



**Supplementary Information for**

Effects of short birth spacing on birth order differences in child stunting:  
Evidence from India

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## Supplementary Information Text

### Alternate regression model using continuous specification for preceding birth spacing (in months)

SI Appendix Fig. S3 plot HAZ and birth spacing for later born children only using several parametric and non-parametric fitting options. For firstborn children there is no preceding birth spacing, hence the regression is estimated dropping first born children. We see that a quadratic in spacing offers a better fit across different specification.

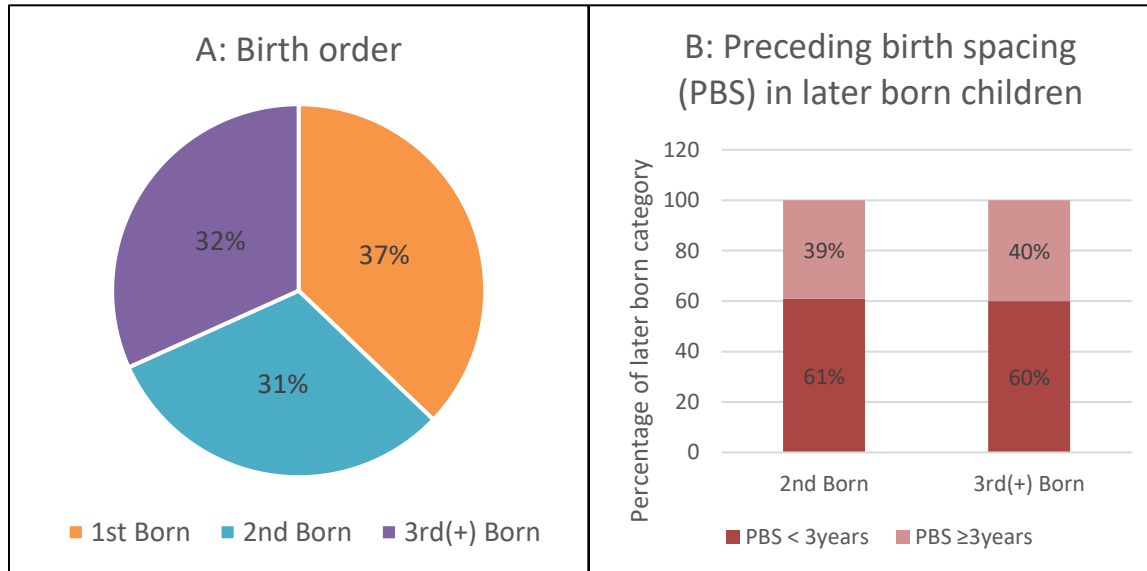
Hence, instead of using categorical variables, we could have used a continuous variable for spacing in months and estimated equation 3 below.

$$(3) \quad Y_{imd} = \alpha_2 2nd\ born_{imd} + \alpha_3 3rd(+)\ born_{imd} + \beta_2 PBS(months)_{imd} \times 2nd\ born_{imd} + \beta_3 PBS(months)_{imd} \times 3rd(+)\ born_{imd} + \gamma_2 PBS(months)^2_{imd} \times 2nd\ born_{imd} + \gamma_3 PBS(months)^2_{imd} \times 3rd(+)\ born_{imd} + \delta X_{imd} + \varepsilon_{imd}$$

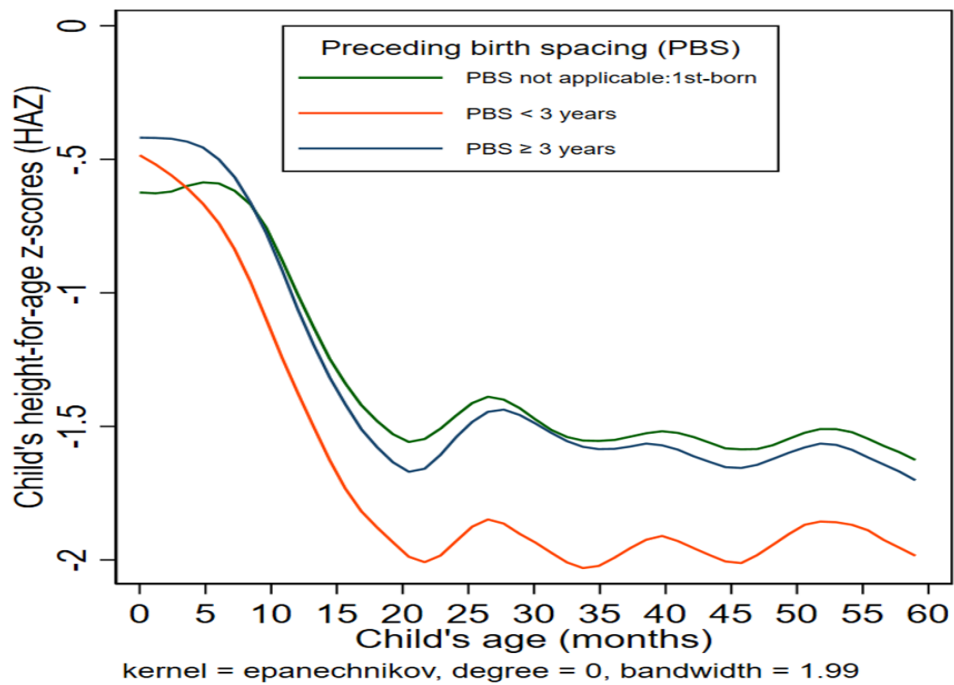
The results for the main specification of covariates with continuous birth spacing is reported in Table S6. With an increase in PBS by 1 month, HAZ increases at a decreasing rate (the coefficient on interaction with PBS is positive and on interaction with PBS-squared term is negative), for all higher order births. A clear understanding of the concavity is, however, obtained from plotting the HAZ outcome across birth spacing length (See Panel A in SI Appendix Fig. S4). We see the curve becomes flat post 36 mo of spacing (X-axis).

Panel B in SI Appendix Fig. S4 plots the marginal effect of birth spacing for each birth order category, i.e., the change in HAZ due to an additional month of PBS for 2nd-bor and 3rd (+)-born children. The confidence interval overlaps for the two later born categories implying that the effect of increasing PBS by a month is similar across the two higher birth order categories.

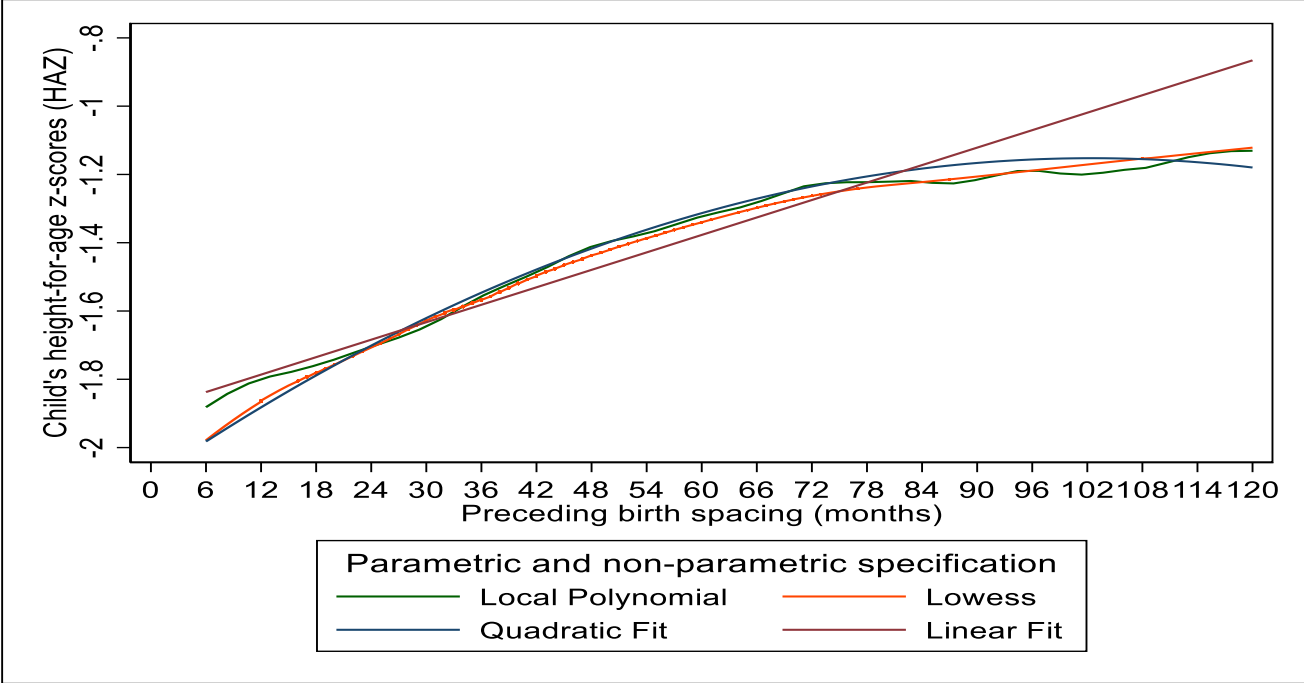
### Supplementary Information: Figures



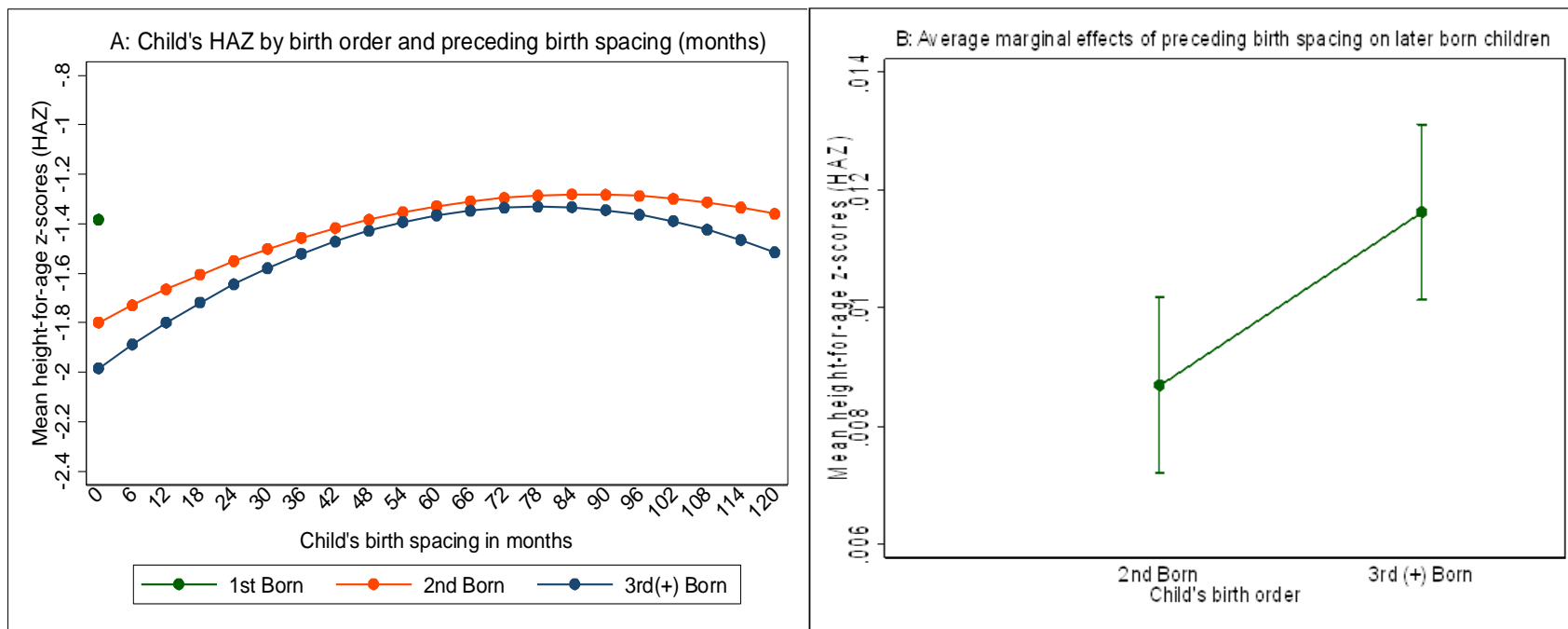
**Fig. S1.** Current distribution of birth order (A) and preceding birth spacing (B) in India. Panel A graphs the current distribution of birth order in India. Birth order is classified into 3 categories: 1st-born for children with birth order 1, 2nd-born for children with birth order 2, and 3rd (+)-born for children with birth order 3 and higher. Panel B graphs the current distribution of length of PBS (PBS < 3 y and PBS ≥ 3 y) for later born children, i.e., 2nd-born and 3rd (+)-born, in India. By definition, firstborn children have no PBS. The percentages represent the dominance of later-born children in the total birth composition (A), and prevalence of PBS < 3 y within the later born category (B).



**Fig. S2.** Mean HAZ by child's age and length of preceding birth spacing. A local polynomial regression of HAZ on child's age is estimated separately for each PBS category (1<sup>st</sup>-born, PBS < 3 y and PBS ≥ 3 y). The figure displays a graph of the smoothed values obtained from those regression. We find that mean HAZ continues to fall till the age of 20 mo and then stabilizes, irrespective of the PBS category.



**Fig. S3.** Relationship between HAZ and preceding birth spacing for later-born children. The figure plots HAZ against a continuous measure of preceding birth spacing (in months) for later born children using several parametric and non-parametric fitting options. We see that a having a quadratic in PBS offers a better fit across different specification.



**Fig. S4.** Predictive HAZ on using continuous measure of preceding birth spacing (PBS), by birth order (A) and average marginal effects of PBS on higher order births (B). Panel A plots Child HAZ by birth order using a quadratic specification of PBS (continuous in months). Panel B plots the average effect on HAZ for every additional month of PBS on children of higher birth order, i.e., 2nd-born and 3rd (+)-born.

## Supplementary Information: Tables

**Table S1.** Descriptive statistics of the control variables used in the regression

	Mean	s.d.	Obs.
Child's age (months)	30.01	17.01	220980 <sup>a</sup>
Child is a girl	48.26	0.50	220980 <sup>a</sup>
Child's birth order	2.26	1.46	220980 <sup>a</sup>
Child's PBS (median)	32.00	24.89	140622 <sup>f</sup>
Elder sibling: alive	55.38	0.50	220980 <sup>a</sup>
Elder sibling: dead	3.77	0.19	220980 <sup>a</sup>
Elder sibling: not applicable (1 <sup>st</sup> -born)	34.48	0.48	220980 <sup>a</sup>
Elder sibling: pregnancy terminated	6.37	0.24	220980 <sup>a</sup>
Mother's age at birth (y)	24.69	4.95	220980 <sup>a</sup>
Child is a single birth	99.23	0.09	220980 <sup>a</sup>
Duration of pregnancy	9.04	0.43	220980 <sup>a</sup>
Child's sibling size (total children born to a woman)	2.54	1.50	220980 <sup>a</sup>
Child was born at a private institution	20.50	0.40	220980 <sup>a</sup>
Child is fully vaccinated as per age	56.12	0.50	220980 <sup>a</sup>
Child received worm tablets in 6 months	27.62	0.45	220980 <sup>a</sup>
Child received iron supplementation	22.87	0.42	220980 <sup>a</sup>
Mother took iron supplements when pregnant	76.97	0.42	160164 <sup>b</sup>
Mother took worm tablets when pregnant	15.37	0.36	160164 <sup>b</sup>
Mother's total tetanus shots before delivery	1.90	0.76	160164 <sup>b</sup>
Mother made 4 or more ANC visits during gestation	47.67	0.50	160164 <sup>b</sup>
Mother received professional prenatal	78.34	0.41	160164 <sup>b</sup>
Mother's health checked before discharge	59.61	0.49	160164 <sup>b</sup>
Mother received postnatal check within 2 months	35.82	0.48	160164 <sup>b</sup>
Child eats a diversified diet (DD)	39.66	0.49	80877 <sup>c</sup>
Child meets minimum dietary adequacy (MDA)	29.82	0.46	80877 <sup>c</sup>
Mother's education (y)	6.21	5.12	222855 <sup>d</sup>
Mother watches TV almost every day	48.69	0.50	222855 <sup>d</sup>
Mother reads news at least once a week	9.87	0.30	222855 <sup>d</sup>
Mother reads news almost every day	7.47	0.26	222855 <sup>d</sup>
Mother's height is < 150 cm	38.25	0.49	222855 <sup>d</sup>
Mother has a low BMI	23.80	0.43	222855 <sup>d</sup>
Mother eats a highly DD	27.82	0.45	222855 <sup>d</sup>
HH is in rural India	76.01	0.43	214683 <sup>e</sup>
HH wealth index	49.86	24.29	214683 <sup>e</sup>
HH size	6.57	2.87	214683 <sup>e</sup>
HH head belongs to SC	19.20	0.39	214683 <sup>e</sup>
HH head belongs to ST	19.81	0.40	214683 <sup>e</sup>
HH head belongs to OBC	39.49	0.49	214683 <sup>e</sup>
HH head belongs to other Caste	17.79	0.38	214683 <sup>e</sup>
HH head caste is missing	3.71	0.19	214683 <sup>e</sup>
HH head is a Hindu	72.34	0.45	214683 <sup>e</sup>
HH head is a Muslim	15.73	0.36	214683 <sup>e</sup>
HH head belongs to other religion	11.94	0.32	214683 <sup>e</sup>
HH has safe handwash facility	57.43	0.49	214683 <sup>e</sup>
HH has piped water	37.31	0.48	214683 <sup>e</sup>
HH openly defecates	44.13	0.50	214683 <sup>e</sup>
HH safely disposes stool	34.14	0.47	214683 <sup>e</sup>
Community level improved toilet (%)	42.50	30.69	214683 <sup>e</sup>

**Source:** Authors' calculation using sample of children aged 0–60 mo with valid data on child height, birth order, and birth spacing, extracted from NFHS Round IV (2015/16)

**Notes:** sd.: standard deviation; Obs.: observations; PBS: Preceding birth spacing; ANC: Antenatal care; DD: Diversified diet; MDA: Minimum dietary adequacy; BMI: Body mass index; NFHS: National Family Health Survey; SC: Scheduled caste; ST: Scheduled tribe; OBC: Other backward caste.

<sup>a</sup>Available for all living children below 5 y, removes cases with invalid covariate values; <sup>b</sup>Available only for the last child born, removes cases with invalid covariate values; <sup>c</sup>Available only for the last child below 2 y, removes cases with invalid covariate values; <sup>d</sup>Removes cases with invalid 'mother level' covariate values; <sup>e</sup>Removes cases with invalid 'HH level' covariate values; <sup>f</sup>Removes 1<sup>st</sup>-born children from calculation of median level of PBS.

**Table S2:** Median preceding birth spacing (PBS) by mother's age

Mother's age	% of sample	Median PBS (in months)	% of sample with PBS < 32 mo
15-19 y	3	22	84
20-29 y	69	28	61
30-39 y	26	38	38
40-49 y	2	45	30

**Source:** Authors' calculation using sample of children aged 0–60 mo with valid data on child height, birth order, and birth spacing, extracted from NFHS Round IV (2015/16)



**Table S3.** (Sub-group Analysis) The effect of birth order on child HAZ, by preceding birth spacing

	1	2	3	4
2nd born X PBS < 3 y	-0.10** (0.04)	0.01 (0.06)	-0.23*** (0.04)	-0.03 (0.06)
2nd born X PBS ≥ 3 y	0.05 (0.04)	0.17*** (0.06)	-0.03 (0.04)	0.14** (0.06)
3rd (+) born X PBS < 3 y	-0.17*** (0.04)	-0.05 (0.07)	-0.33*** (0.04)	-0.10 (0.06)
3rd (+) born X PBS ≥ 3 y	0.02 (0.04)	0.09 (0.07)	-0.09** (0.04)	0.05 (0.06)
Mean outcome of 1 <sup>st</sup> -born	-1.35	-1.35	-1.35	-1.35
PSU fixed effect	Yes	Yes	Yes	Yes
Gestation length	Yes	Yes	Yes	Yes
Previous pregnancy Status	Yes	Yes	Yes	Yes
Prenatal & postnatal care	Yes	Yes	Yes	No
Feeding practices	No	Yes	Yes	No
Sub-group age sample: 2-5 y	No	No	Yes	Yes
Sub-group age sample: 0-2 y	No	No	No	Yes
Observations	151038	71630	127358	77217
R-squared	0.352	0.443	0.38	0.436

**Source:** Authors' calculation using sample of children aged 0–60 mo with valid data on child height, birth order, and birth spacing, extracted from NFHS Round IV (2015/16)

**Notes:** Standard errors appear in brackets and are clustered by mother in all regressions. HAZ: height-for-age z-scores; PBS: Preceding birth spacing; PSU: Primary sampling unit; FE: Fixed effect; NFHS: National Family Health Survey. 1st-born is an indicator for children whose birth order is 1, and is the omitted category; 2nd-born is an indicator for children whose birth order is 2; 3rd (+)-born is an indicator for children whose birth order is 3 or higher; PBS < 3 y is an indicator for children who were born within 36 mo of the preceding birth to their mother; PBS ≥ 3 y is an indicator for children who were born 36 or more months after the preceding birth to their mother.

All Columns include the specification of controls used in our preferred estimation PSU FE, (i.e., on the sample of clusters with two or more children less than 5 y), with the following controls: an indicator for child's age (in months), gender, duration and type of pregnancy outcome (single or multiple); and outcome of previous pregnancy of the mother (alive, dead, or terminated); mother-level variables: mother's age at birth, height (in cm), a measure of diet diversity, and indicator variables for mother's education, daily television viewing, reading of news weekly or more frequently, and low BMI; household controls include a measure for household wealth computed using International Wealth Index, the number of people living in the household, and indicators for caste and religion of the head of the household head, access to safe handwashing facilities, access to piped water for drinking, open defecation, following of safe stool disposal practices, and a measure of community-level availability of improved toilet. Column 1, in addition to above, also controls for health care practices adopted by the mother before and after delivery of the reference child. The sample is restricted to one and the youngest child under 5 y in the family. Before delivery controls include: an indicator for mother having 4 or more prenatal visits, consulting a professional for prenatal care, receiving Iron-Folic Acid supplementation & deworming tablets during pregnancy, total number of tetanus shots during pregnancy, and delivery of the child at a private health care institution. After delivery controls include: an indicator for mother undergoing a health check-up at discharge, receiving postnatal care within 2 mo of delivery, child being fully immunized at the time of survey, child receiving worm tablets and iron supplements within 6 mo before the survey. Column 2 is restricted to the youngest child between 6-24 month in the family and includes dietary intake information: child consuming a diversified diet and meeting minimum dietary adequacy recommendations. Column 3 is the estimation of our preferred model on the age group 2-5 y whereas column 4 is restricted to children under age 2 y. Column 3 and 4 do not include the additional controls listed for column 1 and 2.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

**Table S4.** The effect of birth order on child height, by birth spacing, gender of the child and siblings

Child's gender	Gender of first child		Gender of second child		
	1	2	3		
1st born girl	0.12*** (0.01)				
2nd born boy X PBS < 3 y	-0.14*** (0.03)	2nd born X PBS < 3 y X FBS boy	-0.16*** (0.03)	2nd born X PBS < 3 y X SBS boy	-0.15*** (0.03)
2nd born girl X PBS < 3 y	-0.06 (0.03)	2nd born X PBS < 3 y X FBS girl	-0.16*** (0.03)	2nd born X PBS < 3 y X SBS girl	-0.16*** (0.03)
2nd born boy X PBS ≥ 3 y	0.03 (0.04)	2nd born X PBS ≥ 3 y X FBS boy	0.02 (0.04)	2nd born X PBS ≥ 3 y X SBS boy	0.01 (0.04)
2nd born girl X PBS ≥ 3 y	0.14*** (0.04)	2nd born X PBS ≥ 3 y X FBS girl	0.02 (0.03)	2nd born X PBS ≥ 3 y X SBS girl	0.03 (0.04)
3rd (+) born boy X PBS < 3 y	-0.21*** (0.04)	3rd (+) born X PBS < 3 y X FBS boy	-0.25*** (0.04)	3rd (+) born X PBS < 3 y X SBS boy	-0.24*** (0.04)
3rd (+) born girl X PBS < 3 y	-0.18*** (0.04)	3rd (+) born X PBS < 3 y X FBS girl	-0.26*** (0.04)	3rd (+) born X PBS < 3 y X SBS girl	-0.27*** (0.04)
3rd (+) born boy X PBS ≥ 3 y	-0.02 (0.04)	3rd (+) born X PBS ≥ 3 y X FBS boy	-0.06* (0.04)	3rd (+) born X PBS ≥ 3 y X SBS boy	-0.03 (0.04)
3rd (+) born girl X PBS ≥ 3 y	0.06 (0.04)	3rd (+) born X PBS ≥ 3 y X FBS girl	-0.03 (0.04)	3rd (+) born X PBS ≥ 3 y X SBS girl	-0.05 (0.04)
Mean outcome of 1st born	-1.47		-1.47		-1.47
PSU fixed effect	Yes		Yes		Yes
Gestation length	Yes		Yes		Yes
Previous pregnancy status	Yes		Yes		Yes
Birth order X child's gender	Yes		Yes		Yes
Birth Order X gender of FBS	No		Yes		Yes
Birth order X gender of SBS	No		No		Yes
Observations	21146		211461		211461
R-squared	0.325		0.325		0.325

**Source:** Authors' calculation using sample of children aged 0–60 mo with valid data on child height, birth order, and birth spacing, extracted from NFHS Round IV (2015/16)

**Notes:** Standard errors appear in brackets and are clustered by mother in all regressions. HAZ: height-for-age z-score; PBS: Preceding Birth Spacing; PSU: Primary Sampling unit; FE: Fixed effect; NFHS: National Family Health Survey. 1st Born is an indicator for children whose birth order is 1; 2nd Born is an indicator for children whose birth order is 2; 3rd+ Born is an indicator for children whose birth order is 3 or higher; PBS < 3 y is an indicator for children who were born within 36 mo of the preceding birth to their mother; PBS ≥ 3 y is an indicator for children who were born 36 or more months after the preceding birth to their mother; Boy is an indicator if the child is a boy; Girl is an indicator if the child is a girl; FBS: Firstborn sibling; SBS: Second born sibling. 1st born boy is the omitted category in column 1. 1st-born is the omitted category in column 2 and 3, this category has no elder sibling).

All Columns include the specification of controls used in our preferred estimation PSU FE, (i.e., on the sample of clusters with two or more children less than 5 y), with the following controls: an indicator for child's age (in months), gender, duration and type of pregnancy outcome (single or multiple); and outcome of previous pregnancy of the mother (alive, dead, or terminated); mother-level variables: mother's age at birth, height (in cm), a measure of diet diversity, and indicator variables for mother's education, daily television viewing, reading of news weekly or more frequently, and low BMI; household controls include a measure for household wealth computed using International Wealth Index, the number of people living in the household, and indicators for caste and religion of the head of the household head, access to safe handwashing facilities, access to piped water for drinking, open defecation, following of safe stool disposal practices, and a measure of community-level availability of improved toilet. Column 1 further splits the spacing order indicators by the gender of the reference child.

Column 2 splits the spacing order indicators by the gender of the firstborn sibling. Column 3 splits the spacing order indicators by the gender of the second born sibling.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

**Table S5.** (Sensitivity Analysis) The effect of birth order on child height, by birth spacing

	High fertility states	Mother's education			Mother's age at birth			Different cut-off for PBS	
	1	Illiterate	Less than secondary	Secondary & above	24 y or below	Between 25-29 y	30 y and above	PBS cut-off: 33 mo	
	1	2	3	4	5	6	7	8	
2nd born X PBS < 3 y	-0.09** (0.04)	-0.17** (0.07)	-0.19*** (0.05)	-0.01 (0.15)	-0.13*** (0.05)	-0.16** (0.07)	-0.04 (0.18)	2nd born X PBS < 33 mo	-0.16*** (0.03)
2nd born X PBS ≥ 3 y	0.10** (0.04)	0.06 (0.08)	-0.00 (0.05)	0.23 (0.15)	0.13*** (0.05)	-0.04 (0.07)	0.02 (0.17)	2nd born X PBS ≥ 33 mo	0.01 (0.03)
3rd (+) born X PBS < 3 y	-0.21*** (0.04)	-0.27*** (0.07)	-0.27*** (0.05)	-0.03 (0.18)	-0.16*** (0.05)	-0.28*** (0.07)	-0.18 (0.17)	3rd (+) born X PBS < 33 mo	-0.26*** (0.03)
3rd (+) born X PBS ≥ 3 y	0.01 (0.04)	-0.03 (0.08)	-0.05 (0.05)	0.03 (0.18)	0.18*** (0.06)	-0.06 (0.07)	-0.01 (0.17)	3rd (+) born X PBS ≥ 33 mo	-0.06* (0.03)
Mean outcome of 1st born	-1.35	-1.35	-1.35	-1.35	-1.35	-1.35	-1.35		-1.35
PSU fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Gestation length	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
Previous pregnancy status	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
High fertility states sample	Yes	No	No	No	No	No	No		No
Mother's education sample	No	Yes	Yes	Yes	Yes	Yes	Yes		No
Mother's age at birth sample	No	No	No	No	Yes	Yes	Yes		No
PBS cut-off: 33 mo	No	No	No	No	No	No	No		Yes
PBS cut-off: 2 y	No	No	No	No	No	No	No		No
Observations	115834	60199	106450	12157	114500	54375	25175		211461
R-squared	0.293	0.362	0.383	0.532	0.371	0.472	0.507		0.325

**Source:** Authors' calculation using sample of children aged 0–60 mo with valid data on child height, birth order, and birth spacing, extracted from NFHS Round IV (2015/16)

**Notes:** Standard errors appear in brackets and are clustered by mother in all regressions. HAZ: height-for-age z-score; PBS: Preceding Birth Spacing; PSU: Primary Sampling unit; FE: Fixed effect; NFHS: National Family Health Survey. 1st-Born is an indicator for children whose birth order is 1, and is the omitted category; 2nd-Born is an indicator for children whose birth order is 2; 3rd+ Born is an indicator for children whose birth order is 3 or higher; PBS <3 y is an indicator for children who were born within 36 mo of the preceding birth to their mother; PBS ≥ 3 y is an indicator for children who were born 36 or more months after the preceding birth to their mother; PBS <33 mo is an indicator for children who were born within 33 mo of the preceding birth to their mother; PBS ≥ 33 mo is an indicator for children who were born 33 or more months after the preceding birth to their mother. Column 1 is the high fertility states sample; includes Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand and Assam. Column 2-4 is the subsample for 3 categories of mother's education: illiterate (2), below secondary (3) and secondary & above (4). Column 5-7 is the subsamples for 3 categories of mother's age at birth of the child: Age 24 and below (5), between 25-29 (6), and 30 and above (7). Column 8 compute and reports the preferred PSU FE estimates using a different cut-off for PBS: 33 mo (8).

All Columns include the specification of controls used in our preferred estimation PSU FE, (i.e., on the sample of clusters with two or more children less than 5 y), with the following controls: an indicator for child's age (in months), gender, duration and type of pregnancy outcome (single or multiple); and outcome of previous pregnancy of the mother (alive, dead, or terminated); mother-level variables: mother's age at birth, height (in cm), a measure of diet diversity, and indicator variables for mother's education, daily television viewing, reading of news weekly or more frequently, and low BMI; household controls include a measure for household wealth computed using International Wealth Index, the number of people living in the household, and indicators for caste and religion of the head of the household head, access to safe handwashing facilities, access to piped water for drinking, open defecation, following of safe stool disposal practices, and a measure of community-level availability of improved toilet.

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

**Table S6.** The effects of birth order on child height using continuous measure of preceding birth spacing (in months)

	Variable	1
Birth order	2nd born	-0.37*** (0.03)
	3rd (+) born	-0.52*** (0.03)
Interactions (with continuous PBS): Birth order X PBS	2nd born X PBS (mo)	0.01*** (0.00)
	3rd (+) born X PBS (mo)	0.01*** (0.00)
Interactions (with continuous PBS): Birth order X PBS squared	2nd born X PBS <sup>2</sup> (mo)	-0.00*** (0.00)
	3rd (+) born X PBS <sup>2</sup> (mo)	-0.00*** (0.00)
	Mean outcome of 1st born	-1.39
	Observations	212458
	R-squared	0.166

**Source:** Authors' calculation using sample of children aged 0–60 mo with valid data on child height, birth order, and birth spacing, extracted from NFHS Round IV (2015/16)

**Notes:** Standard errors appear in brackets and are clustered by mother in all regressions. HAZ: height-for-age z-score; BO: Birth order PBS: Preceding birth spacing; NFHS: National Family Health Survey. 1st born is an indicator for children whose birth order is 1, 2nd born is an indicator for children whose birth order is 2; 3rd (+) born is an indicator for children whose birth order is 3 or higher.

The regression include the specification of controls used in our preferred estimation PSU FE, (i.e., on the sample of clusters with two or more children less than 5 y), with the following controls: an indicator for child's age (in months), gender, duration and type of pregnancy outcome (single or multiple); and outcome of previous pregnancy of the mother (alive, dead, or terminated); mother-level variables: mother's age at birth, height (in cm), a measure of diet diversity, and indicator variables for mother's education, daily television viewing, reading of news weekly or more frequently, and low BMI; household controls include a measure for household wealth computed using International Wealth Index, the number of people living in the household, and indicators for caste and religion of the head of the household head, access to safe handwashing facilities, access to piped water for drinking, open defecation, following of safe stool disposal practices, and a measure of community-level availability of improved toilet

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$