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RESEARCH ARTICLE

Effects of parental stature on child stunting in India

Amrita Gupta[1*], John Cleland[2] and T. V. Sekher[3]

[1]Tata Institute of Social Sciences, Mumbai, India, [2]London School of Hygiene and Tropical Medicine, London, UK and [3]International Institute for Population Sciences, Mumbai, India
*Corresponding author. Email: amritagupta7@gmail.com

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Abstract
Adult heights in India are short. Child stunting remains high though the prevalence fell from 48% to 38% in the decade prior to 2016. This study assesses the links between parental height and child stunting using nationally representative data on 28,975 under-five-year-old children from the 2015–16 National Family Health Survey. Parental heights are represented as quintiles. Logistic regression was applied to estimate the effect of parental heights after adjustment for household wealth, parental schooling, place of residence and other covariates. The unadjusted estimates showed the effect on stunting to be similar for maternal height, wealth and education. In the multivariate analysis maternal height emerged as the strongest predictor of stunting, with adjusted odds of 2.85 for the shortest compared with the tallest quintile. The two other strong predictors of stunting were paternal height and wealth, with adjusted odds of close to 2.0 for the lowest quintile relative to the highest quintiles. In comparison, associations between stunting and other factors were minor, with the partial exception of mother's education. The findings underscore the key role of intergenerational influences on stunting. Maternal height has a stronger association with childhood stunting than paternal height and socioeconomic influences such as education and household wealth. The influence of paternal height is also strong, equal in magnitude to household wealth. Health workers need to be alerted to the special needs of short women.

Keywords: Child stunting; Parental heights; Intergenerational effects

Introduction

India has an exceptionally high level of childhood stunting though prevalence fell from 48% in 2005–6 to 38% in 2015–16. Nevertheless, India still accounts for one-third of the global total (IIPS & ICF, 2017). India also has one of the world's shortest adult populations – a reflection of historic poverty, malnutrition and disease – though heights have improved, more for men than women (Deaton, 2008). Growth failure from conception to two years of life is a strong determinant of adult height (Martorell *et al.*, 1994; Victora *et al.*, 2010). Failure in human growth starts *in utero*, becomes prominent during the first year of life and continues until around two years of age (Victora *et al.*, 2010; Martorell & Zongrone, 2012). The proximate causes of growth failure include malnutrition, infections, particularly diarrhoeal disease, poor sanitation and adverse uterine conditions (Black *et al.*, 2008).

The intergenerational effect of short parental stature on stunting in offspring is well established. Much of the evidence concerns maternal height. In a multi-country analysis of data from low- and middle-income countries, a significant effect of maternal height on child stunting was found in 52 of 54 national surveys, after adjustment for a range of covariates including household wealth and parental education (Ozaltin *et al.*, 2010). This link is usually regarded as a reflection of the intergenerational transmission of poverty (Grantham-McGregor, 2007; Martorell & Zongrone, 2012).

One of the most potent risk factors for poverty is being born to poor parents (Martorell & Zongrone, 2012). Evidence also suggests a biological pathway. Women with short height have a reduced store of protein and energy, smaller reproductive organ sizes and limited room for fetal development, leading to low birth weight, which is closely related to childhood stunting (Duggleby & Jackson, 2001).

The Indian literature on links between parental height and child health outcomes, such as stunting, is sparse. Using data from round 3 of the National Family Health Survey (NFHS) conducted in 2005–6, Subramanian *et al.* (2009) found that a 1 cm increase in maternal height was associated with a decrease in relative risk for stunting of 0.97 after adjustment, and a similar but smaller effect of father's height. In a related paper, small but equal associations between mothers' and fathers' body mass index (BMI) and childhood stunting were found, though a district-level analysis found women's BMI to be strongly related to stunting (Subramanian *et al.*, 2010; Menon *et al.*, 2018). Rehman *et al.* (2009) also found an inverse relationship between maternal height and stunting in the urban slums of India. In a study on five countries including India, short maternal height was associated with child stunting. Mothers with height less than 150.1 cm were 3.2 times more likely to have stunted offspring compared with taller mothers (Addo *et al.*, 2013). Another multi-country study analysed the contribution of risk factors to stunting in children aged 2–3 years. For India, the major contributors were low birth weight and prematurity, unimproved sanitation, diarrhoeal disease, with a small contribution of 12% from mother's height (Danaei *et al.*, 2016). However, this analysis fails to take into account that mother's height is strongly related to birth weight.

This paper aims to add to this limited literature by assessing the relationship between parental height and childhood stunting using recent national survey data. The particular objectives were to examine the relative effects of maternal and paternal height; to compare their magnitude with the effects of socioeconomic influences; and to assess the extent to which educational and material success in life, as measured by maternal and paternal schooling and household wealth, moderates or mitigates the disadvantages associated with short stature.

Methods

Data source

Data for the study were taken from the fourth round of India's National Family Health Survey (NFHS-4) conducted in 2015–16. The NFHS is India's equivalent of the Demographic and Health Surveys (DHS). The NFHS provides representative data at the national, state and district levels on population and health indicators. Details of the design and methods have been published by International Institute for Population Sciences (IIPS) and ICF (IIPS & ICF, 2017).

Study population and sample size

The study population for the study included children aged 0–59 months born to mothers aged 15–49 years at the time of the survey and fathers aged 15–54 years. Of all 190,538 surviving under-five children, maternal heights were available for 190,084 while paternal heights were available for a representative sub-sample of 29,039. Data on height were missing for 6% of children and mothers and 12% of fathers. The analysis was based on those children for whom both parents' heights were available, after excluding a small number of implausible values (n=28,975).

Outcome measure

Stunting was the outcome variable for the study. In the NFHS, trained investigators measured the child's height with an adjustable measuring board calibrated in millimetres (IIPS & ICF, 2017). A child was considered stunted when the median score was more than 2 standard deviations under the World Health Organization-determined median scores (WHO, 2008). This binary outcome was preferred to the alternative of height as a continuous variable because of its familiarity and ease of interpretation.

Exposure

The height of the parents was also measured by trained investigators using an adjustable measuring board calibrated in millimetres (IIPS & ICF, 2017). In the absence of any objective standards for assessing adult height, maternal height was represented as a quintile with the following cut-off points: ≤147.0 cm (very short), 147.1–150.0 cm (short), 150.1–153.0 cm (average), 153.1–156.0 cm (tall) and >156.0 cm (very tall). The corresponding categories for paternal height were: ≤157.0 cm (very short), 157.1–161.0 cm (short), 161.1–165.0 cm (average), 165.1–169.0 cm (tall) and >169.0 cm (very tall).

Covariates

The covariates for the study were the education of both parents, household economic status represented as wealth quintiles (based on dwelling construction and household possessions), demographic factors (maternal age at childbirth, birth order and sex of the child), geographic factors (rural–urban and region of residence) and social factors (religion and caste based on the household head). The categorization of covariates is shown in Table 1. Parental education and household wealth were regarded as potential effect-modifiers and the other covariates as potential confounders.

Analysis

Following bivariate descriptive analysis, logistic regression was applied to identify the significant determinants of stunting in India. SPSS (version 20) was used to perform all the statistical analyses. Results from three models are presented: an unadjusted model; a model of maternal height, paternal height, education of both parents and household wealth; and a fully adjusted model that included all covariates. The logic for the selection of models was that education and household wealth represent success in life that may offset the disadvantages associated with short stature and thus may be regarded as moderators, whereas other covariates were considered as potential confounders. All results were weighted to take account of variations in sampling probabilities and standard errors took account of the clustered nature of the sample.

Results

The relationship between maternal and paternal height was essentially linear (Figure 1). Across the five quintiles of maternal height, the percentage of children stunted rose from 24% among the very tall to 54% among the very short – a difference of 30 percentage points. The corresponding estimates for paternal height were 25% and 49% with a difference of 24 percentage points.

Table 2 confirms that the short parents were indeed deprived. Among couples where both parents were short or very short, 40% of wives received no schooling compared with 23% among the group where both spouses were of average or higher height. The corresponding figures for husband's education were 27% versus 12%. Similarly, 38% of short or very short spouses were in the lowest wealth quintile compared with 15% of average or higher height spouses.

All the covariates were significantly associated with stunting, as indicated by the 95% confidence intervals (Model 1, Table 3). Parental education and household wealth were the sources of the most substantial variation. Whereas a little over 20% of children born to mothers or fathers with higher than secondary schooling were stunted, this proportion rose to about 50% for those

Table 1. Weighted frequency for child stunting (children aged 0–59 months) across maternal, paternal, child and household covariates, India 2015–16

Background characteristic	Child stunting	
	n	%
Maternal covariates		
Mother's height (cm)		
>156.0	5719	23.6
153.1–156.0	6091	30.7
150.1–153.0	5886	38.1
147.1–150.0	5645	43.4
≤147.0	5634	53.5
Age at childbirth (years)		
≥30	875	27.2
25–29	3875	28.4
20–24	14,164	37.3
17–19	8366	42.7
<17	1695	42.2
Education		
Higher	2713	20.8
Secondary	13,495	32.2
Primary	4206	43.5
None	8561	49.2
Paternal covariates		
Father's height (cm)		
>169.0	5968	25.3
165.1–169.0	5792	33.5
161.1–165.0	5776	37.7
157.1–161.0	5770	43.6
≤157.0	5669	49.1
Education		
Higher	3680	24.4
Secondary	15,733	35.2
Primary	4561	43.8
None	5001	50.2
Child covariates		
Birth order		
First	10,248	32.5
Second	9088	36.7
Third	4807	41.6
Fourth or higher	4832	46.8

(*Continued*)

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Table 1. (*Continued*)

Background characteristic	Child stunting *n*	%
Sex of the child		
Male	14,964	38.5
Female	14,011	36.7
Household covariates		
Place of residence		
Urban	7464	30.3
Rural	21,511	40.5
Religion		
Hindu	20,904	38.3
Muslim	4614	37.3
Christian	2304	34.5
Sikh	463	23.7
Other	690	37.1
Caste		
Other	4997	29.1
Other Backward Class	11,038	37.8
Scheduled Tribe	6075	41.1
Scheduled Caste	5405	43.8
Wealth quintile		
Highest	4306	21.7
Fourth	4946	29.2
Middle	6065	35.8
Second	6700	43.6
Lowest	6958	50.9
Region		
North	5837	32.4
South	3152	30.0
East	5204	41.8
West	2591	35.9
North East	4105	33.0
Central	8086	44.7
Total	**28,975**	**37.6**

whose parents had no schooling. The range of stunting was similar for household wealth quintiles – from 22% to 51%. Among the demographic variables, birth order showed a strong association with stunting. Maternal age at childbirth had a negative association with stunting, but the difference between girls and boys was very small. It may also be noted that stunting varied by region and caste.

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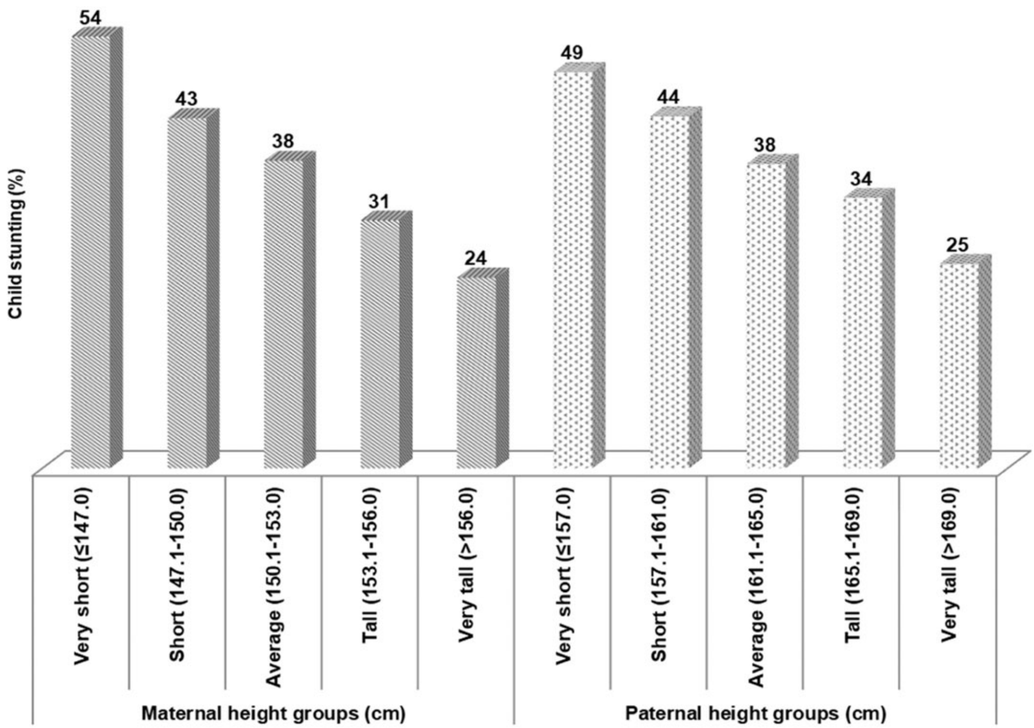

Figure 1. Child stunting by maternal and paternal height groups, India, 2015–16.

Table 3 shows the unadjusted odds ratios (ORs) for stunting for all covariates (Model 1), the adjusted odds ratios (aORs) after controlling for parental education and household wealth (Model 2), and the aORs adjusted for all covariates (Model 3). As explained above, the logic for the choice of models is that education and wealth are expected to mitigate the effects of maternal and paternal height on child stunting while the demographic, geographical and social factors are potential confounders. As the height of the mother decreases, the odds of child stunting increase. Compared with the children born to very tall women with height greater than 156 cm, children born to tall mothers were 1.4 times more likely to be stunted; those born to mothers with average height were twice more likely to be stunted; those born to short mothers were 2.5 more likely to be stunted and children with very short mothers of ≤147 cm height were 3.7 times more likely to be stunted. Similar to maternal height, there was an inverse relation between paternal height and child stunting.

In the second model, after including parental education and economic status, the adjusted odds of stunting by maternal and paternal height groups decreased, particularly for children with very short mothers, with a reduction in odds ratio from 3.74 to 2.71 compared with very tall mothers. Similarly, for father's height, the adjustment for education and wealth made the most pronounced difference for very short fathers relative to very tall fathers – from an OR of 2.79 to an aOR of 1.79. When the additional covariates were added in Model 3, there were small and statistically insignificant increases in these adjusted odds ratios. Both maternal and paternal height remained strong determinants of child stunting. As indicated by the confidence intervals, maternal stature was more closely linked to stunting than paternal stature. The results clearly show that maternal height is the strongest predictor of stunting and that paternal height is as important as wealth, after adjustment for all other factors.

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Table 2. Deprivation in education and economic status by height group, India 2015–16

	Parental height groups (%)			
	Both parents short or very short	Both parents average height or above	Father average height or above and mother short/very short	Mother average height or above and father short/very short
Mother's education				
No education	40.2	22.7	30.0	30.8
Primary	16.4	11.8	16.3	15.2
Secondary	38.7	51.3	45.2	45.5
Higher	4.8	14.1	8.4	8.4
Father's education				
No education	26.6	12.0	16.7	18.2
Primary	20.5	12.3	17.7	16.3
Secondary	46.4	57.4	55.3	54.5
Higher	6.5	18.2	10.3	11.0
Wealth quintiles				
Lowest	37.7	14.8	25.5	25.9
Second	26.4	18.7	24.9	23.7
Middle	18.5	21.2	21.0	20.6
Fourth	11.1	20.8	17.3	16.3
Highest	6.4	24.5	11.3	13.5

All other factors, except rural–urban residence, retained statistically significant associations with stunting in the fully adjusted model. The strongest association was with household wealth; the prevalence of stunting rose monotonically with decreasing wealth with an aOR of 1.90 for the poorest quintile relative to the richest. Though severely attenuated after adjustment, maternal education remained a strong predictor of stunting.

In contrast to the strong adjusted effects of maternal and paternal height, household wealth and maternal education, the adjusted effects of other factors were relatively small. The reduction of the effect of paternal education was pronounced. Of note is the appreciable association between stunting and maternal age at childbirth, with a one-third increase in the odds of stunting for children born to teenage mothers compared with those born to a mother aged 30 or more.

Discussion

The NFHS-4, with its huge sample size, provides an unusual opportunity to assess the associations between the height of both parents and childhood stunting. The study objectives were to establish the relative influences of maternal and paternal stature on stunting, to compare these influences with those of socioeconomic factors, and specifically to assess the degree to which educational and material success mitigates the influence of parental stature on stunting. Though the study confirmed that short parental stature was strongly associated with deprivation in terms of education and wealth, it is by no means an immutable determinant of fate. For instance, among families where both parents were classified as short or very short, close to half of mothers and fathers had received a secondary or higher education and 17% lived in households belonging to the

Table 3. Odds ratios for child stunting (children aged 0–59 months) across maternal and paternal height groups and household covariates, India 2015–16

	Model 1[a]	Model 2[b]	Model 3[b]
Background characteristic	OR (95% CI)	OR (95% CI)	OR (95% CI)
Mother's height (cm)			
>156.0 (Ref.)			
153.1–156.0	1.41 (1.30, 1.53)	1.27 (1.17, 1.38)	1.29 (1.18, 1.40)
150.1–153.0	1.99 (1.85, 2.17)	1.69 (1.56, 1.83)	1.72 (1.58, 1.87)
147.1–150.0	2.49 (2.30, 2.70)	1.95 (1.79, 2.12)	2.03 (1.87, 2.21)
≤147.0	3.74 (3.45, 4.05)	2.71 (2.49, 2.95)	2.85 (2.61, 3.10)
Father's height (cm)			
>169.0 (Ref.)			
165.1–169.0	1.46 (1.35, 1.59)	1.25 (1.15, 1.36)	1.27 (1.17, 1.38)
161.1–165.0	1.79 (1.66, 1.94)	1.43 (1.31, 1.55)	1.49 (1.37, 1.62)
157.1–161.0	2.19 (2.03, 2.37)	1.60 (1.48, 1.74)	1.71 (1.57, 1.85)
≤157.0	2.79 (2.58, 3.02)	1.79 (1.64, 1.94)	1.97 (1.81, 2.14)
Mother's education			
Higher (Ref.)			
Secondary	1.86 (1.69, 2.05)	1.33 (1.18, 1.49)	1.22 (1.09, 1.38)
Primary	2.93 (2.62, 3.27)	1.66 (1.46, 1.89)	1.42 (1.27, 1.66)
None	3.60 (3.25, 3.98)	1.82 (1.60, 2.07)	1.49 (1.33, 1.73)
Father's education			
Higher (Ref.)			
Secondary	1.69 (1.56, 1.84)	1.07 (0.99, 1.19)	1.05 (0.97, 1.17)
Primary	2.45 (2.23, 2.69)	1.11 (0.99, 1.24)	1.10 (1.02, 1.27)
None	3.04 (2.77, 3.33)	1.16 (1.03, 1.31)	1.17 (1.07, 1.35)
Wealth quintiles			
Highest (Ref.)			
Fourth	1.44 (1.31, 1.58)	1.14 (1.03, 1.26)	1.17 (1.06, 1.30)
Middle	1.94 (1.77, 2.11)	1.34 (1.22, 1.48)	1.39 (1.28, 1.57)
Second	2.70 (2.48, 2.94)	1.60 (1.45, 1.77)	1.69 (1.58, 1.96)
Lowest	3.66 (3.36, 3.99)	1.80 (1.62, 2.00)	1.90 (1.77, 2.25)
Age at childbirth (years)			
≥30 (Ref.)			
25–29	1.17 (0.99, 1.38)		1.08 (0.91, 1.28)
20–24	1.66 (1.42, 1.93)		1.27 (1.08, 1.50)
17–19	2.03 (1.74, 2.37)		1.35 (1.14, 1.59)
<17	2.12 (1.78, 2.53)		1.31 (1.08, 1.58)

(*Continued*)

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Table 3. (*Continued*)

Background characteristic	Model 1[a] OR (95% CI)	Model 2[b] OR (95% CI)	Model 3[b] OR (95% CI)
Birth order			
First (Ref.)			
Second	1.14 (1.07, 1.20)		1.04 (0.98, 1.11)
Third	1.48 (1.38, 1.58)		1.12 (1.05, 1.22)
Fourth or higher	1.73 (1.61, 1.86)		1.09 (0.99, 1.17)
Sex			
Male (Ref.)			
Female	0.92 (0.87, 0.96)		0.89 (0.85, 0.94)
Place of residence			
Urban (Ref.)			
Rural	1.47 (1.39, 1.56)		1.02 (0.96, 1.09)
Religion			
Hindu (Ref.)			
Muslim	0.95 (0.89, 1.02)		1.15 (1.07, 1.25)
Christian	0.84 (0.76, 0.91)		1.20 (1.06, 1.37)
Sikh	0.47 (0.38, 0.58)		0.90 (0.71, 1.14)
Other	0.86 (0.73, 1.00)		0.99 (0.83, 1.18)
Caste			
Other (Ref.)			
Other Backward Class	1.46 (1.36, 1.57)		1.14 (1.06, 1.24)
Scheduled Tribe	1.62 (1.49, 1.75)		1.08 (0.98, 1.18)
Scheduled Caste	1.81 (1.67, 1.97)		1.25 (1.14, 1.38)
Region			
North (Ref.)			
South	0.94 (0.85, 1.03)		0.88 (0.79, 0.97)
East	1.53 (1.41, 1.65)		0.82 (0.75, 0.89)
West	1.31 (1.19, 1.44)		1.19 (1.08, 1.33)
North East	1.02 (0.93, 1.10)		0.64 (0.57, 0.71)
Central	1.67 (1.56, 1.79)		1.13 (1.04, 1.22)

[a]Unadjusted odds ratio.
[b]Adjusted odds ratio.
95% confidence interval is given in parentheses.
Ref.=reference category.

top two wealth quintiles. To what extent can educational and economic success weaken the association between short parental stature and poor linear growth in children?

The results were emphatic. The unadjusted estimates showed the associations of stunting with maternal height, wealth and education to be similarly strong and only slightly less pronounced for paternal height. In the multivariate analysis, the odds of stunting by parental height reduced but

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maternal height emerged as the strongest predictor, with adjusted odds of 2.85 for very short mothers compared with the very tall. This relationship was essentially linear. This result is consistent with a multi-country study, which found an adjusted relative risk of 2.1 for stunting among offspring of mothers with a height of less than 145 cm compared with maternal heights of 160 cm or more (Ozaltin *et al.*, 2010). Similar to these results, this study also found maternal height to be a stronger predictor of stunting than wealth or education.

The two other strong predictors of stunting were paternal height and wealth, with adjusted odds of close to 2.0 for the least advantaged quintile relative to the most advantaged. In comparison, associations between stunting and other factors were minor, with the partial exception of maternal education, which is well established as protective of child health and survival.

In countries with near-optimal disease and nutrition environments, adult stature is largely a reflection of genetic endowment. In India, environmental conditions are far from optimal and adult stature may be regarded as a proxy for disadvantage *in utero* and early life, though there will be a genetic and epigenetic contribution. The very strong association between mother's height and poor linear growth of children is thus a reflection of the intergeneration transmission of disadvantage. The contribution of genetics in India is probably small. Even in rich countries, a pooled analysis of twin studies has shown that environmental factors account for most of the variance in children's height, though this contribution declines with age, from 82% at 5 months to 56.5% at 5 years (Dubois *et al.*, 2012).

The relatively small attenuation of the maternal height effect after adjustment for education, wealth and other covariates is surprising. Yet, it is also consistent with international evidence. The multi-country study by Ozaltin *et al.* (2010) found that the relative risk of stunting in children of the shortest relative to the tallest mothers fell only from 2.4 to 2.1 after adjustment for a similar range of covariates that were deployed in this study. One possible explanation is that the measure of wealth, based on possession of consumer durables and household amenities such as water supply and applied nationally, does not adequately capture income and certainly does not attempt to represent household diets. Moreover, household wealth may not translate into improved nutrition and health care for women, particularly in the patriarchal north of India. A second explanation is that more profound changes in the environment than represented by wealth quintiles, such as migration from South East Asia to the USA, are required to offset the poor intra-uterine anatomy associated with low maternal stature, leading to low birth weight and an elevated risk of stunting (Yip *et al.*, 1992).

The association between paternal height and child stunting has been little studied and is not well understood. Much of the literature reviewed by Martorell and Zongrone (2012) found fathers' characteristics to be a relatively unimportant influence relative to those of the mother. For instance, the birth weight of mothers, but not of fathers, was found to be strongly correlated with the birth weight of offspring. Similarly, the growth of mothers in the first 20 months of life was associated with offspring height but not the growth of fathers. The present analysis confirms the finding of Subramanian *et al.* (2009) – that maternal stature in India is more strongly predictive of child stunting than father's stature. Nevertheless, the paternal height–stunting association observed in the NFHS-4 data was very strong, and equal in magnitude to that of household wealth. This may reflect a purely genetic effect. However, there is some evidence that a father's health and nutritional status may affect sperm quality, epigenetic status, DNA integrity and seminal fluid composition in ways that influence fetal growth and health of offspring (Fleming *et al.*, 2018). There is a possibility that these conditions are more prevalent in short than tall men.

What might be the implications of these results for policies to reduce the intergenerational transmission of disadvantage and accelerate the fall in childhood stunting? It is known from the World Health Organization Multicentre Growth Reference Study that, under near-optimal conditions, early growth in Indian children can match that in rich countries but it will take decades to achieve such conditions across the whole country (Garza *et al.*, 2013). However, the decline in India's fertility offers an exciting opportunity for improvement. A woman's pre-conception health and nutrition is a crucially important determinant of fetal and child growth and health; interventions during pregnancy have limited impact (Onis & Branca, 2016; Stephenson *et al.*, 2018). In India, poor pre-conception health of women, including low BMI, is common (Coffey, 2015). Pregnancy preparedness is key and is enabled by low fertility. A two-child norm is now established in India and this represents a quantity-to-quality shift; the smaller the number of children the greater is likely to be the desire to furnish them with the best possible health and schooling. Furthermore, very few couples attempt to delay their first pregnancy following marriage (Pandey & Singh, 2015). Thus newly married couples represent a priority population for educational interventions, with the central message that a flourishing baby requires a mother who is healthy and well-nourished at the time of conception. This message should be accompanied by information that teenage mothers are at elevated risk of experiencing poor growth in children. In addition, health workers, both facility- and community-based, need to be informed that short women are at enhanced risk of poor fetal and infant growth in their offspring and require a special focus.

In conclusion, this analysis shows that a mother's height has a stronger association with childhood stunting in India than socioeconomic influences such as her education and household wealth. The influence of paternal height is also strong, equal in magnitude to household wealth, though less pronounced than that of maternal height. The limitation is that NFHS-4 data do not allow any progress in disentangling the complex interplay of environmental, genetic and epigenetic pathways of influence.

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Conflicts of Interest. The authors have no conflicts of interest to declare.

Ethical Approval. The protocol for NFHS-4 was approved by the International Institute for Population Sciences, Mumbai, and by ICF, who manage the Demographic and Health Survey program. We used anonymized public access data from this survey.

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