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# Biosocial life-course factors associated with women's early marriage in rural India: The prospective longitudinal Pune Maternal Nutrition Study

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## Abstract

**Objectives:** By convention, women's early marriage is considered a sociocultural decision sensitive to factors acting during adolescence such as poverty, early menarche, and less education. Few studies have examined broader risk factors in the natal household prior to marriage. We investigated whether biosocial markers of parental investment through the daughters' life-course were associated with early marriage risk in rural India. We used an evolutionary perspective to interpret our findings.

**Materials and Methods:** A prospective cohort recruited mothers at preconception. Children were followed from birth to age 21 years. Multivariable logistic regression models estimated odds ratios of marrying early (<19 years) associated first with wealth, age at menarche and education, and then with broader markers of maternal phenotype, natal household characteristics, and girls' growth trajectories. Models adjusted for confounders.

**Results:** Of 305 girls, 71 (23%) had married early. Early married girls showed different patterns of growth compared to unmarried girls. Neither poverty nor early menarche predicted early marriage. Girls' non-completion of lower secondary school predicted early marriage, explaining 19% of the variance. Independent of girls' lower schooling, nuclear household, low paternal education, shorter gestation, and girls' poor infant weight gain were associated with marrying early, explaining in combination 35% of the variance.

**Discussion:** Early marriage reflects "future discounting," where reduced parental investment in daughters' somatic and educational capital from early in her life favors an earlier transition to the life-course stage when reproduction can occur. Interventions initiated in adolescence may occur too late in the life-course to effectively delay women's marriage.

KEYWORDS
biosocial life-course risk factors, life-history theory, rural India, women's early marriage, women's education and growth trajectories

## 1 | INTRODUCTION

Early marriage fundamentally links together inequity and disadvantage with many aspects of adolescent, maternal, and child health, as well as having implications for women's autonomy and education (Godha et al., 2013; Goli et al., 2015; Raj et al., 2014). For example, early reproduction is associated with maternal mortality, under-nutrition, and morbidity (Fall et al., 2015; Nguyen et al., 2019). Collectively, these factors also adversely affect the survival, health, and well-being of the next generation, perpetuating cycles of disadvantage (Chari et al., 2017; Finlay et al., 2011). However, in societies where girls generally marry before having children, efforts to delay early childbearing need first to delay the age at which they marry (Marphatia et al., 2017).

Delaying women's early marriage (defined as <18 years by the United Nations) is thus a global priority, as recognized in the Sustainable Development Goals (UN General Assembly, 2015; UN General Assembly, 2018). Nevertheless, the practice remains common in low- and middle-income countries: among women aged 20–24 years, 20% had married or entered a formal union before 18 years (UNICEF, 2021). In India, where our study is based, despite reductions in early marriage in the past decade (Beattie et al., 2019; IIPS, ICF, 2017; MacQuarrie & Juan, 2019), 41% of women aged 20–24 years were still married by 18 years in 2016, with higher rates in rural than urban populations (43% vs. 32%) and among poorer more than wealthier households (55% vs. 23%) (Scott et al., 2021).

Although the UN defines marriage <18 years as "child" marriage, it is important to distinguish between marriage taking place during "childhood" (<14 years of age), "early adolescence" (14–15 years), and "late adolescence" (16–18 years) because the drivers and consequences of marrying at these different age groups are likely to be different (Marphatia et al., 2017; Raj et al., 2014). Moreover, there has recently been an increase in the proportion of girls marrying just *after* 18 years, potentially in response to minimum marriage age legislation and a growing campaign to delay marriage (Center for Reproductive Rights, Centre for Law and Policy Research, 2018; Girls not brides, n.d.). In India, the proportion of women aged 20–24 years marrying between 17 and 18 years in 2000 and 2016 changed minimally (29% vs. 30%), but the proportion marrying between 19 and 20 years increased, from 19% to 28% (Scott et al., 2021).

To date, most research on early marriage has comprised ecological analyses of educational and socioeconomic risk factors that act during adolescence (Bajracharya & Amin, 2012; Beattie et al., 2019; Delprato et al., 2015; MacQuarrie, 2016; MacQuarrie & Juan, 2019; Raj et al., 2014; Scott et al., 2021; Singh & Samara, 1996), reflecting a widespread assumption that the decision to marry daughters is primarily shaped by current household economic circumstances and cultural norms. Globally, promoting secondary education of girls is the key effort to delay marriage, but has had lower than expected impact on delaying marriage (Field & Ambrus, 2008; Raj et al., 2014). One explanation for the limited success of girls' education may be inadequate understanding of the relationship between school dropout and underage marriage, since most studies do not determine which of these events occurred first (Delprato et al., 2015; Wodon et al., 2017). Moreover, whilst natal household poverty is widely suggested to be a key factor associated with early marriage, robust evidence on this assumption is lacking, as most studies use marital household wealth as a proxy for the natal home's socioeconomic status, and often measure it many years after marriage and only on one occasion (Beattie et al., 2019; Delprato et al., 2015; Raj et al., 2014; Scott et al., 2021; Wodon et al., 2017), though see Bajracharya and Amin (2012), Muchomba (2021), and Singh and Espinoza (2016). These limitations in data indicate that the true relationship between education, wealth, and the timing of women's marriage remains poorly understood.

There is increasing evidence that biological factors acting in early life are associated with a range of adult and child health outcomes (Adair et al., 2013; Barker, 1990; Yajnik et al., 2007). This "developmental origins" framework has recently been extended to educational attainment, with studies finding associations between lower maternal nutritional status and poor infant growth with early school dropout (Marphatia et al., 2019; Marphatia, Devakumar, et al., 2016; Martorell et al., 2010). Other than investigating possible links between early menarche and earlier marriage (Aryal, 2007; Field & Ambrus, 2008; Ibitoye et al., 2017; Raj et al., 2015; Sekhri & Debnath, 2014; Singh & Espinoza, 2016; Wells et al., 2019), however, no study has investigated whether biological factors acting in *early life* are also associated with women's early marriage. This is an important omission, and addressing this issue may shed light on how households seek to maximize the comparative advantage of their daughters in the marriage market (Jackson, 2012).

In South Asian countries, marriage typically represents a transaction between the natal and marital households, and the age of the girls at marriage is a product of these negotiations (Jeffrey & Jeffery, 1994; Verma et al., 2013). Dowry (paid by the bride's family to the groom's family upon marriage), albeit illegal in India (Gazette of India, 1986), may drive early marriage because it tends to increase with girls' age and education level (Field & Ambrus, 2008; Jeffrey & Jeffery, 1994). However, natal households may also choose to pay the higher dowry, because greater education can be leveraged to marry daughters to wealthier and more educated grooms (Chiplunkar & Weaver, 2021; Jackson, 2012; Marphatia, Saville, Manandhar, Amable, et al., 2021). Sibling sex composition may also interact with these factors, with older sisters generally delaying the marriage of younger sisters because households have to amass resources for the next dowry; however, the evidence on whether younger sisters accelerate earlier marriages for older sisters is mixed (Pesando & Abufhele, 2019; Vogl, 2013). On the other hand, girls with older brothers are likely to marry early because parents can draw on the dowry received from the son's wife for their own daughter's marriage (Singh & Espinoza, 2016; Vogl, 2013).

In previous work on a population in lowland rural Nepal, we showed that early marriage, independent of early reproduction, was associated with shorter final height in women, and that this was not due to a selection effect (i.e., that shorter women were more likely to be married young) (Marphatia, Saville, Manandhar, Cortina-Borja, et al., 2021). However, those analyses were based on cross-sectional data, and we were unable to examine growth trajectory directly. Here, we take the opposite perspective, and consider whether biosocial factors acting in early life, including growth trajectory, predict the likelihood of women being married early.

To our knowledge, ours is the first study to conduct a comprehensive investigation of a broader range of biosocial factors, acting from early life onwards, that may contribute to early marriage, and we use evolutionary life history theory to help interpret the findings (Wells et al., 2017). While marriage is a conscious decision, in South Asian societies it has major implications for reproductive fitness and hence may benefit from being approached through an evolutionary lens. Our longitudinal cohort is unique worldwide in having collected prospective data on two generations from maternal prepregnancy onwards, including the offspring's growth and educational trajectories from birth to adolescence, age at menarche, and several markers of socioeconomic characteristics measured in the natal household, prior to marriage. This approach contrasts strongly with the retrospective analysis that dominates literature in this area, focusing on factors (mostly socioeconomic) associated with women's marriage measured only after they have married.

## 1.1 | Hypotheses and conceptual framework

Our overarching hypothesis is that early women's marriage represents the consequence of an intergenerational process, integrating multiple biological, and social penalties accumulated by women and girls. Our prospective longitudinal dataset from rural India allows us to test the following hypotheses: that (1) natal household poverty, girls' early menarche, and their lower educational attainment are associated with marrying early; (2) independent of these factors, maternal phenotype, household socioeconomic characteristics, and girls' growth trajectories are associated with early marriage; and (3) girls drop out of school first, and then marry.

We developed a conceptual framework to look beyond the "conventional" risk factors of poverty, early menarche, and less education to investigate whether maternal ($F_0$) phenotype and natal household characteristics, and the daughter's ($F_1$) own developmental trajectories were associated with early marriage (Figure 1). Having measured markers of wealth in the natal household over time, we could also examine whether and at what point in the life-course poverty was associated with early marriage. Our data enable us to examine the timing of marriage and school dropout, in order to identify which of these events occurred first, and whether marriage necessarily involves leaving school and vice versa. This is important, because it may help clarify whether individual families are prioritizing the education of their daughters, or getting them married early. Our biosocial approach may shed new insights into the lower than expected efficacy of current policies and interventions aiming to delay girls' marriage age.

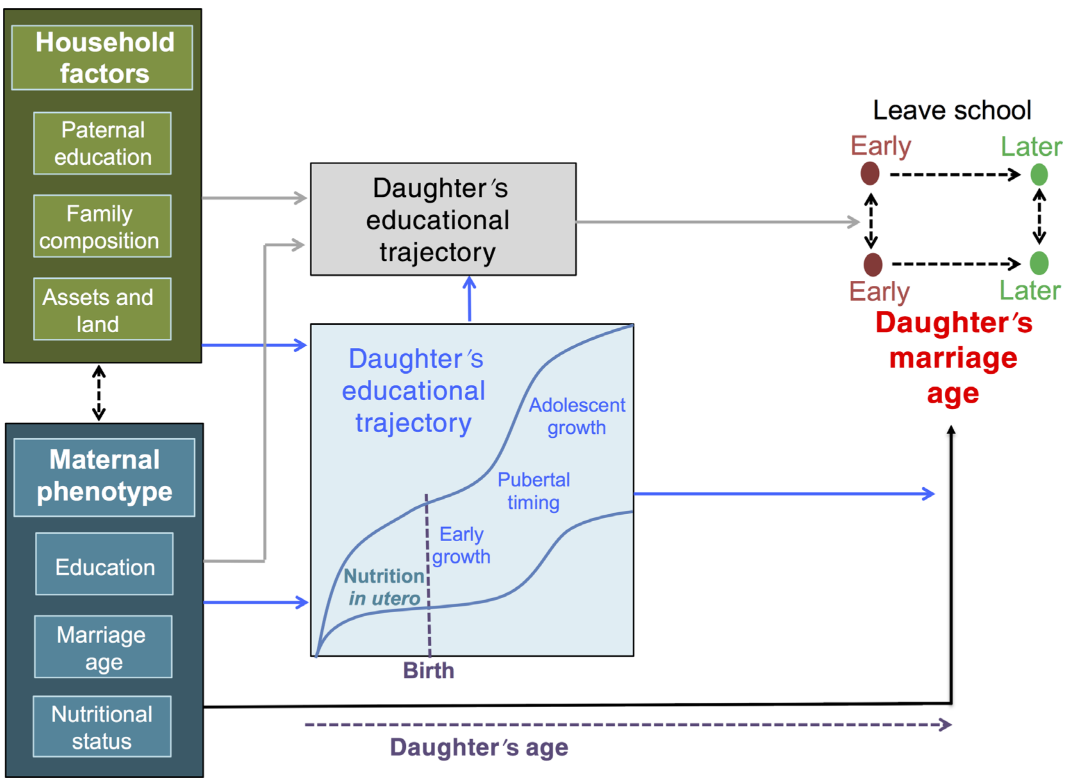


FIGURE 1 Conceptual framework: Biosocial pathways to early marriage. Household factors (green) and maternal phenotype (turquoise) directly shape each of the daughter's growth and maturation (blue), education (gray), and marriage age (red, primary outcome). The daughter's growth and development may also influence household decisions around education and marriage age. These biological and social pathways interact, from early life onwards, to shape the likelihood of early marriage

To interpret data collected within this "biosocial" framework, we draw on evolutionary life history theory. This theory assumes that all organisms are under selective pressure to allocate resources through the life-course to maximize reproductive fitness. In humans, both education and physical development represent processes in which individuals acquire cognitive and somatic capital, respectively, that may promote reproductive fitness (Kaplan et al., 2003). $F_0$ parental resources shape the ability of each $F_1$ individual to acquire their own capital. For example, $F_0$ maternal capital is defined as "any trait, whether somatic or behavioral, that enables differential investment in offspring" (Wells, 2010). Previous studies have associated markers of $F_0$ maternal capital with many aspects of $F_1$ offspring phenotype, including growth, nutritional status, maturation rate, and educational attainment—all traits that are relevant to girls' marriage age (Fall et al., 2015; Marphatia et al., 2019).

In harsh environments, where resource acquisition is compromised, organisms are predicted to discount the long-term future and direct resources to immediate survival and earlier reproduction (Kirkwood et al., 1991). Underlying biological mechanisms may have been shaped by natural selection in past environments to promote reproductive fitness in harsh conditions (Wells et al., 2019). From this perspective, both poor growth in early life and poor educational attainment are predicted to increase the likelihood of early reproduction, as recently reported in a Brazilian birth cohort (Wells et al., 2019). This may involve both social decisions, as well as physical patterns of development. However, these associations may be complex, as chronic under-nutrition may also slow the rate of physical maturation (Belachew et al., 2011). This means that earlier reproduction may be promoted by the family decision to marry the daughter early, without the daughter necessarily undergoing earlier puberty.

## 2 | MATERIALS AND METHODS

### 2.1 | Study setting and participants

Our analysis uses data from the Pune Maternal Nutrition Study (PMNS) in rural Maharashtra state, India, which has been described elsewhere (Joglekar et al., 2007; Rao et al., 2001; Yajnik et al., 2007). Briefly, in 1993, the PMNS identified all married, nonpregnant women of childbearing age across six villages. Between June 1994 and April 1996, 797 women became pregnant, and of the 762 $F_1$ children born to these $F_0$ women, 700 children were recruited into the study (Figure S1). The children were followed-up during childhood (ages 2 and 6), and adolescence (12 and 18 years). The 18-year follow-up focused on the assessment of both diabetes risk traits, and of marriage and education status. Data on $F_1$ marriage age ($n = 648$) were subsequently updated at age 21 years. As only one of 343 $F_1$ boys was married early (<19 years), our analysis focused on the 305 $F_1$ girls, who represent a 90.8% retention rate (305/336 recruited at birth). There were small but unimportant biases between the 31 $F_1$ girls lost to follow-up and 305 retained in the study (Table S1).

Ethical permission for the PMNS was granted by the Ethical Committee at the King Edward Memorial Hospital Research Centre (KEMHRC [VSP/Dir.Off/EC/2166]), by local village leaders and the Indian Health Ministry's Screening Committee. Collection of education and marriage data at the 18-year follow-up was also approved by the Research Ethics Committee, Department of Geography, University of Cambridge, UK. Parents/guardians of adolescents <18 years of age participating in the study gave written informed consent. At the legal majority age (18 years) participants also provided written informed consent.

### 2.2 | Measurements

#### 2.2.1 | Maternal and household characteristics

At baseline, nonpregnant married women underwent detailed anthropometric measurements: weight to 0.5 kg (SECA digital scales, CMS Instruments, UK) and height to 0.1 cm (Harpenden portable stadiometer, CMS). An aggregate prepregnancy adiposity index was constructed by averaging five standard deviation scores (z-scores), generated internally for body mass index (BMI, weight/height$^2$), and four subcutaneous skinfolds (biceps, triceps, subscapular, and suprialliac), measured to 0.1 mm (Harpenden calipers, CMS). Women who became pregnant and were enrolled into the study were assessed during gestation for anthropometry. Duration of pregnancy (weeks) was treated as a marker of $F_0$ maternal nutritional investment in the $F_1$ offspring in utero and was derived from the last menstrual period, but if it differed from the sonographic estimate by 2 weeks, the latter estimate was used. Other maternal traits (age, marriage age, education, and parity) and household characteristics (religion, caste, family type and size, size of agrarian landholding, and paternal education) were recorded by questionnaire at baseline. Socioeconomic status (SES) was measured at baseline and at the 6- and 12-year follow-ups using a standardized Standard of Living Index questionnaire designed by the National Family Health Survey (IIPS, 1999).

#### 2.2.2 | Child characteristics

Within 72 hours of birth, offspring weight was measured to 25 g (spring balance, Salter Abbey, UK) and crown-heel length to 0.1 cm (Pedobaby Babymeter, ETS J.M.B., Belgium). After 2 years, standing height was measured to 0.1 cm (Harpenden stadiometer) and at 6, 12, and 18 years using a wall-mounted Microtoise (CMS, UK). Weight was measured to 0.1 kg using electronic scales (ATCO Healthcare Ltd, Mumbai, India). Age at menarche and age at marriage were recorded prospectively.

At the 18-year follow-up, a detailed questionnaire was administered on $F_1$ educational trajectories from nursery to late adolescence, enabling us to identify the point at which faltering began in school, and then to test prospectively whether this was associated with earlier marriage. To examine the temporal relationship between education and marriage, we also recorded the age, school standard, and reason for leaving school.

## 2.3 | Variables

### 2.3.1 | Exposures

We tested two sets of exposures. Our first set of exposures included “conventional” risk factors of wealth, $F_1$ age at menarche, and $F_1$ educational attainment. Wealth, or SES, was analyzed as a composite variable reflecting caste, education of the household head, housing type, and household material assets (Rao et al., 2001). We used data on SES at three time-points: baseline, and 6- and 12-year follow-ups. At all time-points, the SES score was categorized in time-specific tertiles.

Previous studies have used age at menarche in different ways (Ibitoye et al., 2017), either as a continuous variable (Field & Ambrus, 2008) or using cut-offs for early versus late menarche, most commonly at 13 years of age (Aryal, 2011; Raj et al., 2015). We coded $F_1$ age at menarche as <13 or ≥13 years based on previous studies in India and South Asia (Aryal, 2011; Raj et al., 2015) as our interest was in testing whether earlier menarche was associated with earlier marriage. Education was coded into levels according to the Indian education system (OECD, 2020). Data on $F_1$ education included participation in nursery school (yes or no) and age-related progression in primary standard 1 (entry below expected age of 7 or ≥7 years) and in early adolescence (attending standard younger than expected age or older than expected age). School performance was assessed up to the ninth standard (failed any grade or not failed). Completion was assessed by finishing lower secondary school, indexed by either passing or not taking or failing, the 10th standard exam. This exam, taken around 15 years of age, is perceived as the “tipping point” in shaping subsequent life pathways (Marphatia et al., 2019). We used this binary variable reflecting the level of education completed rather than simply the years of schooling completed because the former appears to be important for marital timing. We also assessed whether girls were still studying at the age of 18 years (yes or no).

Our second set of exposures included broader maternal, household and child characteristics. These included $F_0$ maternal phenotype, defined as age (years), age at marriage (<19 or ≥19 years), parity (0, 1, or ≥2 previous births), height (cm), educational attainment (none to primary [0–5 years] or upper primary/higher [≥6 years]), and an aggregate prepregnancy adiposity index (average of five standard deviation scores [z-scores], generated internally for four skinfolds and BMI weight/height$^2$). Duration of pregnancy (weeks) was treated as a marker of $F_0$ maternal nutritional investment in the $F_1$ offspring in utero.

Household characteristics included the size of agrarian land owned as a second marker of wealth. Agrarian land was coded as low (<3 acres), mid (3–5.99 acres), or high (6 acres). We also included religion (Hindu, Muslim, or Buddhism), caste (low [tribal, scheduled], mid [artisan, agrarian], or high [prestige, dominant]), family type (joint or nuclear), household size (<6 or ≥6 adults), and paternal education (coded similar to maternal education).

For $F_1$ offspring anthropometry, we computed age- and sex-specific z-scores (least mean square option in Microsoft Excel™) for height (cm), weight (kg), and BMI (kg/cm$^2$) at birth, 2, 6, 12, and 18 years using UK rather than WHO anthropometric reference data, because the former adjusts for gestational age and provides a single reference throughout children's development, including puberty (Cole & Green, 1992). To calculate $F_1$ growth trajectories, we then computed conditional z-scores for child height, weight, and BMI at ages 2, 6, 12, and 18 years, to express current size relative to what would be expected based on size at the previous time-point (Keijzer-Veen et al., 2005).

### 2.3.2 | Outcome variable

Our primary outcome variable, “early marriage,” was defined as <19 years of age to maximize statistical power. This age threshold also reflects national trends. In 2016, the median age at marriage of Indian women aged 20–24 years was 19.4 years (IIPS, ICF, 2017). In rural Maharashtra state, where our study is located, 41% had married by 18 years and 53% by 19 years (Heger Boyle et al., 2020). Therefore, girls who marry just after the 18 minimum marriage age cut-off are likely to experience many of the same consequences as those married before this age. Other researchers have also adopted this approach, finding that in contexts where early marriage is the norm, girls who do not marry before 18 years tend do so shortly thereafter, and are broadly similar in terms of social customs, expectations, and lived experiences in the marital home (Pesando & Abufhele, 2019; Schaffnit & Lawson, 2021; Singh & Espinoza, 2016). Overall, regardless of the age cut-off used for early marriage, this life-history stage represents an important period of learning and maturation, which lays the foundation for future reproductive success (Hochberg & Konner, 2019).

## 2.4 | Statistical methods

Chi-square and independent samples t-tests were used in univariate analyses to test for differences in maternal, family, and child characteristics between (a) girls lost at follow-up and those retained in the study at 18 years, and (b) girls who were either married early or were unmarried. $F_0$ maternal age was positively skewed and natural log-transformed, but reported in the original scales in tables. We used all available data for analyses, but some variables had a few missing values, as described in individual tables. Analyses were conducted in SPSS 26 (IBM Corp., Armonk, NY).

Kaplan–Meier survival plots assessed the probability of marrying by age 21 years, related to completion of lower secondary school (10th standard) at the age of 15 years. Among those married by 21 years, we also described the mean age at marriage for those who had not completed lower secondary school, compared to those who had completed this level of education.

**TABLE 1** Sample description, maternal, and household traits stratified by girls' marital status

| | Full sample ($n = 305$) Mean (SD) | Early married ($n = 71$) Mean (SD) | Unmarried ($n = 234$) Mean (SD) | Difference[a] Δ (SE), *p*-value |
|---|---|---|---|---|
| Maternal age (years)[b] | 21.1 (1.17) | 20.7 (1.16) | 21.1 (1.17) | −0.02 (0.02), 0.384 |
| Maternal aggregate adiposity[c] ($n = 302$) | −0.04 (0.80) | −0.15 (0.62) | −0.01 (0.84) | −0.14 (0.09), 0.201 |
| Maternal height (cm) | 152.0 (4.78) | 152.5 (4.39) | 151.9 (4.90) | 0.61 (0.65), 0.343 |
| | *n* (%) | *n* (%) | *n* (%) | *p*-value[d] |
| Maternal marriage age ($n = 293$) | | | | 0.173 |
| <19 years | 200 (68.3) | 51 (75.0) | 149 (66.2) | |
| ≥19 years | 93 (31.7) | 17 (25.0) | 76 (33.8) | |
| Maternal gestation (weeks) | | | | **0.026** |
| Pre-term (<37 weeks) | 31 (10.2) | 11 (15.5) | 20 (8.5) | |
| Early-term (37–39.99 weeks) | 183 (60.0) | 47 (66.2) | 136 (58.1) | |
| Term (≥40 weeks) | 91 (29.8) | 13 (18.3) | 78 (33.3) | |
| Maternal parity | | | | 0.182 |
| 0 births | 96 (31.5) | 26 (36.6) | 70 (29.9) | |
| 1 birth | 105 (34.4) | 18 (25.4) | 87 (37.2) | |
| ≥2 births | 104 (34.1) | 27 (38.0) | 77 (32.9) | |
| Maternal education ($n = 293$) | | | | **0.025** |
| None to primary (0–5 years) | 125 (42.7) | 37 (54.4) | 88 (39.1) | |
| Upper primary+ (≥6 years) | 168 (57.3) | 31 (45.6) | 137 (60.9) | |
| Caste ($n = 304$) | | | | 0.523 |
| Low (tribal, scheduled) | 19 (6.3) | 3 (4.2) | 16 (6.9) | |
| Mid (artisan, agrarian) | 69 (22.7) | 14 (19.7) | 55 (23.6) | |
| High (prestige, dominant) | 216 (71.1) | 54 (76.1) | 162 (69.5) | |
| Family type ($n = 304$) | | | | **0.010** |
| Joint | 44 (14.5) | 54 (76.1) | 27 (11.6) | |
| Nuclear | 260 (85.5) | 17 (23.9) | 206 (88.4) | |
| Family size ($n = 304$) | | | | 0.157 |
| <6 adults | 197 (64.8) | 51 (71.8) | 146 (62.7) | |
| ≥6 adults | 107 (35.2) | 20 (28.2) | 87 (37.3) | |
| Agrarian land size ($n = 290$) | | | | **0.006** |
| Low (<3 acres) | 101 (34.8) | 33 (47.1) | 68 (30.9) | |
| Mid (3–5.99 acres) | 87 (30.0) | 23 (32.9) | 64 (29.1) | |
| High (≥6 acres) | 102 (35.2) | 14 (20.0) | 88 (40.0) | |
| Paternal education ($n = 293$) | | | | **<0.001** |
| None to primary (0–5 years) | 83 (28.3) | 30 (44.1) | 53 (23.6) | |
| Upper primary+ (≥6 years) | 210 (71.7) | 38 (55.9) | 172 (76.4) | |
| Socioeconomic status at baseline | | | | 0.415 |
| Low | 80 (26.2) | 22 (31.0) | 58 (24.8) | |
| Mid | 112 (36.7) | 27 (38.0) | 85 (36.3) | |
| High | 113 (37.1) | 22 (31.0) | 91 (38.9) | |
| Socioeconomic status at 6 years | | | | **0.030** |
| Low | 101 (34.8) | 30 (42.9) | 71 (32.3) | |
| Mid | 71 (24.5) | 21 (30.0) | 50 (22.7) | |
| High | 118 (40.7) | 19 (27.1) | 99 (45.0) | |
| Socioeconomic status at 12 years | | | | 0.081 |
| Low | 65 (23.0) | 19 (30.2) | 46 (20.9) | |
| Mid | 109 (38.5) | 27 (42.9) | 82 (37.3) | |
| High | 109 (38.5) | 17 (27.0) | 92 (41.8) | |

*Note*: Δ between early married and unmarried girls. Boldface values indicate statistically significant differences at $p \leq 0.05$.
Abbreviations: *n*, number; SD, standard deviation.
[a]Independent samples *t*-test.
[b]Maternal age was positively skewed and natural log-transformed, but reported in original scale.
[c]z-score.
[d]$\chi^2$ test.

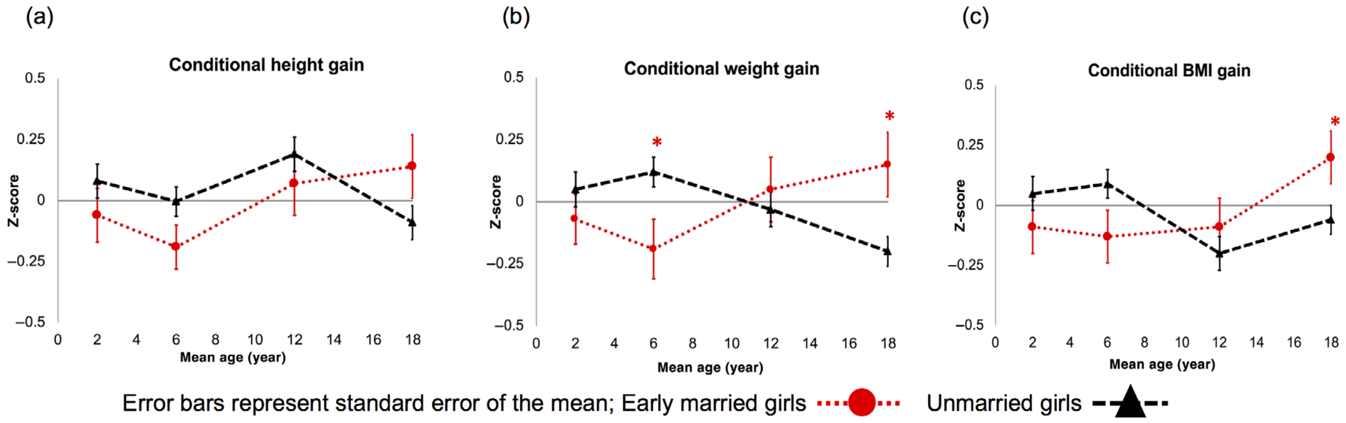


**FIGURE 2** Conditional growth rates in height, weight, and BMI stratified by early married and unmarried girls. (a) Early married girls show poorer conditional height gain between birth and 6 years, but then faster growth between 12 and 18 years; (b) early married girls show poorer conditional weight gain up to 6 years of age, but then faster weight gain from 6 to 18 years; (c) early married girls show poor conditional BMI gain up to 6 years of age, but faster BMI gains between 6 and 18 years. Asterisk indicates $p \leq 0.05$ (see Table S2). BMI, body mass index


**FIGURE 3** Kaplan–Meier survival curve of marriage age by lower secondary school status. From 16 years of age, the probability of marriage is substantially greater among girls who did not complete lower secondary school, compared to those who successfully completed it (logrank $p < 0.001$). This graph relates to the 132 girls who were married by the age of 21 years. Of these 132 girls, 24 (18%) did not complete lower secondary school, and 108 (82%) had completed lower secondary school

To test our first two hypotheses, we fitted multivariable logistic regression models to estimate the probability, via adjusted Odds Ratios (aOR) with 95% Confidence Intervals (CI), of early marriage (<19 years) with conventional risk factors, and then with broader biosocial life-course factors. For hypothesis one, we first associated early marriage with poverty, $F_1$ age at menarche, and $F_1$ educational attainment, and then adjusted these for potential confounders. For hypothesis two, we first developed univariable logistic regression models for a broad range of maternal, household, and $F_1$ factors, and then included these in a multivariable model, which adjusted for confounding variables.

Regression models retained exposure and confounding variables regardless of their statistical significance ($p$-value), as recommended by VanderWeele (VanderWeele, 2019). The highest level of each predictor (e.g., maternal upper primary education) was set as the reference. The Nagelkerke (NK) pseudo $R^2$ value was multiplied by 100 to show the proportion of variance explained in the outcome explained by the models. Our aim was to investigate the association of biosocial factors with girls' early marriage.

For our third hypothesis, we described the proportion of girls who were married and unmarried at the age of 19 years by their schooling status (dropped out or still studying at 18 years). Next, we examined the age at which they left school, and whether this occurred prior to, or after, marrying. We then described the main reason for leaving school for girls who first left school and then married, and vice versa. Finally, we described the median age and interquartile range (IQR) at leaving school for girls who first left school and then married, and vice versa.

## 3 | RESULTS

A description of the sample is presented in Table 1. Mothers were young at recruitment and most had married <19 years. They were relatively short, a third had a normal duration pregnancy, and most were first- or second-time mothers. Mothers were less educated than fathers were. Most families were from the dominant caste, as is typical of these villages (IIPS, ICF, 2018). Households were mostly nuclear in arrangement, with approximately similar distributions across different wealth levels (e.g., SES and size of agrarian land). Among the daughters, 71/305 (23.3%) had married early (<19 years).

### 3.1 | Univariate analyses by girls' marital status

Table 1 also shows some differences in maternal and household characteristics measured at baseline by $F_1$ girls' marital status. Compared to unmarried $F_1$ girls, early married $F_1$ girls were more likely to be born

**TABLE 2** Multivariable logistic regression testing independent associations of conventional risk factors and additional biosocial risk factors with $F_1$ early marriage

| | Model 1: Conventional risk factors NK = 0.144, (*n* = 266)[b] aOR (95%CI), *p*-value | Model 2: Conventional risk factors, confounders[a] NK = 0.194, (*n* = 266)[b] aOR (95%CI), *p*-value | Model 3: Conventional risk factors, confounders,[a] broader biosocial factors NK = 0.350, (*n* = 242)[c] aOR (95%CI), *p*-value |
|---|---|---|---|
| SES baseline (high = ref) | 1.00 | 1.00 | 1.00 |
| Low | 1.50 (0.64, 3.53), 0.351 | 1.53 (0.55, 4.23), 0.412 | 1.56 (0.42, 5.73), 0.502 |
| Mid | 1.16 (0.54, 2.48), 0.705 | 1.10 (0.49, 2.46), 0.820 | 1.10 (0.41, 2.97), 0.844 |
| SES 6 years (high = ref) | 1.00 | 1.00 | 1.00 |
| Low | 1.79 (0.72, 4.45), 0.208 | 1.56 (0.60, 4.02), 0.358 | 1.32 (0.41, 4.27), 0.648 |
| Mid | 2.10 (0.86, 5.13), 0.104 | 2.01 (0.79, 5.13), 0.143 | 1.63 (0.52, 5.14), 0.401 |
| SES 12 years (high = ref) | 1.00 | 1.00 | 1.00 |
| Low | 0.95 (0.34, 2.67), 0.927 | 0.91 (0.31, 2.62), 0.855 | 0.64 (0.17, 2.40), 0.508 |
| Mid | 1.17 (0.53, 2.59), 0.702 | 1.00 (0.44, 2.29), 0.998 | 0.70 (0.25, 1.96), 0.493 |
| $F_1$ menarche (≥13 years = ref) | 1.00 | 1.00 | 1.00 |
| Early (<13 years) | 0.48 (0.24, 0.97), **0.042** | 0.53 (0.25, 1.10), 0.090 | 0.62 (0.26, 1.47), 0.277 |
| $F_1$ 10th standard in school (completed = ref) | 1.00 | 1.00 | 1.00 |
| Not completed | 5.32 (2.27, 12.47), **<0.001** | 5.71 (2.32, 14.06), **<0.001** | 9.20 (2.78, 30.44), **<0.001** |
| Family type (joint = ref) | | | 1.00 |
| Nuclear | | | 3.38 (1.14, 10.03), **0.028** |
| Paternal education (≥6 years = Ref) | | | 1.00 |
| None to primary (0–5 years) | | | 2.19 (0.95, 5.05), 0.065 |
| Maternal education (≥6 years = ref) | | | 1.00 |
| None to primary (0–5 years) | | | 1.02 (0.44, 2.38), 0.955 |
| $F_0$ gestational age (term, ≥40 weeks = ref) | | | 1.00 |
| Pre-term (<37 weeks) | | | 7.17 (1.99, 25.80), **0.003** |
| Early-term (37–39.99 weeks) | | | 3.12 (1.22, 7.98), **0.017** |
| $F_1$ infant weight gain z-score (>1 = ref) | | | 1.00 |
| <−1 z-score | | | 9.36 (2.05, 42.69), **0.004** |
| −1 to 1 z-score | | | 2.06 (0.61, 6.90), 0.243 |
| Constant | 0.16, <0.001 | 0.14, <0.001 | 0.02, <0.001 |

*Note*: Boldface values indicate statistically significant differences at $p \le 0.05$.
Abbreviations: aOR, adjusted odds ratio; 95% CI, confidence interval; *n*, number of participants; NK, Nagelkerke *pseudo* $R^2$; SES, socioeconomic status.
[a]Confounding variables in Models 2 and 3 included agrarian land, caste, and maternal parity.
[b]*n* = 62 early married girls versus *n* = 204 unmarried girls.
[c]*n* = 56 early married girls versus *n* = 186 unmarried girls.

pre- and early-term, to have low parental education, to be from nuclear families, and from households with less agrarian land at baseline, and with low/mid SES at the age of 6 and 12 years. Girls did not differ in maternal age, maternal age at marriage, parity, caste, or SES at baseline.

In terms of absolute size or nutritional status, $F_1$ anthropometric z-scores showed no difference by girls' marital status at birth or at 2 years (Table S2). However, in comparison to the unmarried group, early married girls had lower weight z-score and lower BMI z-score at 6 years. The difference in the age at menarche between early married versus unmarried girls was biologically small (0.28 years, $p = 0.066$), and the probability of attaining menarche did not differ by age between the groups ($p = 0.296$). At 12 and 18 years, the two groups showed no difference in nutritional status. Given these differences in size, the two groups showed contrasting patterns of growth at different time points (Figure 2). Between 2 and 6 years, early married girls experienced poorer conditional weight gain and conditional BMI gain compared to unmarried girls. Conversely, between 12 and 18 years, early married girls experienced greater conditional gains in weight and BMI. The groups did not differ in growth rate over other time intervals (Table S2). In summary, early married girls demonstrated poorer

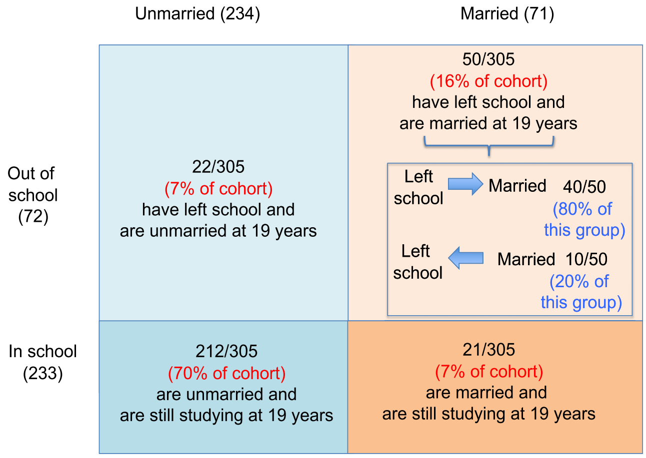


**FIGURE 4** School and marital status, and direction of the association between leaving school and marriage. This figure shows that the relationship between schooling and marriage is more complex than suggested in previous studies. Percentages in red refer to the whole cohort, whereas those in blue refer to the group of 50 girls who were both married and out of school. There is no simple "trade-off" between education and marriage, as shown both by the girls who left school and remained unmarried, and by those who had married, but continued studying. Whilst most girls who had married left school before marrying, some married first and then left school

growth in early childhood, and accelerated BMI gain during adolescence, but did not differ in the age at which they attained menarche.

There was no difference between early married and unmarried girls in nursery school attendance, age-related school participation, or failing in school before the 10th standard. Compared to unmarried girls, early married girls were less likely to have completed lower secondary school (10th standard,~15 years of age), or to be studying at 18 years of age (Table S3). The 10th standard is perceived as the "tipping point" in shaping subsequent life pathways (Marphatia et al., 2019). Kaplan–Meier survival curves show the probability of marrying by age 21 years, related to the completion of lower secondary school status (Figure 3). Girls who had completed lower secondary school continued to have a lower probability of marrying even after 19 years of age. Among those who had married by 21 years, the mean age at marriage for those who had not completed lower secondary school was younger, at 17.70 years, compared to those who had completed this level of schooling (18.96 years, $\Delta = 1.26$ years, 95%CI 0.66–1.86, $p < 0.001$). Regarding timing, we found that $F_1$ girls who had failed in school at any time up to the ninth standard were not more likely to marry early (OR 1.47, 95%CI 0.64–3.38, $p = 0.361$), but they were more likely to be out of school at 18 years (OR 3.27, 95% CI 1.59–7.10, $p = 0.003$).

## 3.2 | Hypotheses

For Hypotheses 1 and 2, we first developed univariable logistic regression models for a broad range of maternal, household, and $F_1$ factors (Table S4).

### 3.2.1 | Hypothesis 1

Our first model tested the following conventional risk factors associated with girls' early marriage identified in previous studies: household poverty, girls' early menarche, and their lower education. Table 2 Model 1 shows that natal household poverty at baseline, 6 and 12 years was not associated with early marriage. $F_1$ girls' early menarche was associated with a reduced risk, and their non-completion of lower secondary education with an increased risk of early marriage. Adjusting for potential confounders (agrarian landholding, maternal parity, and caste) in Model 2 marginally increased the magnitude of the effect of girls' lower education with early marriage (full model Table S4). However, early menarche was no longer associated with early marriage. This model explained 19.4% of the variance in early marriage risk and provides only partial support for our first hypothesis.

### 3.2.2 | Hypothesis 2

Table 2, Model 3 shows that adjusting for confounders (full model Table S5), nuclear household, pre- and early-term birth, low paternal education, and $F_1$ girls' lower conditional weight gain from 2 to 6 years were associated with increased risk of early marriage, independent of $F_1$ girls' non-completion of lower secondary school. This model explained 35.0% of the variance in early marriage risk and provides support for our second hypothesis. Compared to girls' education alone, broader biosocial factors, acting in early life, are associated with early marriage, explaining an additional 15.6% of variance.

### 3.2.3 | Hypothesis 3

Finally, we explored the temporal relationship between schooling and marital status at the age of 19 years. At this time point, 76% (233/305) of the cohort were still in school (Figure 4). Specifically, most (70%, 212/305) were still in school and unmarried, while a minority (7%, 21/305) of girls were married, but still studying. Of the 72 girls who were out of school, representing 24% of the cohort, 69% (50/72) were married. These results suggest there is no stark trade-off between these two life pathways, and that 7% of the full sample of girls (22/305) had left school by 18 years but remained unmarried at 19 years.

Moreover, among those who had married by 19 years and left school (16%, 50/305), we did not find clear evidence in support of our third hypothesis that girls would first drop out of school and then marry. Rather, over three quarters of this group (80%, 40/50) had left school first and then married, whereas the others (20%, 10/50) had married first, and then left school. For those who left school and subsequently married, the median time between these events was 1.0 years (IQR 1.2), whereas for those who married first and then left school, the median interval was 0.26 years (IQR 0.46). Both groups cited school-related factors (poor teaching and learning) as the main reason for leaving school. Seventeen percent of the girls who left school before marrying cited

**BOX 1 Study's contributions to the field**

What is already known?

- Women's early marriage is a social decision among family members, and also a contributing factor to reproductive fitness.
- Less education is associated with early marriage.
- A few studies have linked earlier menarche with earlier marriage, but the evidence is scarce.
- Household poverty is widely assumed to drive early marriage, but is usually measured in the marital household, not the natal household.

What are the new findings?

- Ours is the first study to conduct a comprehensive investigation of a broader range of biosocial factors, acting from early life onwards, that may contribute to early marriage, and we use evolutionary life history theory to help interpret the findings.
- Neither natal household poverty measured at three times through the daughters' life-course, nor early menarche, were associated with early marriage.
- Girls' non-completion of the 10th standard (lower secondary school) was associated with increased risk of marrying early, and in combination with household assets and age at menarche explained 19% of the variance.
- Early marrying girls showed different patterns of growth compared to those not marrying early.
- Independent of girls' lower schooling, a broad range of biosocial factors (nuclear household, low paternal education, lower gestation, and girls' poor infant growth, measured prospectively in the natal household in early life) were associated with increased risk of early marriage, in combination explaining 35% of the variance.

What do the new findings imply?

- To delay marriage, women need more than merely completing lower secondary school.
- Promoting secondary education is crucial, but inadequate in its magnitude of effect to effectively delay women's marriage.
- Interventions initiated in adolescence come too late in the life-course, to effectively target the full range of factors shaping early marriage.
- Evolutionary life history theory and human behavioral ecology provide promising new perspectives from which to understand the persistence of early marriage despite its adverse maternal and child health and human capital outcomes.

marriage as the main reason for leaving school compared to 30% of the girls who married before leaving school.

## 4 | DISCUSSION

To our knowledge, this is the first study of early marriage to go beyond conventional risk factors. It provides evidence for both biological and social factors acting in early life associated with girls' early marriage in a contemporary rural Indian population. No other study that we are aware of has prospective measurements over time, of different markers of natal household wealth, $F_0$ maternal phenotype at preconception, or $F_1$ daughter's growth and maturation from birth to late-adolescence, and educational trajectories from preprimary onwards.

Our results show that early marriage, often perceived as a sociocultural decision based on circumstances during adolescence and driven by poverty, early menarche, and lower education, is also associated with a range of biosocial factors assessed from before birth through the daughter's life-course. We found that early marriage was partly a consequence of not completing lower secondary education. However, we did not associate early marriage with household poverty at baseline, childhood, or early adolescence, or with early menarche. Independent of these conventional risk factors, we linked several other biosocial factors, including shorter duration of $F_0$ pregnancy, $F_1$ girls' poor early growth trajectories, nuclear family, and low paternal education, with early marriage. Compared with a model containing only conventional risk factors, our composite suite of biosocial factors, controlling for potential confounders, explained substantially more variance in the risk of early marriage. Box 1 outlines our study's contributions to the field.

Several authors have proposed theoretical frameworks for exploring how biological and social processes interact to shape disadvantage through the life-course (Evans et al., 2012; Krieger, 2001; Marmot, 2005; Wells, 2016), but none have applied it to understanding early marriage. Evolutionary life history theory may help understand our findings (Hill & Kaplan, 1999). Life history theory predicts that exposure to factors that constrain investment in embodied capital (low parental education, poor $F_1$ physical growth) in early life will favor "future discounting," and the diversion of resources toward immediate survival and earlier reproduction (Kaplan et al., 2003). Consistent with this, we found that several markers of lower investment in early life were associated with an increased risk of early marriage, suggesting that families that are less able to invest in their daughter may, by marrying her, accelerate her transition to the life-course stage when reproduction can commence.

Others have used human behavioral ecology, also underpinned by life history theory, to explore the socioecological drivers of early marriage, and its potential costs and benefits in different cultural contexts (Lawson et al., 2021; Schaffnit & Lawson, 2021; Sheppard & Snopkowski, 2021). Using this perspective, Schaffnit and Lawson (Schaffnit & Lawson, 2021) put forward four hypotheses on the drivers of early marriage. First, in contexts where life expectancy is short, early marriage may be an adaptive strategy aimed at maximizing reproductive success (Sheppard & Snopkowski, 2021), particularly where childbearing occurs after marriage. Second, parent-offspring conflict (Trivers, 1974) is likely to drive child marriages (<15 years): parents from poor households benefit by reducing care and education costs whilst daughters lose out on this investment (Schaffnit, Hassan, et al., 2019). Third, girls with lower genetic relatedness with nonnuclear household members may prefer to marry early to free themselves from unpaid care work. Fourth, both daughters and parents from disadvantaged backgrounds may favor early marriage in the absence of viable alternatives.

Findings from our study in rural India support Schaffnit and Lawson's (Schaffnit & Lawson, 2021) first hypothesis, but not the others. Although marriages are still primarily arranged by parents, the shift in early marriage in our population to late adolescence suggests there may be some negotiation between parents and daughters around the timing of marriage, and the willingness/ability of parents to pay the high dowry for later married and more educated daughters. Moreover, there was no evidence of a clear trade-off between marriage and school dropout. In the context of our study, even if daughters were able to free themselves of labor within the natal household, they are likely to perform a similar (if not greater) level of work in their marital household (Chorghade et al., 2006). Finally, poverty was not associated with adolescent marriage, but as discussed, other markers of disadvantage, from the early-life period onwards, may be more relevant for marital timing.

There is now compelling evidence those developmental trajectories are strongly imprinted by experience during early "critical windows," during which a key exposure comprises the magnitude of maternal nutritional investment during pregnancy (Wells, 2010). Consistent with this, our findings indicate an intergenerational basis to early marriage, beginning with a shorter duration of $F_0$ pregnancy. This reduced investment in utero is followed by poor $F_1$ growth in weight in early childhood, and then a degree of catch-up in weight and BMI, in the early married girls. This suggests that poor early growth is followed by the accretion of body fat, which is beneficial for both reproduction and immune function (Wells et al., 2019). This pattern of growth may give families the impression that these individuals are maturing faster than their peers, which might in turn be interpreted as signaling "readiness" for marriage. However, earlier menarche was not an independent predictor of early marriage, suggesting that early nutritional constraint actually induces a pattern of growth that elicits early marriage without necessarily accelerating sexual maturation.

Our findings are broadly consistent with the analysis of a Brazilian birth cohort, where a composite index of $F_0$ maternal disadvantage (low maternal capital, categorized from maternal height, BMI, education, and income) was associated with increased risk of the $F_1$ daughter reproducing before 18 years. As in our study, the developmental trajectory included poor early growth and subsequent catch-up in BMI (Wells et al., 2019). However, unlike our study, the age at menarche was also delayed in Brazil. In turn, early reproduction was the main reason for daughters having left school early. However, unlike other cross-sectional (Chari et al., 2017; Raj et al., 2015) or longitudinal (Singh & Espinoza, 2016) studies from South Asia, we did not associate early menarche with earlier marriage. Our contrasting findings may reflect that most previous studies measured menarche retrospectively, after women were married, which may introduce recall bias, whereas we measured it prospectively (Leone & Brown, 2020). However, it is also possible that in our rural setting, the adolescent catch-up in BMI in early marrying girls may have occurred too late to accelerate menarche. Previous studies have reported associations between BMI during development (particularly in early life) and age at menarche (Ong et al., 2007; Ong et al., 2009; Parent et al., 2003). Other authors have also suggested that the timing of marriage may not always align with other life history transitions such as the timing of menarche (Schaffnit & Lawson, 2021).

It might seem surprising that we did not find material poverty to be associated with early marriage, however, we note that most previous studies actually measured household wealth in the marital, not the natal, household (Beattie et al., 2019; Delprato et al., 2015; Raj et al., 2014; Scott et al., 2021; Wodon et al., 2017) though see Bajracharya and Amin (2012), Muchomba (2021), and Singh and Espinoza (2016). Conversely, we found that other markers of socioeconomic disadvantage were associated with an increased risk. Low agrarian landholding might implicate household food insecurity, with early marriage of daughters potentially providing relief to such households, by reducing the number of people to feed. The finding that nuclear families are more likely to marry their daughters early likewise suggests that they have lower levels of resources and social support. Regarding social capital, paternal rather than maternal education, as suggested by other studies (Bates et al., 2007), was associated with girls' early marriage, and this was also independent of the daughter's own educational attainment. Low paternal education may signal low social status in the context of marital matches, and in combination with other socioeconomic factors, suggest the need to "offload" the daughter earlier. These penalties then may predispose to lower investment in the marriage itself, for example through lower dowries (Jeffrey & Jeffery, 1994).

As in other studies (Jeffrey & Jeffery, 1994), we found that dropping out in the 10th standard at~15 years, before completing lower secondary school, was the key "tipping point" for early marriage. However, we did not find that leaving school and marrying early were mutually exclusive outcomes, as suggested by other studies (Delprato et al., 2015; Wodon et al., 2017). Although we found that early marriage "pulled" some girls out of school, more commonly it was an unsatisfactory educational experience that "pushed" them out of school, and only some were then married soon after. A minority of girls left school and remained unmarried at 19 years, while others were married by this age but continued studying. The waiting period between leaving school and marrying suggests these decisions were not simple "trade-offs."

Our results have implications for policy and practice. Interventions to delay marriage implemented during adolescence, such as conditional cash transfers to reduce poverty and promote girls' education, and community- and peer-networks aiming to change sociocultural norms, have had inconsistent effects (Forte et al., 2019; Kalamar et al., 2016; Malhotra & Elnakib, 2021; Prakash et al., 2019; Ramanaik et al., 2020). Given the implications of early marriage for reproductive fitness, it should be recognized as critical public health importance (Marphatia et al., 2017), just as public health is increasingly recognized as a key social issue (Jong-Wook, 2005). In societies where marriage is fundamentally a transaction between families, lower investment in daughters through their life-course reflects the unequal structure of social relations, and the lower value attributed to girls and women in society. Broader societal gender inequality must therefore be addressed, in particular because it adversely impacts health outcomes in the next generation, as demonstrated by its associations across countries with low birth weight and child malnutrition and mortality risk (Brinda et al., 2015; Marphatia, Cole, et al., 2016).

Among the limitations, we did not assess whether sibling configuration was associated with adolescent marriage, nor the relative importance of parental perspectives and decision-making on the timing of marriage as found in some studies (McDougal et al., 2018; Raj et al., 2019; Samuels et al., 2017; Schaffnit, Urassa, & Lawson, 2019). Although we collected attitudinal and aspirational data, since they relate to the adolescents' own perspectives, and their perceptions of their parent's expectations, we did not include them in this analysis. It is possible that participants' explanation of the poor quality of education as a reason for early marriage was a socially desired response, and that the real driver of school dropout was early marriage. Our observational study cannot demonstrate causation. Moreover, participation in the long-term study may have influenced marriage decisions in the whole cohort. Although the specific factors we have identified might not generalize to all populations, our broader finding of biosocial pathways leading to early marriage is likely to be widely relevant.

## 5 | CONCLUSION

Marriage is a research topic that does not fit neatly into any one discipline, and yet has broad implications relating both to earlier childbearing and maternal and child physical/mental health, and human capital outcomes. Although recent studies have emphasized the importance of early growth and development for education, equivalent evidence for early marriage is missing. Our study addresses this lacuna, and shows that a number of biosocial factors measured in early life, in the natal household, and prior to marriage, are associated with early marriage. Given our negative findings for two other "conventional risk" factors (early menarche, household poverty), our results shift attention to life-course stages prior to adolescence. Our key message for policy is that promoting secondary education is inadequate in its magnitude of effect, and also comes too late in the life-course, to effectively target the full range of factors shaping early marriage. Early marriage is a key way in which inequalities are imposed on women.

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### CONFLICT OF INTEREST

All authors declare no conflicting interests.

### AUTHOR CONTRIBUTIONS

**Akanksha A. Marphatia:** Conceptualization (equal); data curation (equal); formal analysis (lead); funding acquisition (lead); investigation (equal); methodology (equal); visualization (lead); writing – original draft (lead). **Jonathan C. K. Wells:** Conceptualization (equal); formal analysis (supporting); methodology (equal); visualization (supporting); writing – review and editing (equal). **Alice M. Reid:** Conceptualization (equal); formal analysis (supporting); methodology (equal); supervision (equal); visualization (supporting); writing – review and editing (equal). **Chittaranjan S. Yajnik:** Conceptualization (equal); data curation (equal); formal analysis (supporting); funding acquisition (lead); investigation (equal); methodology (equal); project administration (lead); resources (lead); supervision (equal); visualization (supporting); writing – review and editing (equal).

### DATA AVAILABILITY STATEMENT

Data used in this analysis cannot be shared publicly because of requirements of the local ethics committee and privacy concerns. Data are available from the PI, Dr CS Yajnik (contact via csyajnik@gmail.com) for researchers who meet the criteria for access to confidential data, and who understand the expectations of the local ethics committee and study participants.

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