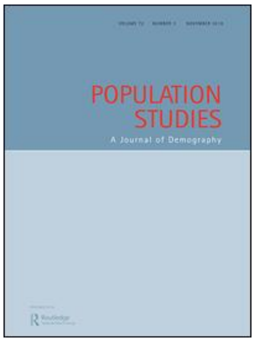

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Disentangling the effects of reproductive behaviours and fertility preferences on child growth in India

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We analysed population data from the 2015–16 National Family Health Survey to disentangle the intricate underlying effects of reproductive behaviours and fertility preferences on child growth. We expected birth interval length to be more strongly associated with stunting than sibsize and these effects to be moderated by whether the child was wanted or unintended (mistimed/unwanted). Regression analyses showed strong and equal effects of short birth interval and sibsize on stunting, when adjusted for potential confounders and unobserved between-mother heterogeneity. There were no statistical associations between stunting and mistiming/unwantedness of index children, suggesting the absence of discrimination against such children. We conclude that while fertility preferences have no effect, reproductive behaviours exert significant influence on child growth. Sibsize has been falling for many years in India but birth interval lengths have remained largely unchanged. The results underscore the need for strengthening uptake of reversible contraceptives to enable longer birth intervals.

Keywords: child growth; stunting; unintended; mistimed; unwanted; preceding birth interval; sibsize; fertility preference; reproductive behaviour; India

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Introduction

Despite substantial improvements in under-five mortality, India continues to report the largest share of undernourished children in the world (UNICEF 2017). Two in five children in India are stunted (IIPS and ICF 2017). Undernourished children experience elevated risks of infections, cognitive and neurological impairment, metabolic disorders, chronic disease, and their economic productivity in later life is low (Gutbrod et al. 2000; Schaible and Stefan 2007; Victora et al. 2008; Hoddinott et al. 2013). The need for a better understanding of the circumstances that lead to poor growth in Indian children is a national health priority.

The first aim of this paper is to assess the linkages between reproductive behaviour and the risk of stunting in children aged under five years in India. Specifically, we examine two indicators of behaviour: preceding birth interval length and sibsize (i.e. the number of surviving children in the family). These two components of family building are, of course, related. Women with large numbers of children are likely to have experienced shorter intervals between births than those with small families, but the association is not so close as to prevent independent examination of each. An important unresolved issue for India is the relative strength of these two risk factors for stunting. The second aim of this paper is to assess links between unintendedness and stunting, and to establish whether or not reproductive attitudes mediate or attenuate associations between birth interval length and stunting and between sibsize and stunting.

A substantial literature, mostly based on the analysis of Demographic and Health Surveys (DHSs), shows evidence on the associations between child growth and birth interval length. While the positive effect of preceding birth interval length on child survival is firmly established, evidence of its effect on stunting is less clear. Using pooled DHS data from 52 different countries between 2006 and 2012, Rutstein and Winter (2014) found a negative association between preceding birth interval length and stunting, after adjusting for a wide range of possible confounders. Compared with intervals from preceding birth to conception of 36–47 months, the adjusted odds of stunting rose monotonically with shorter intervals, with odds of 1.39 for intervals of less than six months. The causal pathways are probably biological, and include poor foetal growth and prematurity owing to maternal depletion, although sibling competition and cross infection may also contribute (Boerma and Bicego 1992; Conde-Agudelo et al. 2012). However, effects on interval length appear to be context specific. An extensive literature review by Dewey and Cohen (2007) showed that out of 50 studies conducted in developed and less developed countries, about half found no significant association between preceding birth interval and child nutritional outcomes, while the rest found the expected adverse effect of short intervals. Their review also found that the association between succeeding birth interval and child nutrition outcomes was mixed, with results in both negative and positive directions.

The literature on the effects of sibsize (or its closely related but imperfect proxy, birth order) on child growth is similarly extensive. An analysis of height-for-age in children aged 3–36 months, based on DHS data from 15 countries, found moderate associations with the presence of a sibling aged under five years but very small associations for the presence of older siblings, suggesting that short intervals between births may be a more important influence on growth than number of siblings (Desai 1992). However, after controlling for preceding interval length, the effect of an under-five sibling on stunting of the index child remained significant in 10 of the 15 surveys. Resource dilution is the obvious explanation for any effects of sibsize on child growth. The pooled analysis by Rutstein and Winter (2014) found the odds ratios of stunting by birth order to be trivial after adjustment for birth interval length and other factors: compared with birth orders one and two, the odds ratio of stunting for birth orders three and four was 1.03, rising to 1.08 for orders five and six. This result suggests that birth interval length may be a more important influence on stunting than number of siblings, though, as discussed shortly, birth order is not synonymous with sibsize.

A limited number of Indian studies have also found mixed results with regard to the association between reproductive behaviours and child stunting. Preceding birth interval and birth order both had significant effects on child stunting in a study using data from the third round of the National Family Health Survey (NFHS), the Indian equivalent of the DHS (Rana and Goli 2018). This study found that children born at the intersectional axes of higher birth order (3+) and short birth interval (<24 months) experienced the highest risk of stunting. Using the same data set and applying an additive quintile regression model, Fenske et al. (2013) found that preceding birth interval and birth order had non-linear positive and negative relationships, respectively, with height-for-age of children under five years. Another study from a city in Madhya Pradesh showed that the risk of stunting was about twice as high among children with a preceding birth interval of <24 months than for those born after intervals of 48+ months (Shahjada et al. 2014). Analysis of data from an urban slum of a city in Uttar Pradesh found that the likelihood of stunting was three times as high among children of third or higher birth order than those of first or second birth order (Srivastava et al. 2012).

A recent study by Jayachandran and Pande (2017) found that children born at higher orders were more likely to be stunted, and the gradient of stunting by birth order was steeper in India than in sub-Saharan Africa. They argued that higher-order children suffer discrimination in terms of resource allocation due to favouritism or preference towards the elder sons. In a reanalysis of the same data, Spears et al. (2019) showed that the omission of sibsize in the analysis was crucial. Indeed, when sibsize was included, they found that higher-order births were less, not more, likely to be stunted. In this paper we use sibsize rather than birth order as the preferred indicator of possible resource constraints within households.

A major problem with any assessment of the association between birth intervals or sibsize and child welfare is endogeneity (Öberg 2017). Couples who choose to have large families may differ in unmeasured attitudes and behaviours from couples who choose small families and these unmeasured factors may influence child welfare, including linear growth. We address this problem in two ways. The first is to apply a mother-level fixed effect model, which is possible for birth interval lengths because children born to the same mother may have different birth intervals, but not possible for sibsize. The second is to introduce fertility preferences into the analysis, in recognition that reproductive choice is far from perfect in India. It has been estimated that about half of all pregnancies in India are unintended, because of lack of access, broadly defined, to contraception (Singh et al. 2018). Though over half of these pregnancies are terminated, a substantial minority of unintended pregnancies are carried to term. The introduction of this preferences perspective allows us to compare, for instance, the link between sibsize and stunting for children who were wanted (and thus a consequence of conscious choice) vs. those who can be classified as unwanted (as a consequence of lack of contraceptive access). To the extent that the sibsize gradient in stunting is similar for both wanted and unwanted children, confidence in a causal link will be increased.

Of course, unintendedness of births may have an independent effect on child welfare, including growth, because of conscious or unconscious discrimination. The results of multi-country analyses are inconclusive on this (Montgomery and Lloyd 1997; Marston and Cleland 2003). Evidence from Bangladesh is also mixed: a study using DHS data found a link between unwantedness and childhood stunting, while another study using longitudinal data from the Matlab surveillance site observed no effect of unwantedness on child survival (Bishai et al. 2015; Rahman 2015). No effect of intendedness on stunting was found in Malawi, but a study in Ethiopia showed that unintended children were more likely to be stunted than their counterparts (Baschieri et al. 2017; Shaka et al. 2020). A review by Gipson et al. (2008) confirmed the paucity of evidence and the conflicting results emerging from the small number of studies.

In India, the evidence is also rather limited. Singh et al. (2012) found, using cross-sectional data from the second round of NFHS, that births reported by mothers as unintended received less prenatal care, had lower vaccination rates, and experienced a higher risk of neonatal death than intended births. Evidence from a follow-up study also showed a positive association between pregnancy unintendedness and adverse child health outcomes in rural India (Singh et al. 2013). Another analysis using longitudinal data from the Young Lives study reported that unintended births were likely to be associated with poor childhood development (Singh et al. 2017). However, these findings are open to doubt because other potential confounding factors, such as birth interval length, family size, and economic status of the household, were not systematically taken into account.

The mixed nature of the available evidence may stem in part from problems with measurement of the intendedness of births. Most of the studies cited so far used retrospective data. Mothers were asked whether each of their recent births was wanted, unwanted, or mistimed at the time of conception. NFHS asked two questions for assessing respondents' fertility intentions: 'When you got pregnant with (NAME), did you want to get pregnant at that time?' If the respondents answered 'yes', the birth was considered 'wanted'. If the respondents answered 'no', then the investigator asked a follow-up question: 'Did you want to have a baby later on, or did you not want any (more) children?' If the response was 'later', the birth was classified 'mistimed', and for those who responded 'no more children', the birth was classified 'unwanted'. Their responses could be affected by post-factum rationalization: mothers might be reluctant to classify young children as unwanted or, perhaps to a lesser extent, mistimed. This assertion is based on evidence from two prospective studies in India and others elsewhere: many women who asserted that they wanted no more children at the baseline survey later reported the births as wanted (Roy et al. 2008; Speizer et al. 2013). Rationalization is not the sole explanation. It is likely that the prospective measure (Do you want any more children?) and the retrospective measure are capturing different dimensions. The first is an abstract planning concept, which may be influenced by the views of the spouse and relatives, whereas the second is likely to be a more personal emotional response to an event that has already occurred.

An alternative way to identify unwanted births is to make use of the question on total desired family size (DFS). The relevant question in the fourth round of NFHS (NFHS-4) is: 'If you could go back to the time you did not have any children and could choose exactly the number of children to have in your whole life, how many would that be?' A comparison of DFS with the number of surviving children (actual family size or AFS) allows us to identify children born in excess of the desired number, who may then be classified as unwanted. For instance, a child with two older siblings born to a mother who stated a desired size of two would be classified as unwanted (AFS > DFS). This measure also has limitations. Women may adjust their desires upwards to enforce consistency with their actual number of children. Preference for sex of the child adds further complication, particularly in the Indian context known for son preference. For instance, a woman may state a two-child family as ideal, but if the first two children are of the same sex, she may want a third.

Based on Indian and international evidence, we put forward two hypotheses: that the association between birth interval and stunting will be stronger than the association between sibsize and stunting, and that fertility attitudes will moderate these associations.

Data and methods

Data

The data for this study were drawn from NFHS-4, the most recent round of the NFHS, conducted in India during 2015–16. The survey collected data on key health and family welfare indicators through face-to-face interviews with 699,686 ever-married women of reproductive age (15–49 years) who were selected using two-stage systematic random sampling (IIPS and ICF 2017). In addition, NFHS-4 collected anthropometric and other health-related data on 259,627 children born to these women in the last five years. Of these, height and weight measurements were available for only 236,455 children. Our final sample included 203,313 children, after excluding multiple births and children aged less than six months at the time of the survey. For the analysis of preceding birth interval, 32 children born following an implausibly short interval of less than seven months and 1,407 cases where the preceding birth interval was more than ten years were dropped (since their inclusion may have produced skewed results), giving a sample of 201,874 for that analysis. Similarly, the analysis comparing AFS with DFS excludes 1,205 cases where mothers reported their desired family size in a non-numeric format.

Outcome variable

Our outcome variable of interest was stunting, measured in terms of *z*-scores representing height-for-age of children aged under five years, based on a WHO reference population (WHO Multicentre Growth Reference Study Group and de Onis 2006). Stunting is the best single indicator of child growth impairment, which stems from inadequate diet, repeated infections, or both. We defined stunting as a binary variable, coded as '1' for those children who fell more than two standard deviations below the median of the reference population and '0' otherwise.

Explanatory variables

The two primary variables of interest for reproductive behaviour were length of the preceding birth interval and sibsize. Children's preceding birth intervals were coded into first births (no interval), >48 months, 37–48 months, 25–36 months, and <25 months. Sibsize was grouped into 1, 2, 3, 4, and 5+ living children born to the same mother, including both those who were older and those who were younger than the child under investigation (the index child). Thus, if there were two under-five children in a household, their sibsize would be the same.

We considered two indicators to measure fertility preferences: whether the mother reported that the birth was mistimed or unwanted, and whether the mother reported actual family size to be larger than desired and hence the birth was deemed unwanted.

Confounding variables

The analyses adjusted for a set of potential confounders at the child, mother, household, and regional levels. The child-level variables included current age of the index child (6–11, 12–23, 24–35, 36–47, and 48–59 months) and their sex. The maternal variables included age of mother at time of birth of the index child (<20, 20–24, 25–29, and 30+ years); maternal height (<145 cm and ≥145 cm); mother's education (primary, secondary, and higher); and current working status. The household-level variables included were place of residence (rural or urban), religion (Hindu, Muslim, and Others), caste (Scheduled Castes (SC), Scheduled Tribes (ST), Other Backward Castes (OBC), and others), wealth quintiles of the household (poorest, poor, middle, rich, and richest), and region (North, South, East, West, Central, and North-east).

Statistical analyses

We fitted a set of binary logistic regression models to estimate the unadjusted and adjusted effects of the preceding birth interval, sibsize, and reproductive attitudes on child stunting. We estimated the adjusted effects of preceding birth interval on stunting by birth intendedness and the effects of sibsize on stunting by the difference between AFS and DFS. We also carried out a stratified analysis on the effects of sibsize by whether the child's birth order exceeded desired family size or not. The bivariate and multivariate estimates were adjusted using nationally representative sample weights for women. All the analyses were carried out using Stata v16.0 (StataCorp).

These methods do not take into account the unmeasured maternal characteristics that may affect both maternal reproductive health behaviours and child health outcomes (Molitoris 2018). To overcome the potential heterogeneity between mothers, a separate 'within-family' analysis was performed; this was restricted to families with two or more children aged under five years. A total of 30,997 children whose mothers had at least one stunted and one normal child were eligible for this sub-analysis. Out of the total of 14,815 mothers fulfilling this condition, 13,464, 1,335, and 16 mothers had two, three, and four children aged under five years, respectively. Using this sample, a binary logistic regression and a conditional binary logistic regression model were applied to assess the association between preceding birth interval and childhood stunting. A conditional binary logistic regression model (*clogit*), that is, a mother-level fixed effect model, was applied to assess the influence of unmeasured heterogeneity on the association between preceding birth interval and stunting of children. The conditional logistic regression model could not be used for sibsize because, by definition, children from the same family have the same sibsize.

A model with fixed (non-random) parameters is called a fixed effects model, and clustered data (such as ours, i.e. mothers with more than one child) are suitable for the fixed effects model. The logistic regression model has individual intercepts that allow for unobserved mother-constant heterogeneity. As maximum likelihood estimation with a dummy variable for each individual can result in inconsistent estimates, a conditional maximum likelihood approach can be used; this does not give estimates of the individual fixed effects but rather of the regression parameters of interest, which for logistic regression, when exponentiated, can be interpreted as odds ratios from the standard logistic regression model (McFadden 1984; Allison 2009). Thus, this model allows us to estimate the odds ratios of child stunting by preceding birth interval controlling for unobserved mother-level heterogeneity.

Results

Descriptive statistics

Table 1 presents the summary statistics for the key explanatory variables. About 37 per cent of all births in the sample were firstborn, 17 per cent were born after an interval of two years or less, and 20 per cent

Table 1 Descriptive statistics of the sample size for the key study variables and prevalence of child stunting among children aged under five years in India, 2015–16

Variables	Sample *n*	Sample Percentage	Prevalence of stunting Percentage (95 per cent CI)
Preceding birth interval (months)			
>48	28,249	13.9	35.8 (35.2, 36.4)
37–48	23,241	11.4	41.9 (41.3, 42.6)
25–36	41,058	20.2	45.5 (45.0, 46.0)
<25	33,845	16.6	48.8 (48.3, 49.4)
First birth	75,481	37.1	34.4 (34.0, 34.7)
Total	201,874	100.0	–
Succeeding birth			
No	148,066	73.3	38.0 (37.7, 38.2)
Yes	55,247	26.7	45.4 (45.0, 45.9)
Total	203,313	100.0	–
Sibsize (number of living children)			
1	50,267	24.7	32.0 (31.6, 32.4)
2	78,009	38.4	37.6 (37.3, 37.9)
3	40,823	20.1	45.5 (45.0, 46.0)
4	18,707	9.2	51.1 (50.3, 51.9)
5+	15,507	7.6	55.4 (54.6, 56.3)
Total	203,313	100.0	–
Intendedness of births			
Wanted then (wanted)	182,531	89.8	39.5 (39.3, 39.7)
Wanted later (mistimed)	9,890	4.9	40.6 (39.6, 41.6)
Wanted no more (unwanted)	10,892	5.4	48.0 (47.0, 48.9)
Total	203,313	100.0	–
Difference between desired and actual number of children			
AFS ≤ DFS	148,015	73.2	37.7 (37.5, 38.0)
AFS > DFS	54,093	26.8	46.1 (45.7, 46.6)
Total	202,108	100.0	–

Notes: CI is the confidence interval. DFS refers to desired family size and AFS to actual family size. Please see the *Data* subsection of 'Data and methods' for detailed information about different sample size across the variables.
Source: Authors' analysis using NFHS-4, 2015–16.

after an interval of two to three years. About 37 per cent of families had three or more surviving children at the time of interview. Only about 5 per cent of births were reported by mothers as mistimed. This proportion increases from 1 per cent for children born after long birth intervals to 8 per cent among those born within two years or less of an older sibling (Table A1 in the Appendix). A similarly small proportion of births (6 per cent) were reported as unwanted and this proportion increases from less than 1 per cent for only children (sibsize '1') to 24 per cent for those with four or more siblings (Table A1). About 27 per cent of children were born at an order in excess of DFS (Table 1) and over half of children of birth order three or higher were born in excess of DFS (Table A1). The descriptive statistics for all study variables are presented in Table A2 in the Appendix.

Table 1 also presents the prevalence of childhood stunting by preceding birth interval, sibsize, and the intendedness of births. The prevalence of stunting falls monotonically with increasing birth interval, from 49 per cent for those with an interval of two years or less to 36 per cent for those with an interval of more than four years. Similarly, stunting decreases as sibsize decreases, from 55 per cent among children in five-child families to 32 per cent among one-child families. The percentage of stunting is almost the same for children reported by mothers as wanted or mistimed (around 40 per cent) but increases to 48 per cent for those who were unwanted. The prevalence of stunting is 38 per cent for those children with mothers whose AFS was less than or equal to their DFS and 46 per cent for those where AFS was higher than DFS.

Preceding birth interval and child growth

Table 2 presents the unadjusted and adjusted odds ratios (ORs) of stunting from the binary logistic regression models, by preceding birth interval, occurrence of a succeeding birth, and mother's classification of birth intendedness. The separate unadjusted models in column (1) show significant associations with interval length, succeeding birth, and whether the index child was classified as unwanted at time of conception, but no association with births classified as mistimed. The second model (column (2)) includes preceding birth interval, succeeding birth, and intendedness together in one model. The effects of interval length are attenuated slightly but not significantly, and the effects of unwantedness are attenuated significantly, while the effects of a succeeding birth increase. We also investigated whether or not breastfeeding status might explain the link between a succeeding birth and stunting. Whereas almost all index children with a younger sibling had been weaned, over half of last-born children were still being fed at the breast.

Table 2 Unadjusted and adjusted odds ratios of child stunting by birth interval, succeeding birth, and birth intendedness in India, 2015–16 ($n = 201{,}874$)

Variables	(1) Unadjusted ORs[1] (95 per cent CI)	(2) Adjusted ORs[2] (95 per cent CI)	(3) Adjusted ORs[3] (95 per cent CI)
Preceding birth interval (months)			
>48	1.00	1.00	1.00
37–48	1.30 (1.25, 1.35)	1.27 (1.22, 1.31)	1.13 (1.08, 1.17)
25–36	1.50 (1.45, 1.55)	1.45 (1.40, 1.49)	1.27 (1.22, 1.31)
<25	1.71 (1.66, 1.77)	1.63 (1.58, 1.69)	1.45 (1.40, 1.50)
First birth	0.94 (0.91, 0.97)	0.87 (0.84, 0.89)	1.07 (1.02, 1.12)
Succeeding birth			
No	1.00	1.00	1.00
Yes	1.35 (1.33, 1.39)	1.45 (1.42, 1.48)	1.02 (0.99, 1.05)
Intendedness of births			
Wanted	1.00	1.00	1.00
Mistimed	1.05 (1.00, 1.09)	0.96 (0.91, 1.00)	1.00 (0.96, 1.05)
Unwanted	1.41 (1.36, 1.47)	1.22 (1.17, 1.27)	1.01 (0.97, 1.06)

[1]Three separate binary logistic regression models were applied for preceding birth interval, succeeding birth, and intendedness of birth, respectively.
[2]Model adjusted for preceding birth interval, succeeding birth, and birth intendedness.
[3]Model adjusted for age and sex of index child; age of mother at birth of index child; number of living children; mother's height, education, and working status; place of residence, religion, caste, and wealth status of the household; and region.
Notes: ORs are odds ratios; CI is the confidence interval. Mistimed and unwanted represent births reported as 'wanted later' and 'wanted no more' at the time of survey. The sample size for this study excludes births whose preceding birth interval is less than seven months or more than ten years.
Source: As for Table 1.

However, we found that stunting was less prevalent in last-born children who had been weaned than among those still breastfeeding (results not shown).

The fully adjusted results in the third model (Table 2, column (3)) indicate significant attenuation of interval length effects. Compared with an interval length of more than four years, the risk of stunting remains higher among children with a preceding birth interval of 37–48 months (OR 1.13; 95 per cent confidence interval (CI) 1.08–1.17), 25–36 months (OR 1.27; CI 1.22–1.31), and <25 months (OR 1.45; CI 1.40–1.50). In this third model, no link between stunting and wantedness or succeeding birth was found.

Sibsize and child growth

Table 3 shows the effects of sibsize and unwantedness, as measured by the difference between AFS and DFS, on child stunting. The unadjusted results show sharp increases in stunting as sibsize increases and a large difference between children born at orders in excess of DFS and other children. After adjustment for DFS vs. AFS, the effects of sibsize actually increase slightly but the direction of effects of the wantedness of the child reverses. Both these effects are attenuated after full adjustment in the third model, though they remain statistically significant. Compared with one-child families, the odds of stunting are higher among mothers with two (OR 1.08; CI 1.04–1.13), three (OR 1.22; CI 1.16–1.29), four (OR 1.35; CI 1.27–1.44), and five or more children (OR 1.52; CI 1.42–1.63). The strength of association between stunting and sibsize is similar to that observed for interval length. Unexpectedly, the odds of stunting in the fully adjusted model remain slightly lower for undesired than for desired children.

Table 4 presents the unadjusted and adjusted effects of sibsize on stunting stratified according to AFS ≤ DFS and AFS > DFS. The unadjusted gradient in stunting is fairly similar in the two groups. The results from adjusted models show that among the children of mothers with higher AFS than DFS, the likelihood of stunting is higher among children with sibsize two (OR 1.24; CI 1.07–1.42), three (OR 1.45; CI 1.26–1.68), four (OR 1.58; CI 1.36–1.83), and five or more (OR 1.77; CI 1.52–2.06) as compared with sibsize one. The increasing risk of childhood stunting from sibsize one to five or more is lower among children with mothers where AFS is less than or equal to DFS, compared with children of mothers where AFS is higher than DFS, but the gradient with increasing sibsize is similar.

A separate analysis for the effect of preceding birth interval was carried out within a restricted sample of children whose mothers had had at least two second or higher-order children in the last five years (Table 5). The addition of mother-level fixed effects made no systematic differences to the log-odds of stunting by interval length.

Discussion

This paper contributes to new knowledge in several ways. First, unlike previous studies, we were able to

Table 3 Unadjusted and adjusted odds ratios of child stunting by sibsize and difference between AFS and DFS in India, 2015–16 (n = 202,108)

Variables	Unadjusted ORs[1] (95 per cent CI)	Adjusted ORs[2] (95 per cent CI)	Adjusted ORs[3] (95 per cent CI)
Sibsize			
1 (Ref.)	1.00	1.00	1.00
2	1.28 (1.25, 1.31)	1.29 (1.26, 1.33)	1.08 (1.04, 1.13)
3	1.77 (1.73, 1.82)	1.89 (1.83, 1.95)	1.22 (1.16, 1.29)
4	2.22 (2.14, 2.31)	2.42 (2.32, 2.52)	1.35 (1.27, 1.44)
5+	2.65 (2.54, 2.76)	2.95 (2.81, 3.09)	1.52 (1.42, 1.63)
Difference between desired and actual number of children			
AFS ≤ DFS(Ref.)	1.00	1.00	1.00
AFS > DFS	1.41 (1.38, 1.44)	0.88 (0.86, 0.91)	0.93 (0.91, 0.96)

[1]Two separate binary logistic regression models were applied for sibsize and difference between DFS and AFS, respectively.
[2]Model adjusted for difference between AFS and DFS, and for AFS.
[3]Model adjusted for age and sex of index child; age of mother at birth of index child; preceding birth interval; succeeding birth; mother's height, education, and working status; place of residence, religion, caste, and wealth status of the household; and region.
Notes: Ref. denotes the reference category. ORs are odds ratios; CI is the confidence interval. DFS refers to desired family size and AFS to actual family size.
Source: As for Table 1.

Table 4 Unadjusted and adjusted odds ratios of child stunting by sibsize, according to difference between AFS and DFS in India, 2015–16 ($n = 202{,}108$)

Sibsize	AFS ≤ DFS	AFS > DFS
Unadjusted ORs (95 per cent CI)		
1 (Ref.)	1.00	1.00
2	1.28 (1.25, 1.32)	1.39 (1.22, 1.58)
3	1.98 (1.91, 2.05)	1.82 (1.61, 2.05)
4	2.40 (2.25, 2.55)	2.43 (2.15, 2.75)
5+	2.47 (2.21, 2.75)	3.01 (2.66, 3.41)
Adjusted ORs[1] (95 per cent CI)		
1 (Ref.)	1.00	1.00
2	1.09 (1.04, 1.15)	1.24 (1.07, 1.42)
3	1.21 (1.13, 1.31)	1.45 (1.26, 1.68)
4	1.36 (1.24, 1.49)	1.58 (1.36, 1.83)
5+	1.46 (1.27, 1.67)	1.77 (1.52, 2.06)

[1]Adjusted models include age and sex of index child; age of mother at birth of index child, preceding birth interval; succeeding birth; mother's height, education, and working status; place of residence, religion, caste, and wealth status of the household; and region.
Notes: Ref. denotes the reference category. ORs are odds ratios; CI is the confidence interval. DFS refers to desired family size and AFS to actual family size.
Source: As for Table 1.

confirm results by taking into account unobserved mother-level heterogeneity. Second, where most studies have used parity or birth order as a predictor, we considered the number of surviving siblings (sibsize) and were able to compare the effects on stunting of family size (via the economic pathway of diluted resources per child) with the effects of preceding interval (via the biological pathway of maternal depletion). Third, our analyses overcome the well-established bias whereby mothers classify children as unwanted at time of conception, by using an alternative measure based on total desired family size. Finally, our study is one of very few to investigate whether or not reproductive attitudes mediate the effects of preceding interval or family size on growth of children.

Contrary to expectations, we found that the effects of birth interval length and sibsize on child growth were similar in magnitude. The percentage of children who were stunted rose monotonically from 36 per cent among those with a preceding birth interval of more than four years to 49 per cent among those with an interval of two years or less. Adjustment for a battery of potential confounders including sibsize, mother's height, education, and household wealth made little difference to the log-odds of stunting by interval length, suggesting that the adverse impact of a short interval is broadly similar across socio-economic strata. The mother-level fixed effect model strongly suggested that unmeasured differences between mothers with varying birth interval patterns cannot account for the link between birth spacing and child growth.

The causal pathways linking short intervals to perinatal, infant, and child outcomes are not clearly established but may include maternal depletion,

Table 5 Effects of preceding birth interval length on childhood stunting in India ($n = 30{,}997$)

	Adjusted ORs (95 per cent CI)	
Preceding birth interval (months)	Without mother-level fixed effects[1]	With mother-level fixed effects[2]
>48 (Ref.)	1.00	1.00
37–48	1.14 (0.99, 1.32)	1.36 (1.16, 1.59)
25–36	1.41 (1.24, 1.62)	1.34 (1.16, 1.55)
<25	2.25 (1.96, 2.57)	1.79 (1.55, 2.07)
First birth	1.32 (1.15, 1.51)	1.29 (1.12, 1.48)

[1]Results from binary logistic model.
[2]Results from conditional binary logistic model (mother-level fixed effect model).
Notes: The fixed effects sample consists of children whose mothers have had at least two second or higher-order births in the last five years of the survey, with at least one positive outcome (at least one child is not stunted). Out of a total of 14,815 mothers, 13,464 mothers had two children, 1,335 mothers had three children, and 16 mothers had four children. Ref. denotes the reference category. ORs are odds ratios; CI is the confidence interval. Models adjust for number of living children, age and sex of index child, and age of mother at birth of index child.
Source: As for Table 1.

competition for maternal attention and household resources, and cross infection (Boerma and Bicego 1992; Conde-Agudelo et al. 2012). The fact that a higher risk of stunting persisted among children with short birth intervals even after adjustment for sibsize suggests that maternal depletion—the lack of time for a mother to recover from lost nutrients during the previous pregnancy, delivery and breastfeeding—may be the main mechanism, rather than cross infection or competition. Previous research has shown that short intervals are associated with prematurity and low birth weight, which are both likely to result in stunting (Conde-Agudelo et al. 2005; DaVanzo et al. 2008).

Our findings have important policy implications. Unlike in many low- and middle-income countries, birth interval lengths in India have changed little over the years (Casterline and Odden 2016). Between 1993 and 2016, the percentage of second and higher-order births occurring within 24 months of the previous birth remained unchanged at around 27 per cent, with around 60 per cent occurring in less than 36 months (Figure A1 in the Appendix). The reason for this stability is evident. Historically, the Indian family planning programme has emphasized sterilization over other methods, and recent attempts to promote long-acting reversible methods have not yet had the desired impact (Srinivasan 2017). So, what needs to be done? The promotion of reversible contraceptives with more effective campaigns and follow-up services with adequate quality of care will be required.

The unadjusted effects of sibsize on childhood stunting were large, and consistent with the pervasive association between number of children and poverty. After adjustment for confounders, the effects of sibsize attenuated more than was the case for interval length, but nevertheless remained as large as those for interval length. These results contrast strongly with those from an analysis of 45 DHS countries by Rutstein and Winter (2014), for reasons that are unclear but which may include a lower ability in India than in other countries for parents to increase income in response to a growing family or to seek support from a wider family network. We addressed the problem of endogeneity using a stratified analysis, according to whether or not the index child was unwanted and found the gradient in stunting with increased sibsize to be similar in both cases. This result enhances a causal interpretation. For the wanted group, it can be argued that couples are choosing to prioritize a large family over the welfare of individual children in terms of nutrition and healthcare, but the same argument is much less plausible for the unwanted group. It is true that in India, as elsewhere, poor couples are more likely to have higher fertility, and thus larger families, than rich couples. They are also more likely to bear unwanted children. In NFHS-4 the average gap between actual and wanted fertility narrows from 0.9 births for the poorest quintile to 0.1 births in the richest (IIPS and ICF 2017). Although we adjusted for a wide range of covariates, it remains possible that the association between sibsize and stunting was affected by residual confounding.

In our analysis, reproductive attitudes, as measured either by mothers' responses on intendedness of the pregnancy or the comparison between reported DFS and AFS, had no effect on stunting after adjusting for reproductive behaviour and other confounding variables. This result is consistent with much of the international literature but contradicts previous findings from India (Singh et al. 2017). The difference may be explained by the larger number of control factors used in this analysis than by Singh and colleagues. It may also reflect the particularly weak measurement of retrospective pregnancy intendedness in NFHS-4 (IIPS and ICF 2017). Only about 5 per cent of births were declared by mothers to be the outcome of mistimed pregnancy and a similar proportion to be the result of an unwanted pregnancy, much lower than the proportion found in earlier rounds of NFHS. However, the measure of unwantedness based on desired family size could be overestimated because *all* children of mothers who reported higher AFS than DFS are categorized into this group. The high incidence of abortion in India is relevant in this context. It has been estimated that well over half of all unintended pregnancies in India are terminated (Singh et al. 2018). Thus, it is most likely that pregnancies carried to term are either intended and welcome or only mildly unwelcome.

We conclude that both shorter birth intervals and higher number of children in a family raise the risk of inadequate growth in children by a substantial and approximately equal degree. Contrary to expectations we found no evidence that unintended or unwanted children are particularly vulnerable to stunting. Thus, the links between the number of children or short intervals and stunting are not attributable to parental attitudes towards particular children whose addition to the family may have been undesired.

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Appendix

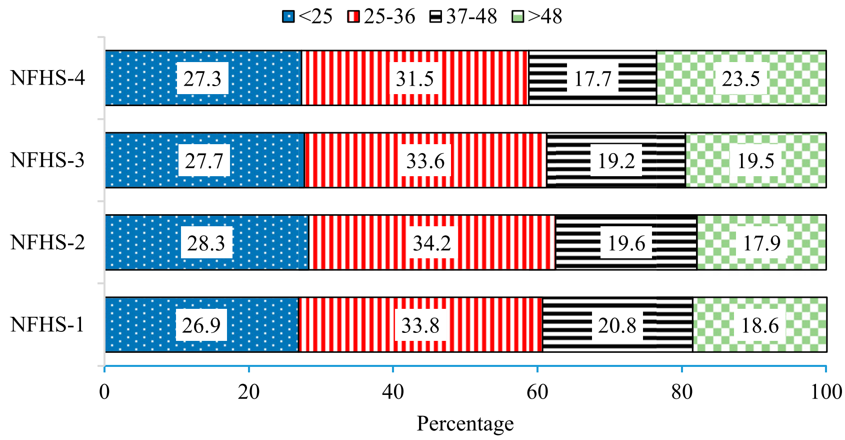

Figure A1 Preceding birth intervals (in months) in India, 1992–93 to 2015–16
Note: Second and higher-order births only.
Source: National Family Health Survey Reports [NFHS-1 (1992–93), 2 (1998–99), 3 (2005–06), and 4 (2015–16)] (IIPS 1995; IIPS and ORC Macro 2000; IIPS and Macro International 2007; IIPS and ICF 2017).

Table A1 Percentage of births that are mistimed or unwanted, by preceding birth interval and sibsize in India, 2015–16

Birth interval and sibsize		
Preceding birth interval (months)	*n*	Percentage mistimed
>48	28,249	1.4
37–48	23,241	2.8
25–36	41,058	4.5
<25	33,845	7.8
First birth	75,481	5.5
Total	201,874	4.8
Preceding birth interval (months)	*n*	Percentage unwanted
>48	28,249	8.2
37–48	23,241	7.7
25–36	41,058	8.2
<25	33,845	8.1
First birth	75,481	1.5
Total	201,874	5.6
Sibsize (number of living children)	*n*	Percentage unwanted
1	50,114	0.8
2	77,741	2.5
3	40,587	8.4
4	18,550	15.2
5+	15,116	23.5
Total	202,108	6.0
Sibsize (number of living children)	*n*	Percentage where AFS > DFS
1	50,114	2.7
2	77,741	10.3
3	40,587	54.6
4	18,550	70.9
5+	15,116	89.0
Total	202,108	28.8

Source: Authors' analysis using NFHS-4, 2015–16.

Table A2 Univariate descriptive statistics for the sample and prevalence of child stunting among children aged under five years in India, 2015–16

	Univariate descriptive statistics		Prevalence of stunting
Variables	*n*	Percentage	Percentage (95 per cent CI)
Childhood stunting			
Normal	122,088	60.1	–
Stunted	81,225	39.9	–
Age of the child (months)			
6–11	22,618	11.1	22.8 (22.3, 23.4)
12–23	44,678	22.0	42.6 (42.1, 43.0)
24–35	44,520	21.9	42.7 (42.2, 43.2)
36–47	46,725	23.0	43.2 (42.7, 43.6)
48–59	44,772	22.0	39.9 (39.4, 40.3)
Sex of the child			
Male	105,311	51.8	40.3 (40.0, 40.6)
Female	98,002	48.2	39.5 (39.2, 39.9)
Age of mother at birth of the index child (years)			
<20	24,957	13.7	42.2 (41.6, 42.8)
20–24	88,843	45.6	39.6 (39.3, 39.9)
25–29	57,498	27.3	38.4 (38.0, 38.8)
30+	32,015	13.4	42.0 (41.4, 42.6)
Mother's height (cm)			

(*Continued*)

Table A2 Continued.

Variables	Univariate descriptive statistics		Prevalence of stunting
	n	Percentage	Percentage (95 per cent CI)
<145	23,131	11.4	59.9 (59.2, 60.5)
145 and above	179,918	88.5	37.3 (37.1, 37.5)
Not measured	264	0.1	41.2 (35.7, 47.0)
Mother's education			
No education	63,107	31.0	52.7 (52.3, 53.1)
Primary	29,871	14.7	45.3 (44.7, 45.9)
Secondary	91,734	45.1	34.0 (33.7, 34.3)
Higher	18,601	9.1	21.4 (20.9, 22.0)
Working status[1]			
Not working	29,053	14.3	38.7 (38.1, 39.3)
Working	6,397	3.1	41.6 (40.3, 42.9)
Not reported/asked	167,863	82.6	40.1 (39.9, 40.3)
Place of residence			
Urban	48,482	23.8	31.9 (31.5, 32.3)
Rural	154,831	76.2	43.1 (42.8, 43.3)
Religion			
Hindu	147,257	72.4	40.0 (39.8, 40.3)
Muslim	31,834	15.7	41.6 (41.1, 42.2)
Others	24,222	11.9	32.9 (31.9, 33.8)
Caste[2]			
Others	35,572	17.5	31.7 (31.3, 32.2)
SC	38,574	19.0	44.5 (44.0, 45.0)
ST	40,017	19.7	45.8 (45.1, 46.5)
OBC	80,226	39.5	40.4 (40.0, 40.7)
Not reported	8,924	4.4	35.9 (34.9, 37.0)
Wealth quintile			
Poorest	52,831	26.0	53.8 (53.4, 54.2)
Poor	47,955	23.6	45.5 (45.0, 46.0)
Middle	40,816	20.1	38.1 (37.6, 38.5)
Rich	34,241	16.8	30.0 (29.5, 30.5)
Richest	27,470	13.5	22.8 (22.3, 23.3)
Regions			
North	38,432	18.9	35.6 (35.0, 36.2)
South	19,863	9.8	30.2 (29.7, 30.7)
West	14,042	6.9	36.7 (36.1, 37.3)
East	42,805	21.1	43.9 (43.4, 44.3)
Central	59,079	29.1	46.6 (46.1, 47.0)
North-east	29,092	14.3	36.4 (35.3, 37.6)
Total	203,313	100.0	39.9 (39.7, 40.2)

[1]The question on working status of women is asked in the 'state' module of NFHS-4, which comprises only 15 per cent of the total sample. Therefore, in our sample, about 83 per cent of the respondents have missing data for working status (coded as 'not reported/asked'). In the list of independent variables, only working status is from the state module.
[2]SC, ST, and OBC stand for scheduled caste, scheduled tribe, and other backward class, respectively.
Notes: The sample consists of children aged under five years, but excludes those under six months to avoid inaccurate measurement. Twin children are also excluded. CI is the confidence interval.
Source: As for Table A1.