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Developmental origins of secondary school dropout in rural India and its differential consequences by sex: A biosocial life-course analysis

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ABSTRACT

We developed a biosocial life-course conceptual approach to investigate maternal and household predictors of secondary school dropout, and to ascertain whether the consequences of dropout differ between girls and boys. We analysed longitudinal biomedical data on 648 mother-child dyads from rural Maharashtra, India. Both maternal (low education, early marriage age, shorter pregnancy duration) and household (low paternal education, low socio-economic status) traits independently predicted dropout. Poor child growth and educational trajectories also predicted dropout, mediating the association of only maternal education. Some girls married despite completing secondary education, suggesting the value of education may be subordinated to the marriage market.

1. Introduction

Secondary education can contribute to upward socio-economic mobility, and moreover provide many other social benefits (Munoz Boudet et al., 2012). Completing secondary education facilitates access to higher education, and is increasingly essential for actively participating in the formal labour market (Colclough et al., 2010). For women, simply participating in secondary education may promote life-long autonomy and greater participation in decision-making (Smith et al., 2003), and in South Asia, may reduce the likelihood of child marriage (Raj et al., 2014). Maternal education may also benefit the next generation. For example, an estimated 4.2 million fewer deaths in children < 5 years between 1970 and 2009 were attributed to women completing lower secondary school (Gakidou et al., 2010). Similarly, in 56 low-/middle-income countries, the greater the level of maternal education, the lower the likelihood of the child being stunted (poor linear growth) (Alderman and Headey, 2017).

While global efforts to promote primary school attendance have been successful, this has merely shifted the problem of dropout to the next educational stage (Kamanda and Sankoh, 2015). Worldwide, 16% of adolescents aged 12–14 years and 37% of those aged 15–17 years were not attending lower or upper secondary school respectively (UIS and UNESCO GMR, 2016). The highest percentages of adolescents not attending secondary school are in Sub-Saharan Africa (92%) and South Asia (70%) (UIS, 2016).

India has the second largest percentage worldwide of its population comprising adolescents (Government of India, 2012). Despite major efforts, school attendance rates drastically decline from 90% at the primary level to 78% at lower secondary and 58% at upper secondary levels (IIPS, 2016). In Maharashtra state where our study is based, only 9.9 years of schooling are completed on average, meaning that most adolescents still do not finish secondary school (Government of Maharashtra, 2014). However, these data are not sex-disaggregated.

National Indian government statistics indicate relative gender equality in schooling enrolment, which may relate to the provision of free, mandatory education until lower secondary, and to programmes specifically encouraging girls' education (Government of India, 2015). However, the ratio of adolescent girls to boys enrolling in secondary school in Maharashtra state is only 0.84, indicating a substantial female disadvantage (Directorate of Economics and Statistics, 2015). Moreover, in the 1990s, studies from rural North India indicated that sex-differences in educational attainment put girls and boys on very different life trajectories (Jeffrey and Jeffery, 1994). It remains unclear whether this remains the case, given substantial recent efforts to improve access to secondary education in India. To address this issue, we need to improve our understanding of the causes and consequences of secondary school dropout in both sexes.

At the individual level, the factors contributing to lower secondary educational attainment remain poorly understood. School-based research typically investigates how education-related factors, and to a

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certain extent household wealth, predict school dropout (Kamanda and Sankoh, 2015). In this approach, adolescents already out of school essentially remain invisible.

In contrast, prospective biomedical studies such as birth cohorts often do collect data on children not in school, and have recently identified poor physical growth and under-nutrition as key predictors of secondary school dropout (Adair et al., 2013). However, the crude markers of schooling used in these studies reduce their utility for educational policy. Recent use of childhood growth data in secondary educational research has been encouraging (Sabates et al., 2013; Hannum and Hu, 2017), but little attention has been directed to broader factors shaping developmental trajectories early in the life-course.

What is missing is a comprehensive understanding of (a) the different factors that predispose individual adolescents to dropout of secondary school, (b) the consequences of leaving school early, and (c) potential sex differences in both contexts. To fill this evidence gap, we use unique longitudinal biomedical and educational data on 648 mother-child dyads from rural India, to study the biosocial predictors of secondary school dropout and its consequences by sex.

First, we develop a novel conceptual model that differentiates between maternal factors, which may relate to children's outcomes through biological and social mechanisms, and family or household factors. Second, we conduct statistical analyses, to identify maternal and household predictors of secondary school dropout in adolescence. These analyses are conducted first for the whole sample, and then separately by sex. Third, we compare the life trajectories of the two sexes according to their level of education completed.

In this article, Section 2 summarises relevant literature on constraints to secondary educational attainment and consequences of dropout. Section 3 presents our biosocial life-course approach and hypotheses. Section 4 explains our dataset and methods. Section 5 presents our findings of the predictors and consequences of secondary school dropout and gender differences therein. Section 6 discusses our findings and Section 7 concludes by outlining implications for policy from our results.

2. Literature Review

Most research on secondary school dropout has focused either on how schools 'push', or families 'pull', adolescents out of school. Only recently have studies adopted broader approaches, to consider factors acting earlier in the life-course. Moreover, schooling is not an end in itself, and educational trajectories need to be considered in the context of what happens after adolescents leave school. Literature on these issues, and gaps in research, are outlined below.

2.1. School-based constraints

Despite recent efforts, secondary education remains inaccessible in many rural areas in India (Agrawal, 2014). Since mandatory free education ends at 14 years, the cost of subsequent schooling, which in rural areas may require private transport and boarding facilities remains prohibitive (Lewin, 2011). Although the recent expansion of quasi-private rural secondary schools has been encouraging, they are largely unregulated and typically provide poor quality education (Härmä, 2011). Poor learning outcomes tend to reflect poor quality of teaching in both government and private secondary schools, due to the increasing use of teachers with inadequate training/certification and contracts (Ron-Balsera and Marphatia, 2012; UNESCO, 2017). Many secondary schools also do not provide the relevant skills and knowledge required to actively participate in rapidly changing rural economies (Alcott and Rose, 2015). Collectively, this scenario may therefore 'push' many adolescents out of school.

2.2. Household-level constraints

Studies identify a complex interplay of household socio-economic characteristics associated with variability in secondary educational attainment, including gender, wealth, caste, religion and location (UNESCO, 2017; Government of India, 2015). This indicates that children may be treated differently for various reasons. For example, an analysis of > 14,000 rural individuals across 12 Indian states showed that the likelihood of transitioning to higher levels of education (primary to lower/upper secondary and tertiary) was lower for rural girls, especially those from less educated, poorer and Muslim households (Bhaumik and Chakrabarty, 2013). Azam and Kingdon (2013) analysis of > 30,000 rural Indian households found equal investment in the primary education of sons and daughters, but that secondary education was prioritised for sons.

In rural areas, low household wealth may also reflect food insecurity, resulting in prioritising children's help with farming and housework over schooling (Moock and Leslie, 1986; Singh and Mukherjee, 2017). Lower parental educational attainment has also been widely associated with less education of children (Drèze and Kingdon, 2001), especially at secondary level (Sabates et al., 2013). In the context of these socio-economic factors, many adolescents may therefore be 'pulled' out of school.

However, despite efforts to address such school and household-level constraints, a significant proportion of adolescents still do not participate in secondary education. This indicates the need to identify broader factors that may contribute to less schooling.

2.3. Developmental constraints

Recent studies have provided evidence that under-nutrition and poor growth in early life are associated with poor educational attainment in both childhood and adolescence (Chávez et al., 2000). For example, a large pooled analysis of > 7900 children from Brazil, Guatemala, India, the Philippines and South Africa found that lower birthweight, and poorer early post-natal growth were associated with increased risk of secondary school dropout (Adair et al., 2013; Martorell et al., 2010). Hannum and Hu's (2017) analysis of > 1800 children in rural China similarly found early chronic under-nutrition to be a key predictor of lower literacy and secondary school dropout. Importantly, the effects of early-life under-nutrition may extend to other domains such as cognition and self-esteem in childhood (Fink and Rockers, 2014; Dercon and Sánchez, 2013), and earning capacity and financial independence in adulthood (Maluccio et al., 2009; Hoddinott et al., 2011).

These findings are important, by implicating biological as well as social pathways to poor educational attainment. In turn, this suggests that we need to expand our conceptual approaches to include educational trajectories, in order to integrate multiple factors within a unified framework.

2.4. Consequences of secondary school dropout for girls and boys

A small number of recent studies in India have described sex-differences in life trajectories in association with the level of educational attainment. For example, in the state of Jharkhand, boys who dropped out of school generally worked on family farms, entered the labor market or undertook vocational training, while girls tended to marry (Rao, 2010). Similar findings were reported in rural villages from Maharashtra and Andhra Pradesh (Maertens, 2013). Such differences in life opportunities are generally found in relation to primary or lower secondary school. What is unclear is whether recent efforts to promote access to education are changing socio-cultural norms around the perceived returns to secondary education and the expected life roles of females and males.

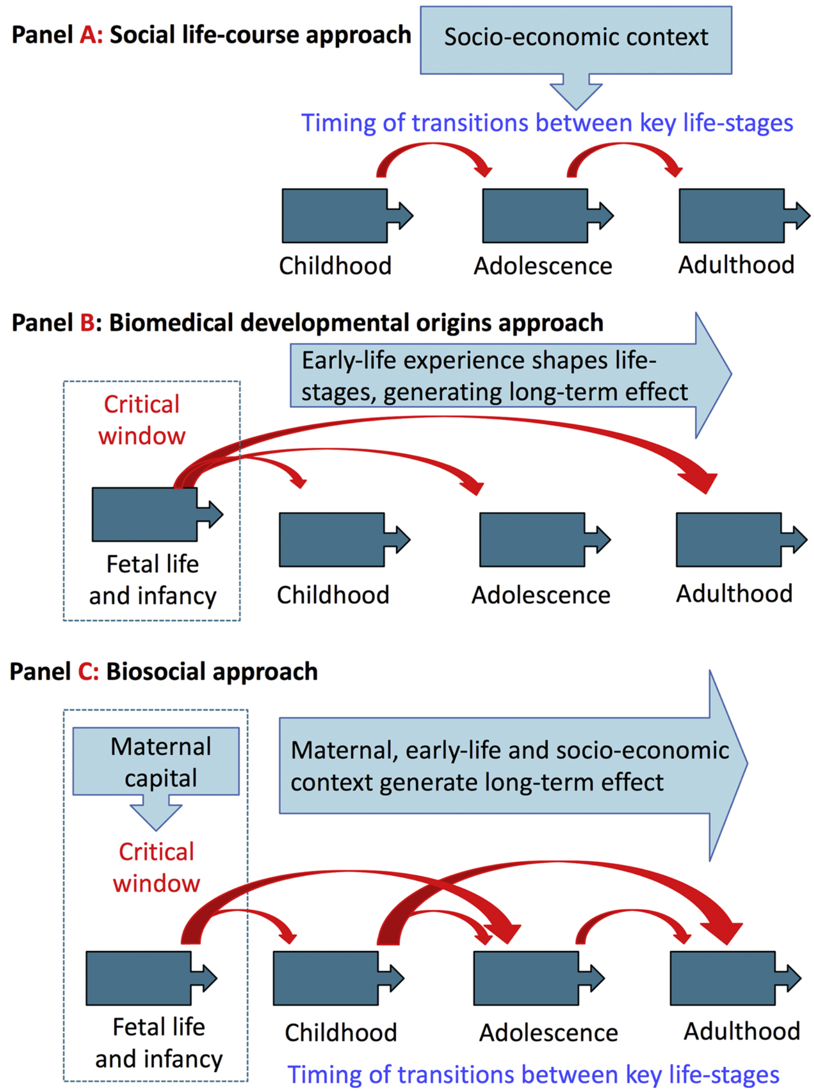


Fig. 1. Life-course perspectives.

3. Expanding the life – course approach

Our new biosocial life-course approach builds on earlier work in both the social and biomedical sciences, as illustrated in Fig. 1. At the broadest level, we use a life-course approach. Life-course approaches may help understand '…the nexus of social pathways, developmental trajectories and social change' (Elder et al., 2003, 10) that contribute to variation in experience, such as the timing of school dropout. Whilst conceptually the life-course approach is inherently multi-disciplinary, in practice disciplines tend to focus on specific aspects of individual life trajectories. Below, we explain how social and biomedical scientists have applied this approach. We then describe how our approach brings these two perspectives together, and the potential value this new 'biosocial' approach adds to educational research.

Panel A in Fig. 1 shows how a 'social life-course approach' has been used to investigate the timing of transitions between key life-stages, broadly defined as childhood, adolescence and adulthood. Social Scientists use this approach to understand how the broader socio-economic context, local institutions and social interactions shape the timing of key turning points and between life-stages (Mayer, 2009; Hörschelmann, 2011). In the context of education research, the focus of this approach is generally on social experience, rather than physical development.

We therefore also draw on the 'developmental origins of adult health and disease' (DOHaD) model (Panel B, Fig. 1), widely used by biomedical researchers to understand how outcomes experienced in early life shapes life-stages, generating long-term effects. The DOHaD approach emphasizes the importance of early 'critical windows' (Lucas, 1991), when many aspects of physical development are especially sensitive to environmental influences (Barker, 2007). Particular attention is paid to nutritional influences during the 'first thousand days', which embrace the period from conception (implicating maternal nutrition) through pregnancy (fetal life) and infancy, to around 2 years of age (Victora et al., 2010; Stephenson et al., 2018). For education research, this provides opportunities to consider early periods of brain development and its sensitivity to environmental factors. For example, studies have associated maternal nutritional transfer in the last weeks of pregnancy and infant growth trajectories with children's poor cognitive and educational outcomes (MacKay et al., 2010; Stein et al., 2013; Martorell et al., 2010; Adair et al., 2013).

A key implication of the DOHaD approach is that environmental factors shaping the earliest stages of development are transduced by maternal biology, which during pregnancy buffers the fetus from external stresses (Wells, 2010). The concept of 'capital' was developed by evolutionary biologists, who consider that individuals invest through the life-course in a stock of 'embodied capital' (Hill and Kaplan, 1999; Kaplan et al., 1995) in order to maximise their chances of survival and reproduction. Such 'capital' includes both somatic traits such as strength, immune function and coordination, and also social qualities related to skill, education and knowledge. Whilst the implications of this pre-conception period for the offspring's growth, cognitive development and health are well-established, few studies have considered how they may extend to social outcomes such as education, especially into late-adolescence (M. Barker et al., 2018; Marphatia et al., 2016).

Panel C, Fig. 1 illustrates how we bring the social and biomedical life-course perspectives together under a holistic 'biosocial' approach. The added value of our approach for educational research is as follows. First, we go further back in the life-course than the current biomedical approach by focusing on maternal capital *prior* to pregnancy. The niche occupied by the foetus can then be considered in terms of 'maternal capital' (Wells, 2010) which refers to both the social and somatic characteristics of the mother which shape not only development in early life, but also the timing of transitions between key life-stages. Although offspring may benefit substantially from maternal capital, they may also be exposed during early 'critical windows' to any *constraints* embodied by the mother, such as low social status or chronic under-nutrition (Wells, 2010). The magnitude of maternal capital prior to pregnancy is thus critical, and has been associated with a range of maternal and child outcomes, although to date, few studies have specifically examined educational outcomes (Stephenson et al., 2018; Marphatia et al., 2016).

Second, we study variability in the timing of transitions between key life-stages in relation to when children enter school, how they progress, why some drop out by adolescence, and how this may place them on different life trajectories in adulthood. This may help understand the life-course emergence of school dropout and its consequences for subsequent life trajectories. Third, we study the maternal, early life and social contexts potentially associated with the timing of these educational transitions and also their consequence for subsequent life trajectories.

Fig. 2 illustrates in more detail the different components of our 'biosocial life-course' approach. Key life-stages, and the timing of transitions between them, are indicated by a vertical arrow at the bottom of the diagram: early-life; childhood; adolescence; late-adolescence. The Figure shows how maternal factors in early-life may be most influential during early critical windows of development, whereas socio-economic factors become important from mid-childhood. Children's growth and educational trajectories may play important mediating roles, connecting across these two periods. Our primary outcome, indicated in red, is 'schooling status in late-adolescence,' which in turn may shape subsequent life trajectories, defined as studying, working or marriage. This model also allows us to consider in detail the emergence of gender differences in educational outcomes and their consequences.

Markers of maternal somatic capital included in our analysis include maternal height, nutritional status and gestation. Height is a marker of health status accumulated through genetic influences and environmental exposures in early childhood (Özaltin et al., 2010). Maternal height has been positively associated with the length of gestation (Chan and Lao, 2009), and in analysis across 54 low-/middle income countries was associated beneficially with infant survival and child nutritional status and growth (Özaltin et al., 2010; Subramanian et al., 2009). In adults, short stature has been associated with increased risk of diabetes and other non-communicable diseases (Wells et al., 2016). Body Mass Index (BMI, weight/height^2) better reflects current nutritional status of mothers and their energy stores for reproduction (Wells, 2010). Gestation, or duration of pregnancy, indexes the duration of exposure to placental nutrition and the magnitude of maternal nutritional investment respectively (MacKay et al., 2010). Markers of maternal social capital include educational attainment. Marriage age may be a marker of both social and biological capital, indexing a shift in women's social status partly reflecting physical maturity and hence signalling readiness for marriage (Marphatia et al., 2017).

To put maternal traits into the rural patriarchal context of our study site, we draw on the social life-course approach to include a range of socio-economic characteristics shown in previous studies to predict children's educational outcomes (Sabates et al., 2013; Bhaumik and Chakrabarty, 2013; Moock and Leslie, 1986). These include markers of the broader socio-cultural context, such as paternal educational attainment, family composition and proxies for wealth such as socio-economic status and agricultural land.

3.1. Hypotheses

To fill gaps in the literature highlighted above, we apply our biosocial life-course approach to unique longitudinal biomedical and educational data on 648 mother-child dyads from rural India. We test five Hypotheses:

1 Girls are more likely than boys to drop out of secondary school
2 Maternal somatic and social factors, independent of household

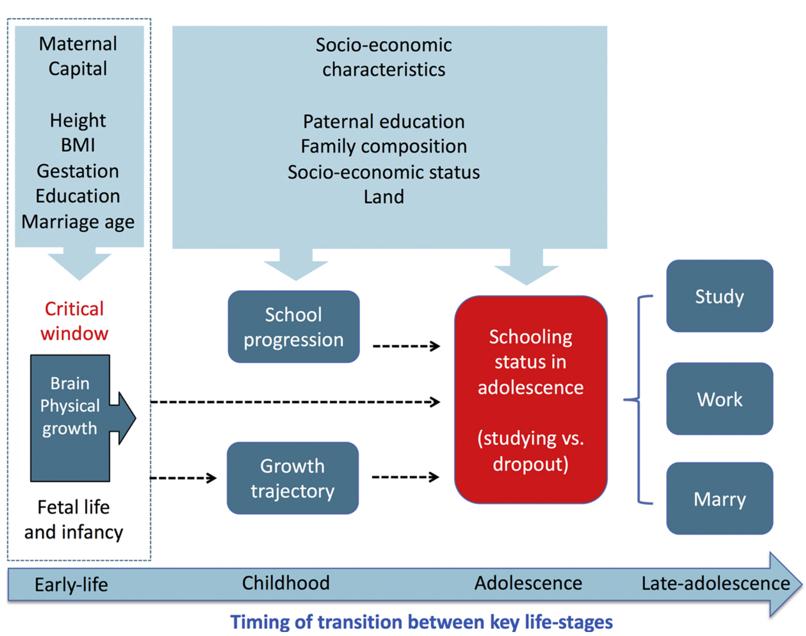


Fig. 2. Study design: Biosocial life-course approach.

socio-economic characteristics, predict dropout

3 Child growth and educational trajectories mediate the associations between maternal factors and schooling status in adolescence
4 Different factors predict secondary school dropout of the two sexes
5 Life trajectories differ between the sexes in late-adolescence, both among those still in school, and those who have dropped out

4. Data

4.1. Study site

The Pune Maternal Nutrition Study (PMNS) 1993 birth cohort initially identified all married, non-pregnant women of child-bearing age (N = 2675) living across six villages in rural Pune district of Maharashtra state, India (Yajnik et al., 2007). Ninety-two percent of these women participated in the initial survey, and of the 1102 women who became pregnant, 814 (73.9%) were enrolled in the study (Yajnik et al., 2007). Of the 762 children born to these women, 700 (91.9%) were recruited into the study (Rao et al., 2001; Yajnik et al., 2007; Joglekar et al., 2007).

Ethical permission was granted by village leaders, the King Edward Memorial Hospital Research Centre (KEMHRC), and the Indian Health Ministry's Screening Committee. Parents/guardians gave signed informed consent and at the legal majority age of 18 years, adolescents gave their consent. At the recent 18-year follow-up the University of Cambridge, UK also granted ethical approval for the collection of educational and social data.

Although the main aim of the PMNS is to investigate health outcomes, such as the associations between maternal nutrition and the life-course progression of cardio-metabolic risk in the offspring (Yajnik et al., 2007), the longitudinal biosocial data on mother-child dyads enables new investigations of social outcomes. We used these data to investigate the independent association of maternal traits prior to pregnancy (during when many somatic markers change), household characteristics, children's growth and educational trajectories with the likelihood of dropping out of secondary school in adolescence.

4.2. Measurements

4.2.1. Maternal pre-pregnancy

At recruitment, before mothers were pregnant, data were collected on a range of maternal traits including nutritional status (weight and height, used to calculate body mass index (BMI) as weight/height^2), reproductive outcomes, marriage age, and educational attainment (Rao et al., 2001). Household data were also collected, and included different proxies of wealth, social grouping (e.g. caste, religion) and paternal educational attainment (Rao et al., 2001). A strength of the study is its prospective nature, such that maternal traits were measured *prior* to conception.

4.2.2. Birth

For the children born to mothers during the study window, gestational age (indicating the duration of pregnancy) length and weight at birth were measured. We treat these as maternal traits, indexing the duration of exposure to placental nutrition and the magnitude of maternal nutritional investment respectively.

4.2.3. Infancy and childhood

Linear growth (height), weight, head circumference and BMI were assessed during infancy, mid-childhood and early-adolescence (Joglekar et al., 2007).

4.2.4. Follow-up at 18 years

At 18-years, a comprehensive follow-up was conducted, which provided the final data for assessing trajectories in growth, nutritional status, and educational attainment. The primary outcome of our study was secondary school dropout.

To characterise educational trajectories, data were collected on age-related participation, progression, performance, attainment and dropout from pre-primary to late-adolescence. We also measured functionally literacy by testing whether participants were able to read choices describing the importance of education, and to write out a priority answer.

In addition, life trajectory data described whether adolescents were studying, working, or married and the age at which these transitions took place.

4.3. Data manipulation

4.3.1. Maternal data

Maternal age (years) was expressed as a continuous variable. Maternal age at marriage was categorised in two groups: < legal age of 18 years or ≥ 18 years as per Indian legislation (Ministry of Women and Child Development and UNICEF, 2007). Only 9% of mothers had completed secondary or higher education. To ensure adequate cases in cells, we categorised maternal education into two levels according to the Indian education system: none to primary (1–5 years), or upper primary or greater (≥6 years) (IIPS, 2010).

Maternal somatic traits included height, nutritional status and parity. Height was used as a continuous value, in centimetres. The continuous value for BMI (kg/m^2) was used to assess nutritional status (WHO Expert Consultation, 2004). Parity was coded as 0 or ≥ 1 births.

Gestational age was treated as a continuous variable, measured in completed weeks. We treated gestational age as a marker of maternal nutritional investment *in utero*.

Birth weight was adjusted for gestational age to give an age- and sex-specific z-score, using reference data from the UK rather than the World Health Organisation (WHO), because the former adjusts for gestational age and provides a single reference throughout all stages of children's development, including puberty (Cole et al., 2012). We treated birth weight as another marker of maternal nutritional investment *in utero*.

4.3.2. Household data

Household characteristics included religion (categorised as Hindu, Muslim, Christian or Budha) and caste (categorised as low [tribal, scheduled caste], middle [artisan, agriculture], or high [prestige, dominant]). Family composition included type (joint or nuclear) and size (≤ 4 adults or ≥ 5 adults). As only 9% of fathers had no education, paternal completed schooling years were categorised as none to primary, 0–5 years, or ≥6 years.

Household wealth was indexed by size of agricultural land owned (low [≤ 2.99 acres], mid [3–5.99] or high [≥ 6 acres]). Overall Socio-Economic Status (SES) was categorised into low [≤24], mid [25–29] or high [≥30] groups. SES was a composite variable reflecting caste, the education level and occupation of the household head, type of housing, and material possessions including ownership of animals and land (S. Rao et al., 2001).

4.3.3. Infant and child data

All infant and child anthropometric data were converted to z-scores using UK reference data as described above. From these data, we then computed conditional z-scores to evaluate growth trajectories (Adair et al., 2013). This approach evaluates size at a given time point relative to what would be expected based on the child's size at the previous time-point. Other than head circumference (cm), which was not available for analysis at the 18-year time-point, child height and BMI conditional z-scores were calculated for ages 2, 6, 12 and 18 years using the LMS option in Microsoft Excel™ for age-related reference ranges (Cole and Green, 1992).

4.3.4. Adolescent 18-year follow-up data

To characterise educational trajectories of the adolescents, we generated categories as follows: attendance in nursery (yes or no); entry age, 1st standard and age-for-grade in early-adolescence (< expected age or ≥ expected age); failing a standard (yes or no) and level failed (primary or secondary+). Markers of performance included functional literacy (yes or no) and 10th standard exam result (if taken, pass or fail).

4.4. Statistical methods

4.4.1. Descriptive results

To describe the characteristics of our sample, we used chi-square and independent sample t-tests to investigate whether maternal, household and child characteristics differed by sex. We also tested for correlations (Pearson's) between maternal and household characteristics using continuous values of these traits.

4.4.2. Hypothesis testing

For hypothesis 1, we used chi-square tests to investigate whether there were significant differences in our primary outcome variable by sex, 'studying vs. dropout' in late-adolescence. We also used the Kaplan Meier Survival Curve to assess whether the timing and rate of school dropout differed between the two sexes (Kirkwood and Sterne, 2003).

To test hypothesis 2, we undertook several analytical steps. First, we used chi-square and independent sample t-tests to test for differences in maternal and household characteristics by our primary outcome variable, 'studying vs. dropout.' Second, variables that significantly differed by these groups were then introduced into univariable logistic regression models. Third, significant predictors from univariable models were included into multivariable logistic regression models. Regression Model 1 investigated whether maternal factors, independent of household socio-economic characteristics, predicted dropout.

For hypothesis 3, we followed a similar approach as hypothesis 2 by first testing for differences in child growth and educational trajectories by studying groups using chi-square and independent sample t-tests. Variables that differed significantly in these analyses were then included into our multivariable logistic regression Model 2, which tested whether child factors mediated the association of maternal and household households.

For hypothesis 4, we stratified multivariable logistic regression Models 1 and 2 by sex. Due to the smaller sample sizes, these sex-specific analyses are exploratory, but nevertheless give preliminary indications of whether different factors predict dropout for adolescent girls and boys.

For hypothesis 5, we used chi-square tests to assess sex-differences in markers of life trajectories, both among those still in school, and those who had dropped out.

4.4.3. Exclusions and reporting of results

We excluded seven mothers with an implausible marriage age of < 10 years. Agricultural land and BMI were right-skewed and therefore natural log-transformed for analysis, but reported as untransformed values in statistical tables. We did not include religion or caste in our models because neither showed substantial variation in our population.

We maintained variables that were borderline significant ($p = 0.051$ to $p = 0.099$) in models, and dropped variables with significance $p > 0.10$.

Our logistic regression models quantified the risk or probability, expressed as Odds Ratios (OR), of dropping out of secondary school. We also reported the 95% Confidence Interval (CI). We tested all continuous variables for linear association with the outcome. We controlled for adolescents' age. In models with the whole sample, we also included child sex. The NagelKerke (NK) value, a pseudo R^2 measure, was multiplied by 100 to show the proportion of variance in secondary educational attainment explained.

All analyses were conducted in SPSS 24 (IBM Corp.).

5. Results

5.1. Descriptive results

Those followed-up at 18 years represented a 92.5% retention rate (648/700). Those followed-up were from the middle and high caste groups, had more educated parents, and mothers with lower BMI compared to those not followed up. These differences were all of small magnitude, and no other differences in baseline maternal or household characteristics were evident (Appendix Table A1). Mean age of adolescents at the last follow-up was 18.3 (range 17.4 to 19.2) years, equivalent to upper secondary school.

Table 1 presents descriptive information on maternal and household characteristics of our sample. Average maternal age was 21 (range 15–38) years. Almost half of the mothers had married before the legal age of 18 years, and 40.6% had completed ≤5 years of schooling. Maternal nutritional status was poor, as indicated by an average BMI of 17.8 kg/m^2, below the cut-off for chronic energy deficiency of 18.5 kg/m^2 (WHO Expert Consultation, 2004). Mean gestational age was 39 weeks (equivalent to term delivery). Maternal characteristics did not differ by the sex of the child.

The majority of our sample was from the Hindu faith, with 68.5% belonging to the higher caste group. About 70% were of mid- to high-SES, primarily living in joint family structures with 66% having fewer than five adult members. A greater proportion of girls than boys were from joint compared to nuclear families.

There were weak to moderate correlations between a few maternal and household characteristics, indicating only limited clustering of favourable traits within families (Appendix Table A2).

Fig. 3a-c shows that relative to UK reference data, the growth trajectories of the two sexes differed. Between 6 to 12 years, in comparison to boys, girls demonstrated significantly greater growth in height (Fig. 3a). Girls were of lower birth-weight and had lower growth in BMI than boys between 6 to 12 years (Fig. 3b). The trajectory of growth in head girth (Fig. 3c) also differed by sex, being faster for boys from 2 to 6 years, but faster for girls from 6 to 12 years. Although head girth was also measured at 18 years, these data were not available for the current analysis.

Table 2 shows that most had attended nursery, taken and passed the lower secondary school leaving exam and were literate. About 17% failed a grade and 32% were over-age for their grade in early-adolescence. We found no significant differences by child sex, suggesting that if given a chance, girls perform as well as boys in school.

5.2. Primary outcome variable

Our primary outcome variable was dropout from secondary school. Among those followed-up, 518 (79.9%) were studying and 130 (20.1%) had dropped out of school. Our rural cohort had a higher upper secondary school attendance rate than the average Indian (54.2%) and Maharashtrian rural populations (55.8%) (IIPS, 2016; IIPS, and ICF, 2018).

5.3. Hypothesis 1

In support of hypothesis 1, a greater proportion of adolescent girls (N = 72 out of 305) than boys (N = 58 out of 343) in our cohort were no longer studying in late-adolescence (23.6% vs. 16.9%, $p \leq 0.05$, indicating a girl/boy ratio of 1.4). The Kaplan-Meier Survival Curve in Fig. 4 shows two critical points in the educational trajectory when dropout rates begin to diverge for the sexes. Box A shows that a greater proportion of boys than girls left school between the 4th and 9th standards. Box B shows that a greater proportion of girls than boys leave school from the 10th standard onwards. Overall, the difference in the rate of school dropout by sex was borderline significant (Log-Rank, Mantal-Cox test $p = 0.063$).

These results suggest that gender disparities in education in this

Table 1
Descriptive results: Maternal traits and household characteristics, stratified by sex.

	All children (N = 648)		Girls (N = 305)		Boys (N = 343)		Sex difference[1]	
Maternal traits	Mean	SD	Mean	SD	Mean	SD	Δ	s.e.
Maternal age (y)	21.39	3.55	21.35	3.61	21.43	3.50	−0.08	0.28
Maternal height (cm)	151.97	4.93	152.02	4.78	151.93	5.07	0.10	0.39
Maternal BMI (kg/m^2)[3]	17.81	1.10	17.81	1.10	17.99	1.10	−0.99	1.01
Gestational age (weeks)	39.01	1.71	39.05	1.61	38.98	1.79	0.07	0.13
Child birth-weight z-score[4]	−1.56	0.86	−1.62	0.91	−1.50	0.80	−0.12	0.07[5]
Maternal traits	**F**	**%**	**F**	**%**	**F**	**%**		**Significance[2]**
Maternal education (N = 626)								ns
None to Primary (0-5y)	254	40.6	125	42.7	129	38.7		
Upper primary + (≥6y)	372	59.4	168	57.3	204	61.3		
Maternal age at marriage[6]								ns
Before legal age of 18y	292	47.2	136	46.9	156	47.6		
After 18y	326	52.8	154	53.1	172	52.4		
Maternal parity								ns
0 births	205	31.6	96	31.5	109	31.8		
≥1 births	443	68.4	209	68.5	234	68.2		
Household characteristics								
Religion								ns
Hindu	628	96.9	299	98.0	329	95.9		
Muslim	15	2.3	4	1.3	11	3.2		
Christian	1	0.2	0	0	1	0.3		
Buddha	4	0.6	2	0.7	2	0.6		
Caste (N = 644)								ns
Lower (Tribal, scheduled)	54	8.4	19	6.2	35	10.3		
Middle (Artisan, agriculture)	149	23.1	69	22.7	80	23.5		
High (Prestige, dominant)	441	68.5	216	71.1	225	66.2		
Family type (N = 644)								**≤0.01**
Nuclear	125	19.4	44	14.5	81	23.8		
Joint	519	80.6	260	85.5	259	76.2		
Family size (N = 644)								ns
≤5 adults	425	66.0	197	64.8	228	67.1		
> 6 adults	219	34.0	107	35.2	112	32.9		
Socio-economic status[7]								0.088
Low (≤ 24)	197	30.4	80	26.2	117	34.2		
Mid (25-29)	225	34.8	112	36.7	113	33.1		
High (≥30)	225	34.8	113	37.1	112	32.7		
Agricultural land size (N = 622)								ns
Low (≤2.99 acres)	224	36.0	101	34.8	123	37.0		
Mid (3.0 to 5.99 acres)	191	30.7	87	30.0	104	31.3		
High (≥6 acres)	207	33.3	102	35.2	105	31.6		
Paternal education (N = 626)								0.079
None to primary (0-5y)	157	25.1	83	28.3	74	22.2		
Upper primary + (≥6y)	469	74.9	210	71.7	259	77.8		

Abbreviations: SD, standard deviation. s.e. standard error. F, frequency. ns = not significant.
[1] Independent samples *t*-test. Δ, difference between girls and boys.
[2] Chi-square test for sex difference.
[3] N = 643, BMI was natural log-transformed but reported as the untransformed value in the Table.
[4] N = 609, adjusts for gestational age.
[5] p = 0.077.
[6] N = 618, excludes seven mothers with marriage age of < 10 years of age.
[7] Composite score.

population are complex, with both sexes at a disadvantage at different points in the educational trajectory. However, by late-adolescence, a greater proportion of girls than boys had dropped out of school.

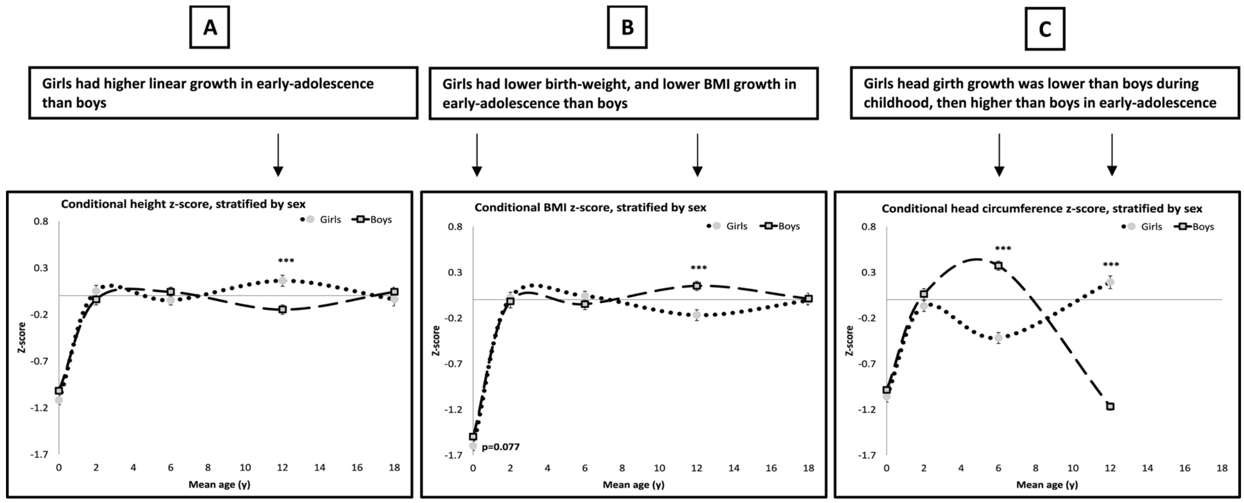
5.4. Hypothesis 2

We first present univariate analyses, testing for differences in maternal and household characteristics in association with our primary outcome, the ‘studying vs. dropout’ groups. We then present multivariable logistic regression models, testing for independent associations of maternal and household factors with the risk of dropout.

5.4.1. Univariate analyses of studying vs. dropout groups

Univariate analyses showed that compared to mothers of the group still in school, a greater proportion of mothers of the dropout group had completed less schooling and married young. Duration of pregnancy was shorter in mothers of the dropout group than in the mothers of those still in school. The families of dropout adolescents had lower household wealth, smaller family size and lower parental education (Appendix Table A3).

Maternal age, height, BMI, parity, child birth-weight and family type did not differ between the two groups. These variables were dropped from subsequent analysis.



Error bars represent standard error of the mean. *p≤0.05, **p≤0.01, ***p≤0.001. Weight, rather than BMI was used at birth.

Fig. 3. Descriptive results: Children's growth trajectories, stratified by sex.

Table 2
Descriptive results: Children's educational trajectories, stratified by sex.

	All children (N = 648)		Girls (N = 305)		Boys (N = 343)		**Significance**[1]
	F	**%**	**F**	**%**	**F**	**%**	
Participation							
Did you attend nursery?							ns
Yes	564	87.0	269	88.2	295	86.0	
No	84	13.0	36	11.8	48	14.0	
Age-specific participation							
Entry age, 1st standard (N = 539)							ns
≤ expected age (≤ 6y)	63	9.9	33	11.0	30	8.9	
≥ expected/higher (> 7y)	576	90.1	268	89.0	308	91.1	
Standard/age early-adolescence[2]							ns
< expected age	205	31.6	98	32.1	107	31.2	
≥ expected age	443	68.4	207	67.9	236	68.8	
Progression							
Did you fail a standard?							ns
Yes	109	16.8	46	15.1	63	18.4	
No	539	83.2	259	84.9	280	81.6	
Level failed (N = 110)							ns
Primary (standards 1-8)	61	55.5	24	52.2	37	57.8	
Secondary + (9-14)	49	44.5	22	47.8	27	42.2	
10th standard exam taken							ns
Yes	589	90.9	283	92.8	306	89.2	
No	59	9.1	22	7.2	37	10.8	
Performance/literacy							
Result 10th exam (N = 589)							ns
Pass	567	96.3	271	95.8	296	96.7	
Fail	22	3.7	12	4.2	10	3.3	
Functionally literate?[3] (N = 644)							0.082
Yes	637	98.9	301	99.7	336	98.2	
No	7	1.1	1	0.3	6	1.8	

Abbreviations: F, frequency. ns = not significant.
[1] Chi-square test for sex difference.
[2] Standard adjusted for 5-year range of follow-up in mid-childhood: 9 years of age = 4th standard; 10y = 5th standard; 11y = 6th standard; 12y = 7th standard; 13y = 8th standard.
[3] Interviewer ticked 'yes' or 'no' if they observed the participant was not able to read 10 choices provided for why education was important to them, and write the most important reason.

5.4.2. Logistic regression analysis of maternal and household factors for the whole sample

In univariable logistic regression models, young maternal marriage age (< 18 years) was associated with secondary school dropout (OR 1.50, CI 95%: 1.01, 2.25), but was confounded by maternal education. Similarly, low agricultural land holding predicted dropout (OR 1.81, CI 95%: 1.10, 2.96) but was mediated by SES. We therefore retained only maternal education and SES in subsequent multivariable analyses.

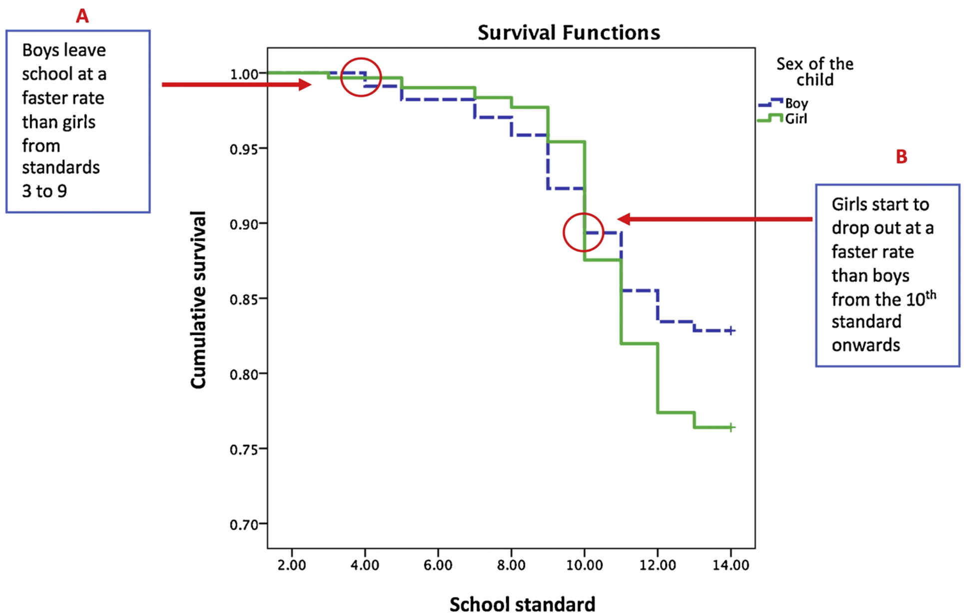


Fig. 4. Rate and time of school dropout, stratified by sex.

The multivariable logistic regression in Table 3 tests whether maternal traits, independent of household factors predicts dropout (Model 1).

In support of hypothesis 2, Model 1 shows that female sex, low education of both mothers and fathers and low- and mid-SES were independently associated with dropout. On the other hand, greater gestational age was protective against school dropout. This model explained 14.3% of the variance in schooling status in late-adolescence.

Overall, these results show that both somatic and social components

Table 3

Multivariable logistic regression model testing independent associations of maternal, household, and child factors with secondary school dropout.

	Model 1: Maternal and household factors OR (N = 626)[1]		Model 2: Maternal, household, child growth and education factors OR (N = 577)[2]	
	NK = 0.143		NK = 0.211	
	Exp B	CI	Exp B	CI
Adolescent traits				
Age (years)	**1.73**	**1.22, 2.44****	**1.55**	**1.05, 2.29***
Sex (Boys = Ref)	1.00		1.00	
Girls	**1.63**	**1.07, 2.49***	1.58	0.98, 2.55[3]
Maternal traits				
Education (≥6y = Ref)	1.00			
None to primary (1-5y)	**1.85**	**1.17, 2.90****		
Gestation (weeks)	**0.85**	**0.76, 0.96****	**0.87**	**0.77, 0.99***
Household characteristics				
SES (High = Ref)	1.00		1.00	
Low	**2.23**	**1.30, 3.82****	**2.57**	**1.38, 4.80****
Mid	**1.86**	**1.09, 3.16***	**2.19**	**1.18, 4.06****
Paternal education (≥6y = Ref)	1.00		1.00	
None to primary (1-5y)	**1.75**	**1.09, 2.82***	**2.18**	**1.33, 3.57****
Child growth				
Growth head girth, infancy			**0.78**	**0.62, 0.98***
Linear growth, ages 6 to 12 years			0.81	0.64, 1.06[4]
BMI growth, ages 12 to 18 years			**1.29**	**1.03, 1.62***
Child education				
Attended nursery (Yes = Ref)			1.00	
No			**2.03**	**1.13, 3.66***
Grade slippage early-adolescence (No = Ref)			1.00	
Yes			**1.97**	**1.22, 3.19****
Constant	0.002		0.004	

Abbreviations: OR, Odds Ratio. NK, Nagelkerke, pseudo R^2. CI: 95% Confidence Interval.

* $p \leq 0.05$.

** $p \leq 0.01$, *** $p \leq 0.001$.

[1] N = 124 dropout vs. N = 502 studying.

[2] N = 104 dropout vs. N = 473 studying.

[3] p = 0.059.

[4] p = 0.088.

Table 4
Multivariable logistic regression model testing independent associations of maternal, household, and child factors with secondary school dropout, stratified by sex.

	Model 1: Maternal and household factors				Model 2: Maternal, household, child growth and education factors			
	Girls OR (N = 293)[1]		Boys OR (N = 333)[2]		Girls OR (N = 281)[3]		Boys OR (N = 315)[4]	
	NK = 0.134		NK = 0.126		NK = 0.190		NK = 0.261	
	Exp B	CI	Exp B	CI	Exp B	CI	Exp B	CI
Adolescents' age	**1.81**	**1.11, 2.96***	**1.73**	**1.06, 2.83***	**1.87**	**1.10, 3.17***	1.61	0.93, 2.80[8]
Maternal phenotype								
Education (≥6y = Ref)	1.00		1.00		1.00		1.00	
None to primary (1-5y)	**1.85**	**1.00, 3.42***	**2.18**	**1.19, 3.99***	1.95	0.99, 3.84[7]	1.76	0.90, 3.43[9]
Gestation (weeks)			**0.82**	**0.70, 0.95****			0.85	0.72, 1.00[10]
Household characteristics								
SES (High = Ref)	1.00		1.00		1.00		1.00	
Low	2.01	0.96, 4.24[5]	**2.52**	**1.15, 5.51***	**2.43**	**1.07, 5.50***	**2.47**	**1.00, 6.07***
Mid	1.82	0.91, 3.67[6]	1.72	0.76, 3.90	1.67	0.76, 3.67	1.60	0.62, 4.15
Paternal education (≥6y = Ref)	1.00				1.00			
None to primary (1-5y)	**1.99**	**1.06, 3.72***			**2.09**	**1.04, 4.21***		
Child growth								
Growth head girth, infancy							**0.69**	**0.49, 0.96***
Linear growth, ages 6 to 12 years					**0.69**	**0.50, 0.94***		
BMI growth, ages 12 to 18 years					**1.61**	**1.15, 2.26****		
Child education								
Attend nursery (Yes = Ref)							1.00	
No							**2.98**	**1.37, 6.47****
Grade slippage early-adol. (No = Ref)							1.00	
Yes							**2.55**	**1.30, 5.00****
Constant	**0.000*****		0.01		**0.000****		0.005	

Abbreviations: OR, Odds Ratio. NK, Nagelkerke, pseudo R^2, CI: 95% Confidence Interval.
* $p \le 0.05$.
** $p \le 0.01$.
*** $p \le 0.001$.
[1] N = 68 dropout vs. N = 225 studying.
[2] N = 56 dropout vs. N = 277 studying.
[3] N = 58 dropout vs. N = 223 studying.
[4] N = 52 dropout vs. N = 263 studying.
[5] p = 0.065.
[6] p = 0.091.
[7] p = 0.054.
[8] p = 0.087.
[9] p = 0.099.
[10] p = 0.057.

of maternal capital, independent of household socio-economic characteristics, predicted dropout. Older adolescents, and girls were more likely to have left school.

5.5. Hypothesis 3

Chronologically, mediating variables occur later in the life-course than exposures. They may help explain the association or pathways connecting exposures to outcomes. We tested whether children's growth and educational trajectories mediated the association of maternal and household factors.

5.5.1. Univariate analyses of studying vs. Dropout groups

Children's growth trajectories differed by dropout status in late-adolescence (Appendix Fig. A1). In comparison to the studying group, the dropout group had lower infant growth in height, BMI and head girth from birth to age 2 years, but higher BMI growth from 12 to 18 years. These factors, which differed significantly between the studying groups, were retained in multivariable models. Growth trajectories during mid-childhood and adolescence did not differ by studying groups and were therefore not included in subsequent analysis.

Child educational trajectories also differed by studying groups (Appendix Table A4). In comparison to the studying group, the dropout group was less likely to have participated in nursery school, and more likely to fall behind in school in early-adolescence, to fail a school standard, and less likely to have taken, and passed the 10th standard exam, and to be functionally literate. We included nursery participation and grade slippage in early-adolescence in multivariable models. We did not include failing a school standard, the 10th standard exam or functional literacy into our regression models because these variables were too closely related to our primary outcome of dropout. The groups did not differ in the standard failed, which was discarded from subsequent analysis.

5.5.2. Logistic regression analysis of child mediators for the whole sample

Table 3, Model 2 showed that being female, lower paternal education, low- and mid- SES, greater BMI growth from 12 to 18 years, not attending nursery school and grade slippage independently predicted school dropout. Greater gestational age, greater infant head girth growth and better linear growth from 6 to 12 years were all protective against dropout. This model explained 21.1% of the variance in schooling status in late-adolescence.

The association of maternal education was mediated by the children's education. This suggests that the effect of lower maternal education is shown through children's poor progression in school.

These results provide little support for hypothesis 3. Both growth and educational trajectories predict school dropout and they only mediate the association of low maternal education. These affects were

Table 5
Life trajectories in late-adolescence by secondary educational attainment, stratified by sex.

	All children (N = 648)		Girls (N = 305)		Boys (N = 343)		Significance[1]
	F	**%**	**F**	**%**	**F**	**%**	
Dropout group (N = 130)							**≤0.001**
Working	74	56.9	18	25.0	56	96.6	
Studying (training course)	4	3.1	3	4.2	1	1.7	
Married	52	40.0	51	70.8	1	1.7	
Studying group (N = 518)							**≤0.001**
Working	0	0	0	0	0	0	
Studying	500	96.5	215	92.3	285	100.0	
Married	18	3.5	18	7.7	0	0	

Abbreviations: F, frequency.
[1] Chi-square test for sex difference.

largely independent of other factors, as reflected in the proportion of variance explained increasing between the two Models, from 14.3% to 21.1% respectively.

5.6. Hypothesis 4

To test whether different factors predicted dropout of girls and boys, Table 4 stratified our multivariable logistic regression Models 1 and 2 from Table 3 by sex.

Model 1 shows the maternal and household factors stratified by sex. For girls, low education of both mothers and fathers and low- and mid-SES were independently associated with dropout. For boys, low maternal education and low SES predicted dropout whereas greater gestational age was protective.

Model 2 shows whether maternal and household factors were mediated by child growth and education factors. For girls, only mid-SES was mediated by child growth. Better linear growth from 6 to 12 years reduced risk of dropout, whereas greater BMI growth from 12 to 18 years increased the risk. These affects were largely independent of other factors, as reflected in the proportion of variance explained increasing between Models 1 and 2, from 13.4% to 19.0% respectively.

For boys, introducing data on growth and educational trajectory slightly reduced the association of low maternal education with risk of dropout. Greater gestational age and infant head growth reduced risk of dropout, whereas not attending nursery and grade slippage both increased it. These affects were largely independent of other factors, as reflected in the proportion of variance explained increasing between the two Models from 12.6% to 26.1% respectively.

These results support hypothesis 4, suggesting that factors predicting dropout differ by sex.

5.7. Hypothesis 5

Understanding the life-course pathways shaping secondary educational attainment is crucial because schooling is likely to shape subsequent life pathways, but potentially in very different ways for the two sexes. That people follow different pathways is not in itself a problem. The concern arises when this divergence contributes to greater levels of social and gender inequality (Kerckhoff, 2001).

Table 5 shows that girls and boys were on different life pathways in late-adolescence according to their schooling status. For those no longer studying in late-adolescence, girls tended to be married, with a minority working, whereas boys out of school were almost all working. Conversely, some of the girls who were still in school were already married. Only one boy in the entire sample, who had dropped out of school, was married.

These findings support our fifth hypothesis: life trajectories following school dropout differed by sex, but in addition, some of the girls who were still studying had also married early.

6. Discussion

Supporting our conceptual approach, both maternal biological and social traits and household socio-economic characteristics were independent predictors of dropout, while child's growth and educational trajectories were largely further independent predictors, mediating the association of only maternal education. Below, we briefly discuss our interpretation of these findings.

We found girls were more likely to have dropped out of secondary school than boys. The greater risk of dropout among girls may be closely associated with their greater likelihood of marriage. This 'trade-off' suggests that the value of girls' secondary education remains subordinated to leveraging a good marriage match. However, an unexpected finding was a few girls continued their education despite being married. Conversely, boys who had dropped out of school were mostly working. These different life trajectories may reflect the persistence of socio-cultural norms that favour differential household investment in the two sexes.

Maternal education was a better predictor than maternal marriage age of the child's dropout, however the two variables were correlated ($r = 0.31$, $p \leq 0.01$) and the former may incorporate some influence of the latter. We found that the quality of foetal nutrition, indicated by greater gestational age and thus longer exposure to placental nutrition, rather than birth weight, predicted dropout even after controlling for child growth. The underlying mechanism may comprise better brain growth *in utero*, as reported in other studies (MacKay et al., 2010). Importantly, we found head circumference growth after birth was protective against dropout, suggesting post-natal brain development also matters.

In relation to our proxies of household wealth, we found that SES was a better predictor of dropout than the area of land owned, though the variables were also correlated ($r = 0.49$, p $p \leq 0.001$). SES may be more important because of the financial investment required to educate children into late-adolescence.

Child growth and educational trajectories were largely independent predictors of dropout, though they mediated the effect of maternal education. However, maternal education is likely to have shaped children's participation in early learning and potentially also grade slippage, and hence dropout.

Beyond lower maternal education and low SES, which predicted dropout for both sexes, we also observed some sex differences in the relevant factors. For girls, early physical maturity in adolescence may have functioned as a social signal for the readiness for marriage and hence leaving school. In contrast, boys' secondary school dropout appeared to have a stronger 'developmental origin', with greater gestational age and better infant growth in head girth being protective against leaving school. Interestingly, faltering in school only affected boys' dropout whereas parental education was a better proxy for girls' dropout than their own education. Due to the smaller samples sizes, these sex differences are exploratory and require confirmation in future studies.

6.1. Strengths and limitations

Our results have the typical caveats of any observational analyses: we show correlations rather than causality (Behrman, 1996). We cannot compare the effect sizes of the different predictors because they are in different units. However, we can test for independent associations of each variable, holding constant for other predictors. Our results for sex-stratified models may be less robust because of smaller sample sizes. Nevertheless, they were large enough to detect significance in predictive factors. We could not assess how school-level factors (e.g. teaching and learning practices) may have contributed to dropout because these variables were difficult to collect given the wide geographic spread of our cohort and schools. However, we were able to draw on children's school progression and performance data, which provided proxies for overall learning achievement. Although we did not directly measure cognitive development, which may partly explain poor progression in school, our two markers of fetal development provide indirect proxies of this variable.

7. Conclusion

Despite substantial efforts to promote secondary education in India, especially for girls, our findings suggest that Spring (1976) insight from four decades ago remains valid: adolescence is arguably when education functions most strongly as a 'sorting machine' for people in rapidly developing countries. Secondary educational attainment is particularly relevant to shaping sex differences in life trajectories thereafter.

Our study is unique in the educational field in testing whether factors acting in the period prior to school-entry and even before birth predicted secondary school dropout. We developed a biosocial life-course model to investigate whether markers of maternal biological and social capital were associated with dropout independent of household characteristics. We also tested whether child growth and educational trajectories mediated these associations. We explored whether different factors predicted dropout of the sexes.

Previous studies have found associations between poor quality teaching and learning, household poverty and preferences, and poor infant growth on the one hand, and school dropout on the other hand. Our study contributes new evidence on the gradual process leading to secondary school dropout, related to both maternal biological and socio-economic factors. The pathways shaping the educational attainment of girls and boys also differed. However, both sexes were disadvantaged at different points in their schooling careers. The broader consequence of this variability in educational attainment is how it 'sorts' individuals along gendered life trajectories. Secondary education is a key turning point in the lives of adolescents, and more research is required on why the increased schooling of girls has not as yet changed gendered norms around expected social roles. Our results suggest that greater efforts, throughout the life-course, are required, including improving maternal nutritional status at preconception, supporting growth from infancy through to adolescence, reducing the cost of secondary school, and expanding access to tertiary and employment opportunities for especially girls in rural areas.

Conflict of interest

None

Role of funding sources

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Appendix A

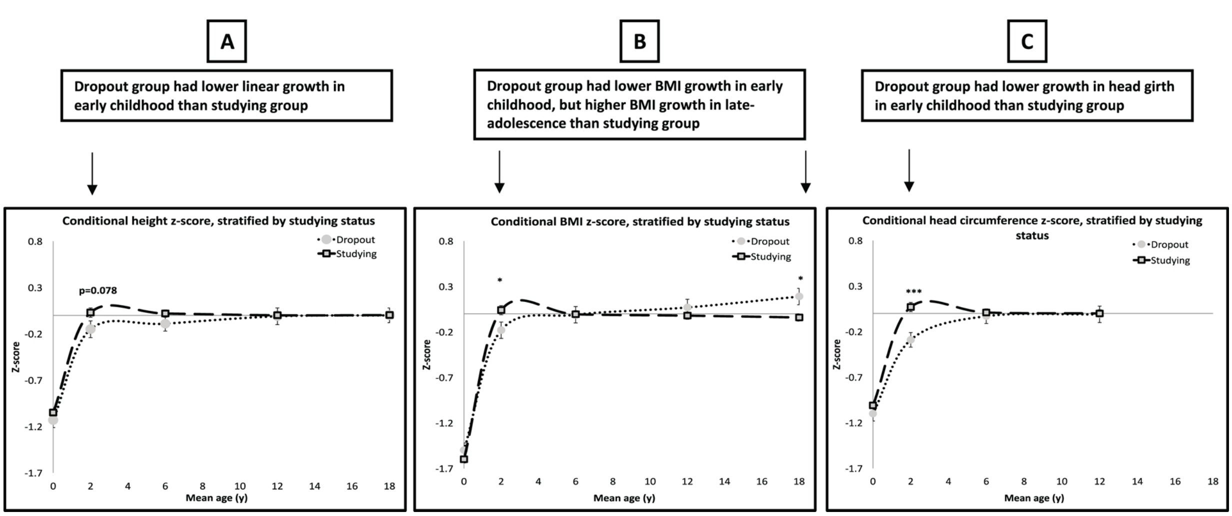

Fig. A1. Univariate analysis: Children's growth trajectories. stratified by dropout vs. studying groups.

Table A1
Baseline characteristics, stratified by 42 adolescents lost to follow-up vs. 648 followed-up at age 18 years.

	Lost to follow-up (N = 42)		Followed-up (N = 648)		Difference[1]	
	Mean	SD	Mean	SD	Δ	s.e.
Maternal age (y)	20.71	2.67	21.39	3.55	−0.68	0.56
Maternal marriage age (y)[3]	17.22	2.85	17.67	2.52	−0.45	0.41
Maternal parity (births)	1.12	1.11	1.20	1.17	−0.08	0.18
Maternal height (cm)	152.09	4.81	151.97	4.93	0.12	0.78
Maternal BMI (kg/m^2)[4]	18.73	1.10	17.81	1.10	1.05	**1.02****
Gestational age	38.92	1.91	39.01	1.71	−0.09	0.27
Child birth-weight z-score[5]	−1.65	0.96	−1.56	0.86	−0.09	0.16
	F	**%**	**F**	**%**		**Significance**[2]
Maternal education[6]						**≤0.05**
None to primary (0-5y)	24	57.1	254	40.6		
Upper primary + (≥6y)	18	42.9	372	59.4		
Religion (N = 659)						ns
Hindu	40	95.2	628	96.9		
Muslim	2	4.8	15	2.3		
Christian	0	0	1	0.2		
Buddha	0	0	4	0.6		
Caste (N = 656)						**≤0.05**
Lower (Tribal, scheduled)	9	21.4	54	8.4		
Mid (Artisan, agricultural)	7	16.7	149	23.1		
High (Prestige, dominant)	26	61.9	441	68.5		
Family type (N = 656)						ns
Nuclear	7	16.7	125	19.4		
Joint	35	83.3	519	80.6		
Family size (N = 656)						0.073
≤4 adults	22	52.4	425	66.0		
≥5 adults	20	47.6	219	34.0		
Socio-economic status[7]						ns
Low	16	38.1	197	30.4		
Mid	12	28.6	225	34.8		
High	14	33.3	225	34.8		
Agricultural land size[8]						ns
Low (≤2.99 acres)	16	42.1	224	36.0		
Medium (3 to 5.99 acres)	8	21.1	191	30.7		
High (≥6 acres)	14	36.8	207	33.3		
Paternal education[9]						**≤0.05**
None to primary (0-5y)	17	40.5	157	25.1		
Upper primary + (≥6y)	25	59.5	469	74.9		
Sex of cohort child						0.062
Girl	26	61.9	305	47.1		
Boy	16	38.1	343	52.9		

Abbreviations: SD, standard deviation. s.e. standard error. F, frequency. ns = not significant.

** p ≤ 0.01.

[1] Independent samples *t*-test Δ, difference between lost to follow-up and followed-up groups.

[2] Chi-square test differences in not followed vs. followed-up groups.

[3] N = 659; excludes seven mothers with marriage age of < 10 years of age.

[4] N = 684. BMI was natural log-transformed but reported as the untransformed value in the Table.

[5] N = 649, adjusts for gestational age.

[6] N = 659.

[7] N = 689.

[8] N = 629.

Table A2
Correlations between maternal and household characteristics.

	Marriage Age (y)[1]	Parity (no. of births)	Maternal height (cm)	Maternal BMI (kg/m²)[2]	Maternal schooling (y)	Household SES (composite score)	Agricultural land (acres)[2]	Paternal schooling (y)	Gestational age (weeks)	Birthweight adjusted for gestational age (z-score)
Maternal age (y)	**0.34****	**0.65****	−0.06	0.02	**−0.11****	−0.05	0.03	**−0.11****	−0.008	**0.16****
Marriage age (y)[1]		−0.08	0.06	0.06	**0.30****	0.07	0.01	**0.19****	0.02	0.06
Parity (no. of births)			**−0.10****	−0.02	**−0.31****	−0.16	0.08	**−0.23****	−0.06	**0.20****
Maternal height (cm)				−0.04	0.07	**0.09***	**0.14****	**0.10***	0.08	**0.08****
Maternal BMI (kg/m²)[2]					0.07	−0.01	−0.04	0.03	**0.08***	**0.11****
Maternal schooling (y)						−0.04	0.05	**0.56****	**0.12****	0.01
Household SES (score)							**−0.49****	**0.13****	0.04	0.01
Agricultural land[2]								0.10	0.05	0.04
Paternal schooling (y)									**0.13****	**0.01**
Gestational age										**0.39****

[1] Excludes seven mothers with marriage age < 10 years.
[2] Agricultural land size and BMI were natural log-transformed. Pearson correlation.
* $p \leq 0.05$.
** $p \leq 0.01$.

Table A3
Univariate analysis: Maternal phenotype and household characteristics, stratified by dropout vs. studying groups.

	Dropout (N = 130)		Studying (N = 518)		Difference[1]	
Maternal traits	Mean	SD	Mean	SD	Δ	s.e.
Maternal age (y)	21.29	3.57	21.42	3.54	−0.13	0.35
Maternal height (cm)	151.68	4.84	152.04	4.96	−0.36	0.48
BMI (kg/m²)[3]	17.99	1.12	17.81	1.10	1.01	1.01
Gestational age (weeks)	38.58	2.03	39.12	1.60	0.54	**0.17*****
Birth-weight z-score[4]	−1.54	0.85	−1.56	0.86	−0.02	0.09
	F	**%**	**F**	**%**		**Significance**[2]
Maternal traits						**≤0.001**
Education (N = 626)						
None to Primary	72	58.1	182	36.3		
Primary + (> 6y)	52	41.9	320	63.7		
Marriage age[5]						**≤0.05**
Before legal age of 18y	70	56.5	222	44.9		
After 18y	54	43.5	272	55.1		
Maternal parity						ns
0 births	38	29.2	167	32.2		
≥1 birth	92	70.8	351	67.8		
Household traits						ns
Family type (N = 644)						
Nuclear	28	21.5	97	18.9		
Joint	102	78.5	417	81.1		
Family size (N = 644)						**≤0.05**
≤5 adults	97	74.6	328	63.8		
> 6 adults	33	25.4	186	36.2		
Socio-economic status[6]						**≤0.01**
Low (≤ 24)	49	37.7	148	28.6		
Mid (25-29)	51	39.2	174	33.7		
High (≥30)	30	23.1	195	37.7		
Agricultural land (N = 622)						**≤0.05**
Low (≤2.99 acres)	55	44.4	169	33.9		
Mid (3.0 to 5.99 acres)	38	30.6	153	30.7		
High (≥6 acres)	31	25.0	176	35.3		
Paternal education (N = 626)						**≤0.001**
None to primary	52	41.9	105	20.9		
Primary + (> 6y)	72	58.1	397	79.1		

Abbreviations: SD, standard deviation. s.e. standard error. F, frequency. ns, non-significant.
[1] Independent samples *t*-test. Δ, difference between dropout and studying groups.
[2] Chi-square test for differences by studying groups.
[3] N = 643, BMI was natural log transformed but reported as the unlogged value in Table.
[4] N = 609, adjusts for gestational age.
[5] N = 618, excludes seven mothers with marriage age of < 10 years of age.
[6] N = 647, composite score.

Table A4
Univariate analysis: Children's educational trajectories, stratified by dropout vs. studying groups.

	Dropout (N = 130)		Studying (N = 518)		Significance[1]
	F	**%**	**F**	**%**	
Participation					
Did you attend nursery?					**≤ 0.001**
Yes	101	77.7	463	89.4	
No	29	22.3	55	10.6	
Age-specific participation					
Age at entry, 1st standard (N = 639)					0.084
≤ expected for age (≤ 6y)	111	88.1	476	92.8	
> expected/higher (≥ 7y)	15	11.9	37	7.2	
Standard/age early-adolescence[2]					**≤ 0.001**
≤ expected age	61	46.9	144	27.8	
≥ expected age	69	53.1	374	72.2	
Progression					
Did you fail a standard?					**≤ 0.001**
Yes	58	44.6	51	9.8	
No	72	55.4	467	90.2	
Level failed (N = 110)					ns
Primary (1-8 y)	29	49.2	32	62.7	
Secondary or higher (≥ 9 y)	30	50.8	19	37.3	
10th standard exam taken					**≤ 0.001**
Yes	79	60.8	510	98.5	
No	51	39.2	8	1.5	
Literacy					
Result 10th standard exam(N = 589)					**≤ 0.001**
Pass	61	77.2	506	99.2	
Fail	18	22.8	4	0.8	
Functionally literate?[3] (N = 644)					**≤ 0.001**
Yes	122	94.6	515	100	
No	7	5.4	0	0	

Abbreviations: F, frequency. ns, non-significant.

[1] Chi-square test for differences by dropout and studying groups.

[2] Standard adjusted for 5-year range of follow-up in mid-childhood: 9 years of age = 4th standard; 10y = 5th standard; 11y = 6th standard; 12y = 7th standard; 13y = 8th standard.

[3] Interviewer ticked 'yes' or 'no' if they observed participant was not able to properly read 10 choices provided for why education was important to them, and write the most important reason.

References

Adair, L., Fall, C., Osmond, C., Stein, A., Martorell, R., Ramirez-Zea, M., Sachdev, H., et al., 2013. Associations of linear growth and relative weight gain during early life with adult health and human capital in countries of low and middle income: findings from five birth cohort studies. Lancet 382 (9891), 525–539. https://doi.org/10.1016/S0140-6736(13)60103-8.

Agrawal, T., 2014. Educational inequality in rural and urban India. Int. J. Educ. Dev. 34, 11–19. https://doi.org/10.1016/j.ijedudev.2013.05.002.

Alcott, B., Rose, P., 2015. Schools and Learning in Rural India and Pakistan: Who Goes Where, and How Much Are They Learning? Prospects 45 (3), 345–363. https://doi.org/10.1007/s11125-015-9350-5.

Alderman, Harold, Headey, Derek D., 2017. How important is parental education for child nutrition? World Dev. 94 (June), 448–464. https://doi.org/10.1016/j.worlddev.2017.02.007.

Azam, M., Kingdon, G., 2013. Are girls the fairer sex in India? Revisiting intra-household allocation of education expenditure. World Dev. 42, 143–164. https://doi.org/10.1016/j.worlddev.2012.09.003.

Barker, D.J.P., 2007. The origins of the developmental origins theory. J. Intern. Med. 261 (5), 412–417. https://doi.org/10.1111/j.1365-2796.2007.01809.x.

Barker, Mary, Dombrowski, Stephan U., Colbourn, Tim, Fall, Caroline H.D., Kriznik, Natasha M., Lawrence, Wendy T., Norris, Shane A., et al., 2018. Intervention strategies to improve nutrition and health behaviours before conception. Lancet 391 (10132), 1853–1864. https://doi.org/10.1016/S0140-6736(18)30313-1.

Behrman, Jere R., 1996. The impact of health and nutrition on education. World Bank Res. Obs. 11 (1), 23–37. https://doi.org/10.1093/wbro/11.1.23.

Bhaumik, S., Chakrabarty, M., 2013. Educational Attainment in India: What Drives Transition? ICRA Bulletin: Money & Finance.

Chan, Ben Chong-Pun, Lao, Terence Tzu-Hsi, 2009. Maternal Height and Length of Gestation: Does This Impact on Preterm Labour in Asian Women? Aust. N. Z. J. Obstet. Gynaecol. 49 (4), 388–392. https://doi.org/10.1111/j.1479-828X.2009.01006.x.

Chávez, A., Martínez, C., Soberanes, B., 2000. The effect of malnutrition on human development: a 24-year study of well-nourished and malnourished children living in a poor Mexican Village. In: Dufour, D., Goodman, A., Pelto, G. (Eds.), Nutritional Anthropology: Biocultural Perspectives on Food and Nutrition. Mayfield Publishing, Mountain View:USA, pp. 234–251.

Colclough, Christopher, Kingdon, Geeta, Patrinos, Harry, 2010. The changing pattern of wage returns to education and its implications. Dev. Policy Rev. 28 (6), 733–747. https://doi.org/10.1111/j.1467-7679.2010.00507.x.

Cole, T., Green, P., 1992. Smoothing reference centile curves: the LMS method and penalized likelihood. Stat. Med. 11 (10), 1305–1319. https://doi.org/10.1002/sim.4780111005.

Cole, T., Wright, C., Williams, A., 2012. Designing the new UK-WHO growth charts to enhance assessment of growth around birth. Arch. Dis. Child. Fetal Neonatal Ed. 97 (3), F219–22. https://doi.org/10.1136/adc.2010.205864.

Dercon, Stefan, Sánchez, Alan, 2013. Height in mid childhood and psychosocial competencies in late childhood: evidence from four developing countries. Econ. Hum. Biol. 11 (4), 426–432. https://doi.org/10.1016/j.ehb.2013.04.001.

Directorate of Economics and Statistics, 2015. Economic Survey of Maharashtra 2014-5, 54th Issue. Government of Maharashtra, Mumbai: India.

Drèze, Jean, Kingdon, Geeta Gandhi, 2001. School participation in rural India. Rev. Dev. Econ. 5 (1), 1–24. https://doi.org/10.1111/1467-9361.00103.

Elder, G., Kirkpatrick Johnson, M., Crasnoe, R., 2003. The emergence and development of life course theory. In: Mortimer, J., Shanahan, M. (Eds.), Handbook of the Life Course. Plenum, New York: USA, pp. 3–19.

Fink, G.ünther, Rockers, Peter C., 2014. Childhood Growth, Schooling, and Cognitive Development: Further Evidence from the Young Lives Study. Am. J. Clin. Nutr. 100 (1), 182–188. https://doi.org/10.3945/ajcn.113.080960.

Gakidou, E., Cowling, K., Lozano, R., Murray, C., 2010. Increased educational attainment and its effect on child mortality in 175 countries between 1970 and 2009: a systematic analysis. Lancet 376 (9745), 959–974. https://doi.org/10.1016/S0140-6736(10)61257-3.

Government of India, 2012. Census of India 2011. Government of India, New Delhi: India.

Government of India, 2015. Millennium Development Goals India Country Report 2015.

Ministry of Statistics and Programme Implementation, Delhi: India.
Government of Maharashtra, 2014. Maharashtra Human Development Report, 2012. Towards Inclusive Human Development. Sage Publications, New Delhi: India.
Hannum, Emily, Hu, Li-Chung, 2017. Chronic undernutrition, short-term hunger, and student functioning in Rural Northwest China. Int. J. Educ. Dev. 54 (May), 26–38. https://doi.org/10.1016/j.ijedudev.2016.12.002.
Härmä, J., 2011. Low Cost Private Schooling in India: Is It pro Poor and Equitable? Int. J. Educ. Dev. Access Equity Trans. Educ. Low Income Countries 31 (4), 350–356. https://doi.org/10.1016/j.ijedudev.2011.01.003.
Hill, K., Kaplan, H., 1999. Life history traits in humans: theory and empirical studies. Annu. Rev. Anthropol. 28 (January), 397–430. https://doi.org/10.1146/annurev.anthro.28.1.397.
Hoddinott, J., Maluccio, J., Behrman, J., Martorell, R., Melgar, P., Quisumbing, A., Ramirez-Zea, M., Stein, A., Yount, K., 2011. The Consequences of Early Childhood Growth Failure Over the Life Course. Discussion Paper 01073. USA: IFPRI, Washington DC.
IIPS, 2010. District Level Household and Facility Survey DLHS-3, 2007-2008. International Institute for Population Studies, Maharashtra." Mumbai: India.
IIPS, 2016. National Family Health Survey - 4: 2015-16." State Fact Sheet. Ministry of Health and Family Welfare, Government of India, New Delhi:India.
IIPS, and ICF, 2018. National Family Health Survey (NFHS-4) 2015-16. IIPS, Maharashtra." Mumbai.
Jeffrey, P., Jeffery, R., 1994. Killing My Heart's Desire: education and female autonomy in rural North India. In: Kumar, N. (Ed.), Women As Subjects: South Asian Histories. University of Virginia Press, Charlottesville: USA, pp. 125–171.
Joglekar, C., Fall, C., Deshpande, V., Joshi, N., Bhalerao, A., Solat, V., Deokar, T., et al., 2007. Newborn size, infant and childhood growth, and body composition and cardiovascular disease risk factors at the age of 6 years: the pune maternal nutrition study. Int. J. Obes. 31 (10), 1534–1544. https://doi.org/10.1038/sj.ijo.0803679. (2005).
Kamanda, Mamusu, Sankoh, Osman, 2015. A systematic review of the status of children's school access in low- and middle-income countries between 1998 and 2013: using the INDEPTH network platform to fill the research gaps. Glob. Health Action 8 (1), 28430. https://doi.org/10.3402/gha.v8.28430.
Kaplan, H., Lancaster, J., Johnson, S., Bock, J., 1995. Does Observed Fertility Maximize Fitness among New Mexican Men? Hum. Nat. 6 (4), 325–360. https://doi.org/10.1007/BF02734205.
Kerckhoff, A., 2001. Education and social stratification processes in comparative perspective. Sociol. Educ. 74, 3–18. https://doi.org/10.2307/2673250.
Kirkwood, B., Sterne, J., 2003. Essential Medical Statistics, 2nd ed. Blackwell Pub., Oxford: UK.
Lewin, K., 2011. Expanding access to secondary education: can India catch up? Int. J. Educ. Dev. Access Equity Trans. Educ. Low Income Countries 31 (4), 382–393. https://doi.org/10.1016/j.ijedudev.2011.01.007.
Lucas, A., 1991. Programming by early nutrition in man. In: CIBA Foundation Symposium (Ed.), The Childhood Environment and Adult Disease. John Wiley & Sons, London: UK, pp. 38–55.
MacKay, D., Smith, G., Dobbie, R., Pell, J., 2010. Gestational age at delivery and special educational need: retrospective cohort study of 407,503 schoolchildren. PLoS Med. 7 (6), e1000289. https://doi.org/10.1371/journal.pmed.1000289.
Maertens, A., 2013. Social norms and aspirations: age of marriage and education in rural India. World Dev. 47, 1–15. https://doi.org/10.1016/j.worlddev.2013.01.027.
Maluccio, J., Hoddinott, J., Behrman, J., Martorell, R., Quisumbing, A., Stein, A., 2009. The impact of improving nutrition during early childhood on education among guatemalan adults. Econ. J. 119 (537), 734–763. https://doi.org/10.1111/j.1468-0297.2009.02220.x.
Marphatia, A., Devakumar, D., Wells, J., Saville, N., Reid, Alice, Costello, A., Manandhar, D., Osrin, D., 2016. Maternal phenotype, independent of family economic capital, predicts educational attainment in lowland Nepalese children. Am. J. Hum. Biol. 28 (5), 687–698. https://doi.org/10.1002/ajhb.22852.
Marphatia, A., Amable, G., Reid, A., 2017. Women's marriage age matters for public health: a review of the broader health and social implications in South Asia. Front. Public Health 5 (269), 1–23. https://doi.org/10.3389/fpubh.2017.00269.
Martorell, R., Horta, B., Adair, L., Stein, A., Richter, L., Fall, C., Bhargava, S., et al., 2010. Weight gain in the first two years of life is an important predictor of schooling outcomes in pooled analyses from five birth cohorts from low- and middle-income countries. J. Nutr. 140 (2), 348–354. https://doi.org/10.3945/jn.109.112300.
Mayer, K., 2009. New directions in life course research. Annu. Rev. Sociol. 35, 413–433. https://doi.org/10.1146/annurev.soc.34.040507.134619.
Ministry of Women and Child Development, and UNICEF, 2007. Handbook on the Prohibition of Child Marriage Act, 2006. Government of India, New Delhi: India.
Moock, Peter R., Leslie, Joanne, 1986. Childhood malnutrition and schooling in the Terai Region of Nepal. J. Dev. Econ. 20 (1), 33–52. https://doi.org/10.1016/0304-3878(86)90004-0.
Munoz Boudet, A., Petesch, P., Turk, C., Thumala, A., 2012. On Norms and Agency: Conversations About Gender Equality With Women and Men in 20 Countries. USA: World Bank, Washington DC.
Özaltin, E., Hill, K., Subramanian, S., 2010. Association of Maternal Stature With Offspring Mortality, Underweight, and Stunting in Low- to Middle-Income Countries. JAMA J. Am. Med. Assoc. 303 (15), 1507–1516. https://doi.org/10.1001/jama.2010.450.
Raj, Anita, McDougal, Lotus, Silverman, Jay G., Rusch, Melanie L.A., 2014. Cross-Sectional Time Series Analysis of Associations between Education and Girl Child Marriage in Bangladesh, India, Nepal and Pakistan, 1991-2011. PLoS One 9 (9), e106210. https://doi.org/10.1371/journal.pone.0106210.
Rao, N., 2010. Aspiring for distinction: gendered educational choices in an indian village. Comp. A J. Comp. Educ. 40 (2), 167–183. https://doi.org/10.1080/03057920903546021.
Rao, S., Yajnik, C., Kanade, A., Fall, C., Margetts, B., Jackson, A., Shier, R., et al., 2001. Intake of micronutrient-rich foods in rural indian mothers is associated with the size of their babies at birth: pune maternal nutrition study. J. Nutr. 131 (4), 1217–1224. https://doi.org/10.1093/jn/131.4.1217.
Ron-Balsera, M., Marphatia, A., 2012. Do public private partnerships fulfil the right to education? An examination of the role of non state actors in advancing equity, equality and justice. In: Robertson, S., Mundy, K., Verger, A. (Eds.), Public Private Partnerships in Education: New Actors and Modes of Governance in a Globalizing World. Edward Elgar Publishing Ltd.
Sabates, Ricardo, Hossain, Altaf, Lewin, Keith M., 2013. School drop out in Bangladesh: insights using panel data. Int. J. Educ. Dev. Educ. Poorest 33 (3), 225–232. https://doi.org/10.1016/j.ijedudev.2012.09.007.
Singh, Renu, Mukherjee, Protap, 2017. Whatever She May Study, She Can't Escape from Washing Dishes': Gender Inequity in Secondary Education – Evidence from a Longitudinal Study in India. Compare: A J. Comparat. Int. Educ. 1–19. https://doi.org/10.1080/03057925.2017.1306434.
Smith, L., Ramakrishnan, U., Ndiaye, A., Haddad, L., Martorell, R., 2003. The Importance of Women's Status for Child Nutrition in Developing Countries. Research Report 131. USA: IFPRI, Washington DC.
Spring, J., 1976. The Sorting Machine. USA: David MacKay, New York.
Stein, Aryeh D., Barros, Fernando C., Bhargava, Santosh K., Hao, Wei, Horta, Bernardo L., Lee, Nanette, Kuzawa, Christopher W., et al., 2013. Birth status, child growth, and adult outcomes in low- and middle-income countries. J. Pediatr. 163 (6), 1740–1746. https://doi.org/10.1016/j.jpeds.2013.08.012. e4.
Stephenson, Judith, Heslehurst, Nicola, Hall, Jennifer, Schoenaker, Danielle A.J.M., Hutchinson, Jayne, Cade, Janet E., Poston, Lucilla, et al., 2018. Before the beginning: nutrition and lifestyle in the preconception period and its importance for future health. Lancet 391 (10132), 1830–1841. https://doi.org/10.1016/S0140-6736(18)30311-8.
Subramanian, S., Ackerson, L., Davey Smith, G., Na, J., 2009. Association of maternal height with child mortality, anthropometric failure, and anemia in India. JAMA 301 (16), 1691–1701. https://doi.org/10.1001/jama.2009.548.
UIS, 2016. UIS Tellmaps." UNESCO EAtlast of Out-of-School Children – How Many Adolescents Are Excluded from School? 2016. http://tellmaps.com/uis/oosc/#!/tellmap/-1522571971.
UIS, and UNESCO GMR, 2016. Leaving No One behind: How Far on the Way to Universal Primary and Secondary Education? UNESCO GMR.
UNESCO, 2017. Global Education Monitoring Report 2017/18. Accountability in Education. Meeting Our Commitments. UNESCO, Paris: France.
Victora, C., de Onis, M., Hallal, P., Blössner, M., Shrimpton, R., 2010. Worldwide timing of growth faltering: revisiting implications for interventions. Pediatrics 125 (3), e473–80. https://doi.org/10.1542/peds.2009-1519.
Wells, J., 2010. Maternal capital and the metabolic ghetto: an evolutionary perspective on the transgenerational basis of health inequalities. Am. J. Hum. Biol. 22 (1), 1–17. https://doi.org/10.1002/ajhb.20994.
WHO Expert Consultation, 2004. Appropriate body-mass index for asian populations and its implications for policy and intervention strategies. Lancet 363 (9403), 157–163. https://doi.org/10.1016/S0140-6736(03)15268-3.
Yajnik, C., Deshpande, S., Jackson, A., Refsum, H., Rao, S., Fisher, D., Bhat, S., et al., 2007. Vitamin B12 and Folate Concentrations during Pregnancy and Insulin Resistance in the Offspring: The Pune Maternal Nutrition Study. Diabetologia 51 (1), 29–38. https://doi.org/10.1007/s00125-007-0793-y.