shorter than their more narrowly spaced siblings but then catch up over time. This finding is roughly consistent with maternal physiological regression theory, which hypothesizes worse early life outcomes for very widely spaced children.

Columns 5-8 show analogous results using weight-for-height as the regression out- come variable. Simple OLS, fixed effects, and our previous panel model results were all consistent for closely spaced children, showing significantly lower weight-for-height that persisted over time. However, in contrast to panel model results, when comparing very widely spaced children to their own siblings, there is no evidence that they received more nutritional investments over childhood. Thus, the health and investment trajec- tories of very widely spaced children roughly mirror those of closely spaced children when comparing within sibling pairs. Specifically, results suggest closely and widely spaced children partially caught-up to their siblings in height despite no evidence they received additional nutritional investments over childhood.

4 Discussion

We used longitudinal data collected between 2002 and 2016 on a cohort of approx- imately 4,000 children from four low-and middle-income countries to document the association between birth spacing and height trajectories over childhood. We found decreased height among children who were more narrowly spaced (less than three years) compared to children who were more widely spaced (three to seven years). However, we also found evidence of compensatory growth (estimated gaps in height that con- verge to the null) for closely spaced children. We also found that very widely spaced children (seven years or more) were of similar height to the reference spacing group (three to seven years) at age 1, but outgrew their more narrowly spaced counterparts over childhood.

4.1 Subgroup Findings and Mechanisms

Our panel weight-for-height (and to a lesser extent prenatal investment) results suggest that very widely spaced children (seven or more years) received substantially more nu- tritional investment over much of childhood, particularly males. This is consistent with the positive and widening height gap observed for this group over childhood. However, our family fixed effects model suggests that much of this difference may be explained by unobserved confounding influences of the child's family. Thus, considerable cau- tion should be taken if interpreting the observed associations between very wide birth spacing and improved height trajectories as a causal relationship.

For closely spaced children (under three years), we found a strong positive associa- tion between birth spacing and prenatal care-seeking. This suggest that the effects of birth spacing on prenatal growth and development may be partially driven by parental investment behavior. However, our mediation analysis of prenatal investments suggests that underlying maternal physiological factors play a primary role in explaining the emergence of height gaps by age 1.

After age 1, our stratified results provided evidence of catch-up growth for closely spaced males but roughly constant height gaps for females. However, our weight-for- height results suggest that closely spaced males did not receive significant additional nutritional investments over their childhood that would allow them to catch up in height to males who were more widely spaced. This supports the observed compen- satory growth after age one as an underlying biological phenomenon as opposed to being driven by parental investment behavior. Moreover, closely spaced females maintained a similar height trajectory as more widely spaced females despite evidence of substan- tially lower nutritional investments over childhood. These empirical finding—catch-up growth without remedial investments for males and equal growth with fewer invest- ments for females—provide evidence of substitutability (a concave curvature) in the health production function. Results from the family fixed effects model corroborate these finding, even suggesting compensatory growth without remedial investments for very widely spaced children when compared to their own sibling.

In general, economic theory emphasizes that substitutability should be accompanied by compensatory investments (Ashenfelter and Card, 2010; Currie and Almond, 2011), which we did not observe in our data for either sex. We propose several possible ex- planations that may serve to reconcile these two seemingly contradictory observations. First, it is possible that some families were unable to optimally compensate closely spaced children due to financial constraints on available resources. This seems a vi- able potential explanation given data was collected from four low- and middle-income countries, where financial institutions are generally less developed (Svirydzenka, 2016). Second, it may be that parents were not able to easily observe the adverse effects of short spacing and, as a result, did not see a need for improving their child's growth through compensatory investments. In order to explore this possibility, we examined the association between birth spacing and caregiver perceptions of child size from birth to age 5 (see Appendix Table 13). We did not find a statistically significant relation- ship between close birth spacing and caregivers perception of size, suggesting this as a viable explanation. However, point estimates suggest caregivers may have perceived closely spaced children to be smaller at birth and at age 1, but not at age 5. It therefore could be that the bulk of parental investments to compensate for poorer growth among closely spaced children are provided between ages 1 and 5 and that we simply do not have the necessary data within this time frame to observe these behaviors.

Finally, it may be that weight-for-height is too noisy or blunt of a short-term mea- sure of nutritional and other remedial investments. However, we found that closely spaced children received no more investments than widely spaced children across other possible measures of investment in our data—both in terms of meal frequency and va- riety (see Appendix Table 14)—which does not support this explanation. Nonetheless, it is possible that a more precise measure of investment or specific types of investments (e.g. parental time spent with children, emotional investments, etc.) may exhibit negative associations with birth spacing. While we have proposed several possible expla- nations for the limited evidence of compensatory parental investments in our analyses, it is clear that additional research is needed to convincingly disentangle the biological and behavioral channels through which birth spacing may alter childhood growth and development.

4.2 Study Limitations

There are several important limitations to our study that warrant discussion. First, we found considerable attenuation over time in initial height gaps associated with birth spacing, and the trajectory indicates a potential convergence of gaps to the null. How- ever, given the relatively short (15-year) period over which our sample was observed, we are unable to say whether convergence is assured in the long-run, particularly as children continue through periods of rapid growth and development during adolescence. Moreover, aggregate compensatory growth appears to be driven by males with little attenuation observed for females.

Second, our family fixed effects model provided no evidence that unobserved family characteristics are substantially influencing our panel model results for closely spaced children. However, there are several important caveats surrounding this conclusion. Firstly, it is important to reiterate that the composition of our panel sample differs from our pooled sibling sample. This is primarily because the pooled sample is limited to families with two non-first-born siblings without missing data. Secondly, a com- mon methodological criticism of the literature that relies on family fixed effects is the inability to adequately account for within-family heterogeneity in unobservable char- acteristics (Rosenzweig and Wolpin, 1988; Rosenzweig, 1986). Likewise, our use of a family fixed effect would not be sufficient in adjusting for any time-varying residual confounding that is associated with differential birth timing decisions across siblings (e.g. family wealth shocks or mother's employment status). However, in spite of these caveats, it is important to recall that our main results were estimated longitudinally on a single birth cohort of children. Therefore, even if some residual confounding re- mains, it does not invalidate the fact that there was catch-up growth among children who were more narrowly spaced in our panel sample—nor does it invalidate evidence that supports compensatory growth as an underlying biological as opposed to purely behavioral phenomenon. These findings provide novel evidence on the shape of the health production function over childhood and the influence of parental investment response to early health differentials.

Lastly, while we observed possible convergence in height in our sample across birth spacing groups, disparities in other outcomes may persist or emerge. For example, several studies have found longer intrapartum spacing to be associated with improved school test scores in older siblings, though the effects were found to be minimal for younger siblings (Broman et al., 1975; Buckles and Munnich, 2012). Further investi- gation along this line is warranted in order to determine the extent to which gaps in other key outcomes of health and development may persist over time for children who are more closely or widely spaced.

5 Conclusions

While our findings were somewhat mixed for very widely spaced children, we find that short preceding birth intervals are associated with growth faltering by early child- hood. This suggests that interventions aiming to increase birth intervals and support the healthy timing and spacing of pregnancies may be particularly important in pro- moting early childhood health and development. After infancy, we find evidence of substitutability in the evolution of child health, implying sustained investments over childhood may be able to combat the early negative effects of birth spacing. For ex- ample, our findings suggest that policies to promote increased nutritional investment for closely spaced girls could successfully narrow the persistent health gaps observed in our sample. Moreover, substitutability implies that such remedial investments would promote both equity and efficiency in the allocation of investments for child health; in contrast, dynamic complementarities imply a trade-off between equity and efficiency. Finally, it is essential that we continue to investigate the biological and behavioral mechanisms through which birth spacing may contribute to child health. A more thorough understanding of these causal pathways is essential for the development of effective policies, programs, and evidence-based interventions that seek to promote healthy growth and development in children from conception through adolescence and into adulthood.

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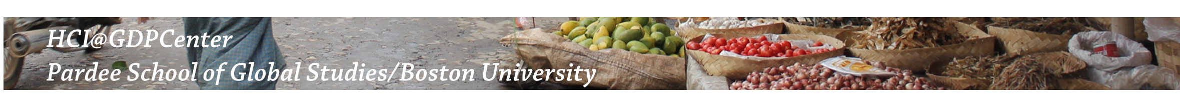

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Appendix

Appendix A: Variable Construction

Height/HAZ: We used height (cm) and height-for-age z-scores (HAZ) provided directly in the survey data sets. Included in analyses were all observations within WHO's recommended HAZ flexible exclusion range (Organization, 1995). Specifically, we dropped observations whose z-scores were more than plus or minus five from the mean of the sample for each age, or whose HAZ was greater than three. Such extreme values are believed by the WHO to be measurement error.

Community: Binary indicator for reported community of residence in the first round of the survey.

Male: Binary indicator for child reported as male.

Mother's Age at Birth: Derived from the combined houshold rosters.

Wealth Index: The study provided a constructed wealth index based on sub-indices of housing quality, access to services, and consumer durables (for additional details see Azubuike and Briones (2016)). We used the YLS constructed household wealth index from the fourth survey round.

Caregiver's Education: Years of education of the primary caregiver reported in the first round of the survey

Total Siblings: Derived from the combined houshold rosters.

Older Siblings: Derived from the combined houshold rosters, top coded at having three or more older siblings.

Meal Frequency: In the last three survey rounds data was collected on the frequency of eating in the past 24 hours (or a "normal" day). Seven yes/no questions were asked on if the child ate any food before breakfast, breakfast, food between breakfast and midday meal, midday meal, food between midday meal and evening meal, evening meal, and food after the evening meal. Our variable is a simple sum of these frequencies.

Meal Variety: In the last three survey rounds data was collected on the variety of food eaten in the past 24 hours (or a "normal" day). Yes/no questions were asked for eating each of up to 20 food groups depending on the survey round and country (i.e. eggs, cheese/milk, cactus). Our variable is a simple sum of the total number of categories reported eaten.

Prenatal Care: We used the level of antenatal care variable provided in the first round data set. The YLS study team constructed the variable as follows: a mother that reported no antenatal care was given a zero. For those who had antenatal visits, one was added if the first visit was when they were four months pregnant or before, one was added if the mother had five or more visits in total, and one was added if the mother was given tetanus injections. This gave a value between zero and three for all mothers.

Wanted: This variable is an indicator that takes a value of one if the parent responded yes to following: *"At the time you became pregnant with 'NAME' did you want to become pregnant?"*

Professional at Birth: This variable is an indicator that takes a value of one if the parent reported a doctor, nurse, or midwife was present during the child's delivery.

Home Birth: This variable is an indicator that takes a value of one if the parent reported the child's delivery was at home.

Perceived Birthsize: Caregiver's perception of birth size was collected in round one: *"When 'Name' was born, was he/she very large, large, average, small, or very small?"* This variable takes values between one (very small) and five (very large).

Perceived Height: Caregiver's perception of comparative height was collected in survey rounds 1-2: *"Compared to other child of this age would you say 'Name's' is the same height, taller, or shorter?"* This variable takes values between one (shorter) and three (taller).

Perceived Weight: Caregiver's perception of comparative weight was collected in survey rounds 1-2: *"Compared to other child of this age would you say 'Name's' is the same weight, heavier, or lighter?"* This variable takes values between one (lighter) and three (heavier)

Appendix B: Robustness Results

In our main analyses we grouped children into three birth spacing groups—less than 3, 3-7, and 7+ years. We chose these categories primarily based on WHO birth spacing recommendations and to keep groups large enough to maintain statistical precision—particularly for sub-group analyses. However, we also examined robustness of main panel results to defining finer birth spacing groups. Table 4 provides results based on seven spacing groups—less than 2 years, 2-3, 3-4, 4-5, 5-6, 6-7, and 7+ years. Spacing of 4-5 years is now the reference group. We found similar patterns in the two shortest spacing groups, though point estimates were marginally lower for those spaced less than two years compared to 2-3 years. There were no statically significant differences at any age for the 3-4, 5-6, or 6-7 year spacing groups. These findings further motivated our choice to group together 3-7 years of spacing as our reference category in our main analyses.

Table 4: Birth spacing and child height

	Age 1	Age 5	Age 8	Age 12	Age 15
Space <2	-0.839***	-0.556**	-0.498	-0.308	-0.486
	(0.191)	(0.263)	(0.306)	(0.422)	(0.398)
Space 2-3	-0.741***	-0.442*	-0.233	-0.359	-0.031
	(0.198)	(0.238)	(0.288)	(0.385)	(0.367)
Space 3-4	-0.058	0.063	0.105	-0.137	0.245
	(0.173)	(0.245)	(0.289)	(0.413)	(0.394)
Space 5-6	0.039	0.331	-0.214	0.002	-0.188
	(0.215)	(0.284)	(0.376)	(0.448)	(0.444)
Space 6-7	-0.357	-0.238	-0.354	-0.347	-0.585
	(0.273)	(0.371)	(0.429)	(0.601)	(0.503)
Space 7+	0.107	0.737***	0.860***	1.248***	0.608
	(0.209)	(0.285)	(0.329)	(0.391)	(0.397)
Ind	4094				

Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

While we used raw height as our primary child health outcome, we examined the robustness of results to standardized height-for-age and stunting. Height-for-age is measured by a child's WHO height-for-age z-score (*HAZ*), which is standardized against an international reference population sample. As *HAZ* is standardized based on the age-specific standard deviation of height in the reference population—and this standard deviation increases with age—it is possible for two children to diverge in height over time but the gap in their respective *HAZ* scores to decrease. This is why we used raw height as our primary outcome (we also controlled for age in months in all regressions). Stunting is a binary indicator that is defined by a child's *HAZ* falling below two standard deviations from the WHO MGRS reference median height. Including stunting as an outcome allows for more direct comparison of our findings with the existing estimates from the literature.

Table 5: Birth spacing and height-for-age (HAZ)

	Age 1	Age 5	Age 8	Age 12	Age 15
Space <3	-0.305***	-0.115***	-0.049	-0.035	-0.034
	(0.053)	(0.035)	(0.034)	(0.033)	(0.037)
Space 7+	0.045	0.144***	0.171***	0.199***	0.093**
	(0.069)	(0.049)	(0.047)	(0.046)	(0.042)
Ind	4094				

Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

Table 5 shows panel model results with height-for-age as the outcome. Compared to using raw height, similar, but somewhat stronger patterns emerged. *HAZ* gaps for closely spaced children were negative and significant at age one but diminished and become insignificant by age eight. For very widely spaced children, the *HAZ* gap was insignificant at age one, but positive and significant at all older ages (though it dropped some at age fifteen). Overall, *HAZ* results indicate that closely and very widely spaced children outgrew the reference spacing group relative to their projected height-for-age trajectory based on an *international reference population.*

Table 6: Birth spacing and stunting

Odds ratios reported. Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, *p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age

	Age 1	Age 5	Age 8	Age 12	Age 15
Space <3	1.333***	1.383***	1.372**	1.144	1.089
	(0.078)	(0.144)	(0.199)	(0.115)	(0.089)
Space 7+	0.991	0.688**	0.527***	0.796	0.888
	(0.096)	(0.107)	(0.113)	(0.121)	(0.103)
Ind	4094				

(months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

Appendix C: Results Tables

Table 7: Birth spacing and child height

	Raw					Adjusted				
	Age 1	Age 5	Age 8	Age 12	Age 15	Age 1	Age 5	Age 8	Age 12	Age 15
Space <3	-1.142***	-1.200***	-0.988***	-0.951***	-0.828***	-0.720***	-0.547***	-0.300	-0.244	-0.210
	(0.200)	(0.231)	(0.226)	(0.253)	(0.294)	(0.139)	(0.165)	(0.197)	(0.227)	(0.273)
Space 7+	0.467*	1.666***	1.871***	3.141***	2.140***	0.177	0.679***	0.931***	1.350***	0.663**
	(0.239)	(0.313)	(0.336)	(0.481)	(0.390)	(0.172)	(0.235)	(0.275)	(0.321)	(0.320)
Ind	4094					4094				

Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

Table 8: Birth spacing and child height by sex

	Females					Males				
	Age 1	Age 5	Age 8	Age 12	Age 15	Age 1	Age 5	Age 8	Age 12	Age 15
Space <3	-0.663***	-0.645***	-0.526	-0.726*	-0.664*	-0.818***	-0.419*	-0.064	0.264	0.110
	(0.209)	(0.242)	(0.323)	(0.388)	(0.354)	(0.165)	(0.233)	(0.278)	(0.335)	(0.400)
Space 7+	0.279	0.823**	1.222***	1.405***	0.784*	0.099	0.623**	0.836**	1.437***	0.809*
	(0.261)	(0.369)	(0.440)	(0.504)	(0.427)	(0.228)	(0.295)	(0.347)	(0.450)	(0.484)
Ind	1927					2167				

Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, survey round, season of birth, and community.

Table 9: Birth spacing and child height: India and Ethiopia

	India					Ethiopia				
	Age 1	Age 5	Age 8	Age 12	Age 15	Age 1	Age 5	Age 8	Age 12	Age 15
Space <3	-0.424*	-0.129	-0.081	0.028	-0.156	-1.387***	-0.948***	-0.732*	-0.498	-0.573
	(0.251)	(0.246)	(0.331)	(0.359)	(0.527)	(0.302)	(0.351)	(0.423)	(0.525)	(0.510)
Space 7+	-0.183	-0.291	-0.242	-0.779	-1.457*	0.390	1.083**	1.195**	1.140**	1.354*
	(0.545)	(0.527)	(0.697)	(0.794)	(0.807)	(0.351)	(0.525)	(0.470)	(0.562)	(0.702)
Ind	1057					1133				

Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

Table 10: Birth spacing and child height: Vietnam and Peru

	Vietnam					Peru				
	Age 1	Age 5	Age 8	Age 12	Age 15	Age 1	Age 5	Age 8	Age 12	Age 15
Space <3	-0.707***	-0.650*	-0.482	-0.532	-0.343	-0.219	-0.420	0.135	0.109	-0.007
	(0.200)	(0.334)	(0.414)	(0.521)	(0.671)	(0.157)	(0.318)	(0.314)	(0.364)	(0.358)
Space 7+	0.212	0.522	0.791	1.611***	0.970*	0.359	1.449***	1.991***	2.761***	1.813***
	(0.240)	(0.393)	(0.486)	(0.559)	(0.572)	(0.278)	(0.426)	(0.476)	(0.683)	(0.513)
Ind	969					935				

Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

Table 11: Mitigation effect of prenatal investment variables

	Age 1	Age 5	Age 8	Age 12	Age 15	Age 1	Age 5	Age 8	Age 12	Age 15
Space <3	-0.678***	-0.521***	-0.322	-0.257	-0.130	-0.650***	-0.452***	-0.236	-0.165	-0.067
	(0.132)	(0.163)	(0.208)	(0.236)	(0.265)	(0.136)	(0.170)	(0.213)	(0.239)	(0.264)
Space 7+	0.217	0.869***	1.100***	1.704***	0.995***	0.210	0.850***	1.075***	1.677***	0.973***
	(0.181)	(0.243)	(0.302)	(0.340)	(0.340)	(0.180)	(0.242)	(0.302)	(0.341)	(0.340)
Low prenatal care						-0.006	0.234	-0.001	-0.063	-0.296
						(0.229)	(0.349)	(0.419)	(0.411)	(0.503)
Mid prenatal care						-0.013	0.257	0.098	-0.471	-0.696
						(0.223)	(0.382)	(0.427)	(0.466)	(0.572)
High prenatal care						0.248	0.547	0.501	-0.058	-0.325
						(0.254)	(0.430)	(0.470)	(0.535)	(0.616)
Wanted						0.014	0.349*	0.419*	0.481*	0.278
						(0.094)	(0.179)	(0.225)	(0.267)	(0.266)
Pro at birth						0.525***	0.283	0.495	0.688	1.088***
						(0.193)	(0.258)	(0.368)	(0.441)	(0.350)
Home birth						0.153	0.001	0.006	0.049	0.442
						(0.170)	(0.222)	(0.327)	(0.454)	(0.371)
Ind	3694					3694				

Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community. No prenatal care is the reference group for level of prenatal care.

Table 12: Birth spacing and weight-for-height

	Females					Males				
	Age 1	Age 5	Age 8	Age 12	Age 15	Age 1	Age 5	Age 8	Age 12	Age 15
Space <3	-2.123***	-2.298***	-4.001***	-4.786**	-3.877*	-0.954*	0.316	0.034	-1.186	0.785
	(0.581)	(0.803)	(1.179)	(1.920)	(2.349)	(0.574)	(0.754)	(0.843)	(1.464)	(1.799)
Space 7+	1.858**	0.930	0.534	3.588	2.106	0.366	1.893*	3.384**	6.126**	8.502***
	(0.867)	(1.233)	(1.874)	(3.291)	(3.604)	(0.879)	(1.004)	(1.467)	(2.615)	(3.293)
Ind	1897					2126				

Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

Table 13: Caregiver perceptions of child size

	Birthsize	Weight		Height	
		Age 1	Age 5	Age 1	Age 5
Space <3	0.970	0.967	1.011	0.995	1.021
	(0.040)	(0.043)	(0.048)	(0.036)	(0.047)
Space 7+	1.036	1.116*	0.984	1.032	1.036
	(0.055)	(0.063)	(0.053)	(0.069)	(0.061)
Obs	4243	4259	4355	4251	4361

Odds ratios reported. Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

Table 14: Childhood nutritional investments

	Birthsize	Weight		Height	
		Age 1	Age 5	Age 1	Age 5
Space <3	0.970	0.967	1.011	0.995	1.021
	(0.040)	(0.043)	(0.048)	(0.036)	(0.047)
Space 7+	1.036	1.116*	0.984	1.032	1.036
	(0.055)	(0.063)	(0.053)	(0.069)	(0.061)
Obs	4243	4259	4355	4251	4361

Robust standard errors (clustered at the community level) in parentheses, p-values—*** p<0.01, ** p<0.05, * p<0.1. Additional independent variables in all regressions: mother's age at birth, mother's age at birth squared, age (months), age squared, wealth index, total number of siblings, caregiver's education, and dummies for number of older siblings, sex, survey round, season of birth, and community.

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