Four Essays on Health and Nutrition of Indian Women and Children

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List of Abbreviations

2SLS	two-stage least squares
AFHC	adolescent friendly health center
ANC	antenatal care
ARI	acute respiratory infections
ARSH	Adolescent Reproductive and Sexual Health Strategy
AWC	*anganwadi* centres
BMI	body mass index
CEB	Census Enumeration Block
CNNS	Comprehensive National Nutrition Survey
CSSM	Child Survival and Safe Motherhood
DAG	Directed Acyclic Graph
DEVTA	Deworming and Enhanced Vitamin A supplementation
DHS	Demographic and Health Survey
DPT	diphtheria pertussis and tetanus
ELBW	extremely low birthweight
g/dl	grams/ decilitre
GBD	Global Burden of Disease
Hb	haemoglobin
HC	hip circumference
ICDS	Integrated Child Development Services
ICPD	International Conference on Population and Development
IDA	Iron-deficiency anaemia
IFA	iron-and-folic-acid
IMNCI	Integrated Management of Neonatal and Childhood Illnesses
IUGR	intrauterine growth restriction
IV	instrumental variable
LBW	low birthweight
MeSH	Medical Subject Headings
mmHg	millimetres of mercury
MoHFW	Ministry of Health and Family Welfare
NCD	non-communicable disease
NFHS	National Family Health Survey
NFSA	National Food Security Act
NIPI	National Iron Plus Initiative
POSHAN	Prime Minister’s Overarching Scheme for Holistic Nourishment
PPS	probability proportional to size
PSU	primary sampling unit
PTB	preterm birth
RCH	Reproductive and Child Health
RKSK	*Rashtriya Kishore Swaasthya Karyakram*
RMNCH+A	Reproductive Maternal Newborn Child Health + Adolescent Health

SC	scheduled castes
SDG	Sustainable Development Goal
ST	scheduled tribe
THR	take home ration
VAD	Vitamin A deficiency
VAS	vitamin A supplementation
VIF	Variance inflation factor
VLBW	very low birthweight
WC	waist circumference
WHO	World Health Organization
WHR	waist-to-hip ratio

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1 Four Essays: An Introduction

India, with a population of over 1.4 billion, has received considerable appreciation for its success in improving the overall health of its people. In India, the life expectancy of birth (LEB), a summary measure of mortality, has increased from 60.4 years in 1990 to 70.2 years in 2017 among females and from 58.9 years in 1990 to 67.8 years in 2017 among males (Vollset et al., 2020). This tremendous improvement in population health could be attributed to overall development of socioeconomic condition of population, increased access to healthcare, whereas some biological and environmental factors also played a crucial role (GBD 2019 Universal Health Coverage Collaborators, 2020; Singh et al., 2017). With an increase in LEB, the under-five mortality rate has reduced substantially between 1990 (108 deaths per 1000 birth) and 2017 (36 deaths per 1000 birth) (GBD 2019 Demographics Collaborators, 2020). In addition, India has already achieved a below replacement level of fertility with a total fertility rate or TFR (average number of children a woman delivers over her lifetime) of 2.0 children per woman in 2019-2021 (International Institute for Population Sciences and ICF, 2021), down by nearly half since 1990 (Vollset et al., 2020).

The remarkable improvement in population health in India was guided by various development policies including India's population policy, public health policy and improvement in healthcare infrastructure. While these policies and programmes were designed for overall improvement of India's population, targeted interventions to strengthen health and nutrition of Indian's children (India State-Level Disease Burden Initiative Child Mortality Collaborators, 2020; India State-Level Disease Burden Initiative Malnutrition Collaborators, 2020) and youth (aged 15-24 years) (Barua et al., 2020; Sivagurunathan et al., 2015) have been the focus of India's public health policy. Of the various targeted programme launched till date, the contribution of the National Health Mission in strengthening adolescent and child health has been highly recognized. The National Health Mission was launched in 2005, under which the Adolescent Reproductive and Sexual Health Strategy (ARSH) was introduced. For the most part, the ARSH Strategy employs a clinic-based approach focused on building the capacity of different cadres of health workers and reorienting and branding existing public health facilities as adolescent friendly health centers (AFHCs). The Strategy also set clear standards for quality improvement of services and developed guidelines to implement and monitor them. In 2014, in line with the new National Reproductive Maternal Newborn Child Health + Adolescent Health (RMNCH+A) Strategy's commitment to a continuum of care approach, the Ministry of Health and Family Welfare replaced the ARSH Strategy with *Rashtriya Kishore Swaasthya Karyakram* (RKSK), broadened the focus beyond sexual and reproductive health to include non-communicable diseases, nutrition, mental health, substance misuse and injuries and violence.

In the evolution of child health policy, the Government of India came up with the National Policy for Children in 1974 to prioritize child health, nutrition, orphan and destitute children and children with disabilities. Maternal and child health care became an integral part of the 1977 ??, the family planning program programme with the recognition that reduction in infant and child mortality is directly proportional to reduction in birth rate. A Child Survival and Safe Motherhood (CSSM) programme was launched in 1992 to reduce infant and maternal mortality rates. The government also introduced the Reproductive and Child Health (RCH) Programme Phase I during 1997–98 to fulfil the unmet need for family welfare services in the country, especially among the poor and underserved, which was later integrated with CSSM in 2005. Experience from RCH Phase I determined the contours of RCH II, which was a paradigm shift from a 'one size fits all' design to an approach where sub-national requirements, capacities and performances were considered and steered to stimulate demand for services. RCH Phase II adopted Integrated Management of Neonatal and Childhood Illnesses (IMNCI) in 2005. IMNCI consolidated preventive and curative elements to improve the skills of healthcare staff, overall health systems and family and community health practices.

Currently, there are various interventions being implemented to improve the health of children (Mathur and Reddy, 2019). These are: a) *Janani Shishu Suraksha Karyakaram* which entitles all pregnant women delivering in public health institutions to absolutely free and no expense delivery including Caesarean section; b) India Newborn Action Plan to reduce neonatal mortality and stillbirths; c) Integrated Action Plan for Pneumonia and Diarrhoea launched in the four states with highest child mortality (Uttar Pradesh, Madhya Pradesh, Bihar and Rajasthan); d) Village Health and Nutrition Days organized for imparting nutritional counselling to mothers and improve child care practices; e) Mother and Child Tracking System to ensure registration and tracking of all pregnant women and newborn babies so that provision of regular and complete services are ensured; f) *Rashtriya Bal Swasthya Karyakram* to provide comprehensive care to all children in the age group of 0–18 y in the community (with a 4D thrust to screen for and manage birth defects, diseases, deficiencies and developmental delays, including disabilities); g) National Iron Plus Initiative for the prevention of anaemia among the vulnerable age groups, women of reproductive age, pregnant and lactating women; and h) Mission *Indradhanush* to achieve 90% full immunization coverage of India by year 2020.

Undernutrition of children has been a major challenge to child survival, growth and cognitive development. The Integrated Child Development Scheme (ICDS), launched in 1975, has addressed the nutrition and education needs of pre-school children and evolved over time to cover the 0–6 y age range. POSHAN *Abhiyaan*, a recently launched nutrition mission, aims to improve the nutritional status of children in this age range, adolescent girls, pregnant and lactating women. While the push to eliminate undernutrition is essential, the rising threat of overweight and obesity among children and adolescents needs to be addressed through programmes promoting healthy nutrition and physical activity (Mathur and Reddy, 2019).

With this programme and policy environment designed to strengthen health and nutrition of Indian youths and children, this cumulative doctoral thesis identified four areas of research. Of the four research manuscripts (hereafter essays), three research articles have been published in research journals. The summary of each research essay is presented below, and all essays have been presented in detail in subsequent chapters of the dissertation.

1.1 Essay 1

Using a nationally representative dataset for India, this study sets up a quasi-experimental study design – instrumental variable (IV) approach to assess the causal effect of age of marriage among young women (aged 15-24 years) on their nutritional status. Age of menarche was used as an IV. Findings suggest that one year increase in age of marriage could yield two percentage point increase in underweight and six percentage points reduction in overweight, including obesity. Each year increase in the age of marriage could result into three percentage points decrease in the waist-to-hip ratio (WHR) of ≥0.85 centimeter (cm), and four percentage points decrease in waist circumference (WC) of >80 cm. Delayed marriage could protect young women from increasing their body mass index, weight, WHR, WC, and hip circumference. We explored a potential mechanism through which the age of marriage could affect nutritional status. Our analytical approach and study findings were verified with various robustness checks.

1.2 Essay 2

India has an unacceptably high burden of vitamin A deficiency (VAD) among children aged 6-59 months. To mitigate VAD and its adverse effects on child health, the Indian government runs a nationwide vitamin A supplementation (VAS) programme. However, the effect of VAS in reducing child morbidity and mortality remains inconclusive and has been debated globally. In this paper, we estimate the effect of VAS on two indicators of child nutrition - anaemia (categorized into any anaemia, and mild/moderate anaemia) and anthropometric failure (categorized into stunting, wasting, and underweight) among children aged 6-59 months. Using the nationally representative 2015-2016 National Family Health Survey dataset from India, we estimated household and mother fixed-effects of VAS on select types of child anaemia and anthropometric failure. Findings from both the household fixed-effects and mother fixed-effects analysis showed that VAS does not influence any types of childhood anaemia and anthropometric failure in India. We discussed the findings considering existing literature and possible limitations of the study. Infirm association of Vitamin A on anaemia and anthropometric failure is probably indicative of targeted VAS intervention, as opposed to universal VAS programme.

1.3 Essay 3

This study used a wide range of information on parental sociodemographic, physical and behavioral characteristics as well as on the presence of non-communicable diseases among parents and examined the association of these attributes with anthropometric failure, anaemia and mortality of their children aged 0-59 months. Findings revealed that children of fathers aged 30-39 years were less likely to experience anthropometric failure and anaemia; however, survival of children of fathers below 18 years at marriage could be threatened. Parental education had protective association with children's anthropometric failure, anaemia and under-five mortality. With increasing maternal height, children had lower odds of anthropometric failure and under-five mortality. Tobacco use by mothers was associated with increase in under-five mortality, and children with diabetic fathers had higher odds of under-five mortality.

1.4 Essay 4

This study assessed intake of iron-and-folic-acid (IFA) tablet/syrup (grouped into none, <100 days of IFA consumption or <100 IFA, and ≥100 days of IFA consumption or ≥100 IFA) among prospective mothers and its association with various stages of low-birthweight (ELBW: extremely low-birthweight, VLBW: very low-birthweight, and LBW: low-birthweight) and neonatal mortality (death during day 0-1, 2-6, 7-27, and 0-27) in India. The cross-sectional,

nationally representative, 2015-2016 National Family Health Survey (NFHS-4) data were used. Weighted descriptive analysis, and multiple binary logistic regression modelling were used. A total of 120,374 and 143,675 index children aged 0-59 months were included to analyze LBW and neonatal mortality, respectively. Overall, 30.7% mothers consumed ≥100 IFA in 2015-2016, and this estimate ranged from 0.0% in Zunheboto district of Nagaland state to 89.5% in Mahe district of Puducherry of India. Multiple regression analysis revealed that children of mothers who consumed ≥100 IFA had lower odds of ELBW, VLBW, LBW, and neonatal mortality during day 0-1, as compared to mothers who did not buy/receive any IFA. Consumption of IFA (<100 IFA and ≥100 IFA) had protective association with neonatal death during day 7-27, and 0-27. Consumption of IFA was not associated with neonatal death during day 2-6. While ≥100 IFA consumption during pregnancy was found to be associated with preventing select types of LBW and neonatal mortality, a large variation in coverage of ≥100 IFA consumption across 640 districts is concerning.

2 Age of marriage and nutritional status among women aged 15-24 years: a nationally representative quasi-experimental study in India*

RAJESH KUMAR RAI

ABSTRACT

Using a nationally representative dataset for India, this study sets up a quasi-experimental study design – instrumental variable (IV) approach to assess the causal effect of age of marriage among young women (aged 15-24 years) on their nutritional status. Age of menarche was used as an IV. Findings suggest that one year increase in age of marriage could yield two percentage point increase in underweight and six percentage points reduction in overweight, including obesity. Each year increase in the age of marriage could result into three percentage points decrease in the waist-to-hip ratio (WHR) of ≥0.85 centimeter (cm), and four percentage points decrease in waist circumference (WC) of >80 cm. Delayed marriage could protect young women from increasing their body mass index, weight, WHR, WC, and hip circumference. We explored a potential mechanism through which the age of marriage could affect nutritional status. Our analytical approach and study findings were verified with various robustness checks.

Keywords: anthropometry, nutrition, youth, quasi-experiment, instrumental variable, India

* This manuscript is yet to be submitted to a research journal

2.1 Introduction

Age of marriage among women is often considered as an indicator of their well-being, their opportunity and choice for personal development, and their success in caring for families and children (Batyra et al., 2021; Desai and Andrist, 2010; Raj et al., 2010; Sagalova et al., 2021a; Wahhaj, 2015). Marriage before the age of 18 for women is defined as child marriage (Efevbera and Bhabha, 2020). Child marriage is a violation of Article 16(2) of the Universal Declaration of Human Rights (UNFPA and UNICEF, 2010). and in a landmark international consensus, the Programme of Action was adopted by signatories of the International Conference on Population and Development (ICPD) in 1994, to eliminate child marriage (United Nations, 1995). However, as estimated in 2018, globally, nearly 21% of women aged 20-24 years had married as children (United Nations Children's Fund, 2018). South Asia is home to the largest number of child brides (Marphatia et al., 2017; Raj et al., 2012) whereas India has the largest number of child brides (nearly 223 million) in the world. The state of Uttar Pradesh in India alone houses nearly 36 million child brides (United Nations Children's Fund, 2019). According to the 2019-2021 National Family Health Survey (NFHS), nearly 26.8% of women aged 20-24 years got married before the age of 18 years in India, which is only 3.5 percentage points reduction from the 2015-2016 NFHS (23.3%) (International Institute for Population Sciences, 2021).

The causes of child marriage are multifactorial (Psaki et al., 2021; Sagalova et al., 2021b). Deprived by an opportunity of higher education (even an undergraduate degree), girls who are married before the age of 18 years are likely to conceive soon after the marriage (United Nations Children's Fund, 2018; Nguyen et al., 2019), even if she is neither physically nor mentally ready (United Nations Children's Fund, 2018; United Nations Children's Fund, 2019). Early conception and unintended pregnancies among child brides often result into adverse maternal and offspring health outcomes (Goli et al., 2015; Sagalova et al., 2021c; United Nations Population Fund, 2010). Poor maternal and child health result into increased immediate out-of-pocket expenses for the girl and her household, including lasting effects on household earnings and reduced productivity. Among adverse health outcomes that manifest due to child marriage, effects on the nutritional status of women are insufficiently documented (Efevbera et al., 2019). A girl's nutritional status can decline if she marries early, which is often linked to early childbearing, poverty within the household, and to traditional gender norms around women's role and place when it comes to meals (Efevbera et al., 2019; Parsons et al., 2015). The adverse impact on their nutritional status might be mediated by woman's bargaining power and their preferences regarding investment on themselves (Yount et al., 2018; Wodon et al., 2017) and young women are especially vulnerable to these negotiations.

Efforts to prevent child marriage by the Indian government dates to 1929, a pre-independence era, when The Child Marriage Restraint Act was introduced. The Act was replaced by The Prohibition of Child Marriage Act, 2006, which also prescribed 18 years as the minimum age of consent for marriage for women (Ministry of Women and Child Development, 2021). In June 2020, the Ministry for Women and Child Development, Government of India, set up a task force to review matters pertaining to age of motherhood, imperatives of lowering maternal mortality ratio, improvement of nutritional levels and related issues (Ministry of Women and Child Development, 2020) and one of several recommendations the task force presented was to increase the minimum legal age of marriage from 18 years to 21 years (Ministry of Women and Child Development, 2021). The Minister of Women and Child Development argued that "the existing laws do not adequately secure the Constitutional mandate of gender equality in marriageable age among men and women," and "women are often put to disadvantageous position regarding higher education, vocational instruction, attainment of psychological maturity and skill-sets, etc." After multiple rounds of debate, the Bill on Prohibition of Child Marriage (Amendment) Act, 2021, was passed in the Parliament of India in December 2021 for raising the age for marriage of women from 18 to 21 years (Ministry of Women and Child Development, 2021). Aside from constitutional amendments, the state and central governments run various conditional cash transfer programmes to prevent child marriage (Sekher, 2012). However, critiques have argued if conditional cash transfer is being effective in addressing deeper issues related to child marriage, such as the agency of adolescent girls in their marriage decisions, sexual rights within marriage, and social norms within their own communities (Amin et al., 2016).

In this study, we explore the negative effects of age of marriage among young women (aged 15-24 years) on select indicators of their nutritional status, using a nationally representative dataset of India. Undertaking an assessment of the negative impact of age at marriage on young woman's nutritional status in India is the first of its kind. We set up a quasi-experiential study - the instrumental variable (IV) strategy (Angrist and Pischke, 2009) to establish the causal effect of age of marriage among young women (aged 15-24 years) on total nine indicators of their nutritional status, represented by body mass index or BMI (measured in kilogram per meter square or kg/m^2), thinness (BMI of <18.5 kg/m^2), which is also known as underweight, overweight including obesity (BMI of ≥ 23 kg/m^2), weight (measured in kg), waist circumference (WC) measured in centimeter (cm), WC with increased risk of metabolic complications (meaning WC of >80 cm), hip circumference (measured in cm), waist-to-hip ratio or WHR, and WHR with substantially increased risk of metabolic complications (meaning WHR of ≥ 0.85 cm). We used age of menarche (defined as the first menstrual bleeding that marks the beginning of a female's reproductive life) as an IV, to instrument for age of marriage, which was first introduced by a study conducted in Bangladesh in 2008 (Field and Ambrus, 2008). Since then, various studies conducted in India (Chari et al., 2017; Carpena and Jensenius, 2021; Dhamija and Roychowdhury, 2020; Roychowdhury and Dhamija, 2021; Sekhri and Debnath, 2014) and elsewhere (Delprato et al., 2015; Huang et al., 2019; Sunder, 2019) agree that the age of menarche is largely biologically determined (Dvornyk and Waqar-ul- Haq, 2012; Karapanou and Papadimitriou, 2010) and thus it is plausibly exogenous and affects later-life outcomes only through its impact on the age of marriage. As empirically demonstrated in earlier studies (Chari et al., 2017; Carpena and Jensenius, 2021), the age of menarche is strongly correlated with the age of marriage, as once a girl reaches puberty she is married off, partly to avoid unwanted pregnancies (Caldwell et al., 1983). We also explored the potential mechanism through which the age of marriage affects nutritional status of woman. We also made various robustness checks for our study findings.

2.2 Methods

2.2.1 *Dataset and study population*

We use a nationally representative cross-sectional dataset of 2019-2021 Demographic and Health Survey (DHS), commonly known as the fifth round of the National Family Health

Survey (NFHS-5) in India (International Institute for Population Sciences and ICF, 2021). Conducted under the stewardship of the Ministry of Health and Family Welfare, Government of India, NFHS-5 is widely used to inform India's public health programmes and policies. NFHS-5 covered 707 districts (as of March 31, 2017), spreading across 28 states and 9 union territories of India. For sampling, each district was stratified into urban and rural areas, and the survey adopted a stratified two-stage sampling design. PSUs were identified as villages in rural areas and Census Enumeration Blocks (CEBs) were counted as PSUs in urban areas. NFHS-5 had a household response rate of 97.5%. For the interview, NFHS-5 sampled 724,115 women aged 15-49 years and 101,839 men aged 15-54 years residing in 636,699 households. Further details about the sampling procedure of NFHS-5 can be reviewed from its published report (International Institute for Population Sciences and ICF, 2021).

NFHS-5 collected information on the age of menarche among currently married young women aged 15-24 years (International Institute for Population Sciences and ICF, 2021), making it possible to design this impact assessment. Limiting the information to young women prevented from recall errors about their age of menarche. Secondly, it is the first time NFHS-5 collected information on four anthropometric indices: height, weight, waist circumference, and hip circumference. For this study, we used the "Individual Recode" data file (or woman data file), retrieved from https://dhsprogram.com/ after requesting the same. In this file, information on total 724,115 women aged 15-49 years was collected, of which 241,180 women belonged to age group of 15-24 years and 81,557 of these 241,180 women had reported being in a marital union (also called "currently married women" in NFHS-5) on the survey date. We excluded never married (n: 158,224), widowed (n: 327), divorced (n: 345), and separated women (n: 727) from the analysis. As a next step, of the currently married women, we selected the women who got married on or after the year they reached their menarche, which left us with 78,724 women. As the final sample, 71,832 women were found eligible for analyzing BMI, thinness, overweight including obesity, and weight, whereas 71,669 women were included for the analysis of WC, WC>80 cm, hip circumference, WHR, and WHR $\geq$ 0.85 cm. A schema of sample derivation is presented in **Figure 2.1**.

2.2.2 *Outcome events*

Total nine indicators of the nutritional status of young women were defined by the measurement of their anthropometric indices: height, weight, and body circumferences (Lele et al., 2016). While the height of an individual reflects the linear growth of skeleton, (under or over) weight is indicative of imbalances between intake and expenditure of dietary energy, potentially triggered by many factors including physical activity, diet quality, and illness that cause deposition or loss of muscle, fat, and other tissues (Lele et al., 2016). Given the nonlinear relationship between height and normal body weight, the principal indicator of weight for adolescents and adults is the BMI, defined as a person's weight in kilograms divided by the square of the person's height in meters (kg/m^2). For this study, using information on height and weight, four measures of nutritional status, which are applicable for Asians (WHO Expert Consultation, 2004) were developed, namely BMI, thinness (BMI of <18.5 kg/m^2) or underweight, overweight including obesity (BMI of $\geq$23 kg/m^2), and measured weight. In NFHS-5, the height of adults was measured with SECA 213 stadiometer while SECA 874 digital scale was used to measure the weight (International Institute for Population Sciences and ICF, 2021). NFHS-5 dataset provided information on BMI up to two decimal points whereas the datapoints on weight are provided up to one decimal point.

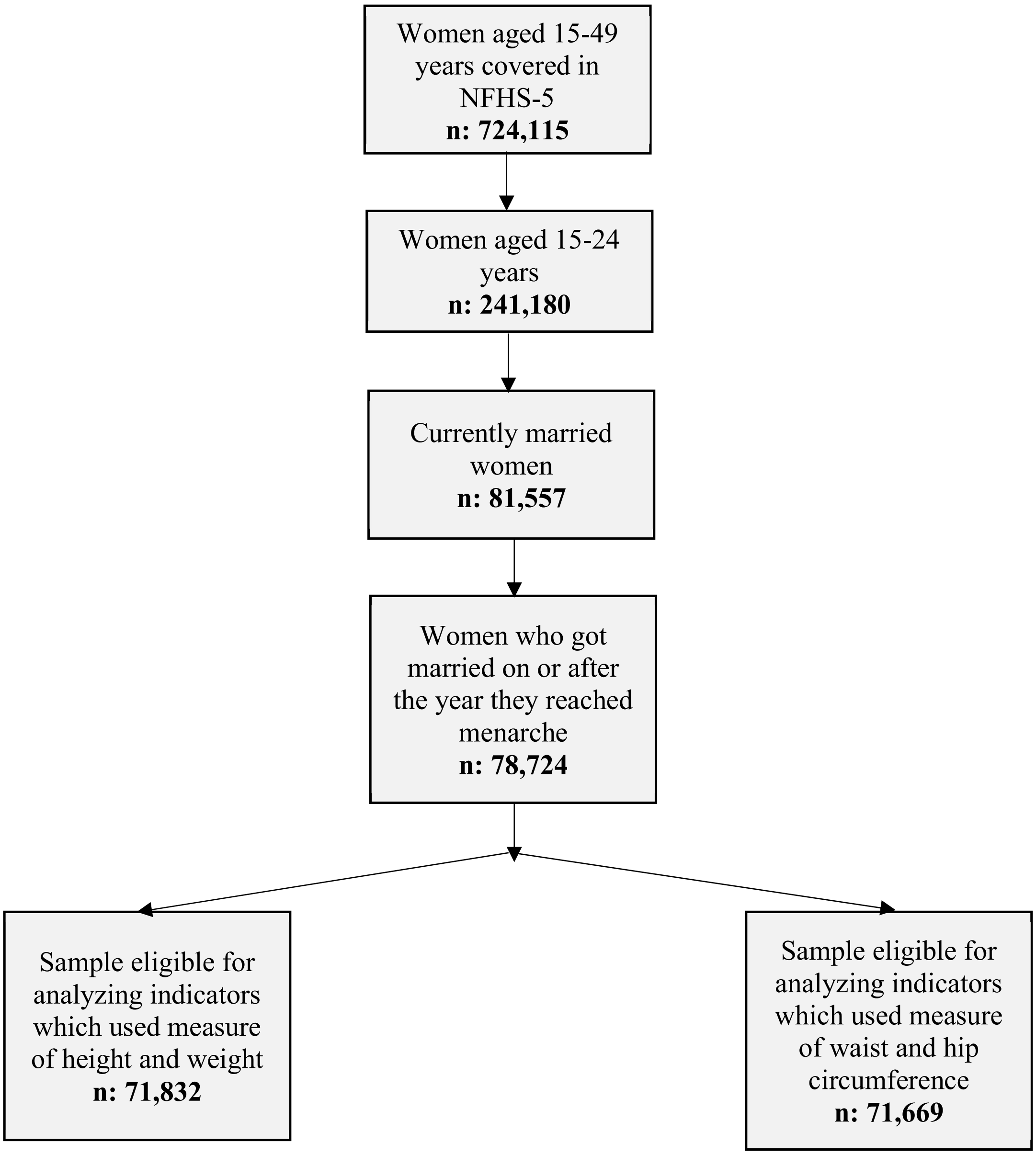

Figure 2.1. A schema of sample derivation.

In addition of the four outcome events mentioned above, five additional nutritional outcome events were developed using the measurements of waist and hip circumference. As the location of accumulated fat in the body has a significant influence on the metabolic conditions of the body, circumferences may provide a more accurate predictor than BMI of cardiovascular risk, type 2 diabetes, and metabolic syndrome (Lele et al., 2016). The outcome variables of interest were waist circumference or WC (measured in centimeter or cm), WC with increased risk of metabolic complications (>80 cm), hip circumference or HC (measured in cm), WHR, and WHR with substantially increased risk of metabolic complications (≥0.85 cm) (World Health Organization, 2011). In NFHS-5, waist and hip circumference measurements was taken by using Gulick tapes (International Institute for Population Sciences and ICF, 2021).

2.2.3 *Covariates*

To estimate the causal effect between the age of marriage among women aged 15-24 years and their nutritional status, adjustment of control variables is not essential in IV strategy. However, adjustment of control variable provides precision of estimates while minimizing the chance of potential violation of IV assumptions (Bärnighausen et al., 2017). Control variables representing woman's characteristics (height in meters and year of birth), and household level characteristics (altitude of living, household size, wealth index, religion social group, place of residence, district) were used. The choice of control variable was guided by a recent study (Sunder, 2019) conducted in Uganda to study the impact of age of marriage on woman's education and reproductive and maternal healthcare use using the age of menarche as an IV. NFHS-5 provides the variable wealth index, a proxy indicator of economic groups, calculated using household assets and durables (Rutstein and Johnson, 2004). For social groups, as per the Constitution of India, Scheduled Castes, Scheduled Tribes and Other Backward Classes are historically socially and economically disadvantaged populations, whereas the 'Others' category represents the population that has historically been relatively more privileged (Rai et al., 2022).

2.2.4 *Causal identification: age of menarche as an IV*

Descriptive statistics were produced to understand the characteristics of the sample. We used age at menarche as an IV for the timing of marriage in a two-stage least squares (2SLS) estimation strategy to demonstrate the impact of age of marriage on indicators of young women's nutritional status. The 2SLS model specifications could be written as below:

First stage: $Age\ of\ Marriage_j = \alpha_0 + \alpha_1\, Age\ of\ Menarche_j + \alpha_2 Controls_j + \eta^1$

Second stage*:* $Y_j = \delta_0 + \delta_1 Age\ of\ Marriage_j + \delta_2 Controls_j + \eta^2$

The variables representing nutritional status Y_j would be for woman j; **Age of Marriage** j is the age at marriage of the woman; **Age of Menarche** j is the age at which a woman reached her menarche and **Controls** j include all the control variables that could potentially shape the outcome of interest. Both variables – age of menarche and age of marriage – were treated as continuous variables in the 2SLS estimation strategy. While BMI, weight, WC, HC, and WHR were treated as continuous outcome variables; rest of the variables – thinness/underweight, overweight including obesity, WC of >80 cm and WHR of ≥0.85 cm – were used as binary (0, 1) outcomes in the estimation strategy. It is worth mentioning that to run the IV regression model for BMI, thinness, and overweight including obesity, the height of the woman was not controlled as a potential covariate, because the measurement of BMI itself includes the height of a woman. Robust standard errors were clustered at the district level. Appropriate sample weighting provided with NFHS-5 dataset was used in the descriptive analysis. Statistical software Stata, v.14 (StataCorp., 2015) was used to execute the entire analysis.

In NFHS-5, women aged 15-24 years were asked “How old were you when you had your first monthly period?” The response was recorded as age in completed years. In IV method of impact assessment, three assumptions or conditions must be met for the age of menarche to be able to identify effects of age of marriage on the nutritional status of women aged 15-24 years; they are i) relevance condition and assumptions of ii) exclusion restriction and iii) monotonicity (Bärnighausen et al., 2017). Relevance condition states that the instrument – age of menarche – must be able to explain sufficient variation in the endogenous explanatory variable, and this condition is testable. As proposed by Staiger and Stock (Staiger and Stock, 1997) the F statistic of the excluded regressor in the first stage in 2SLS estimator was well above the critical value of 10 (the Kleibergen-Paap rk Wald F statistic), indicating the age of menarche is sufficiently strong for this study.

Secondly, the assumption of exclusion restriction entails that the instrument – age of menarche – must causally affect the outcome (woman’s nutritional status) only through the endogenous explanatory variable (Angrist et al., 1996). As argued in earlier studies in India (Chari et al., 2017; Carpena and Jensenius, 2021; Dhamija and Roychowdhury, 2020; Roychowdhury and Dhamija, 2021; Sekhri and Debnath, 2014) and elsewhere (Delprato et al., 2015; Huang et al., 2019; Sunder, 2019), the age of menarche is exogenous because it is biologically determined, thus a random life event. However, the assumption of exclusion restriction could be challenged as the age of menarche in India could be influenced by woman’s socioeconomic and nutritional conditions (Dahiya and Rathi, 2010; Nandi et al., 2020; Pathak et al., 2014). To control for the variation, a range of variables were adjusted in our IV strategy. The height of woman is suggested to be a proxy indicator of their childhood nutritional status (Field and Ambrus, 2008; Chari et al., 2017; Sunder, 2019). Research suggests that children with a lower stature in childhood and infancy have a lower height in adulthood (Adair, 2007; Currie and Vogl, 2013). Thus, controlling for woman’s height in this study offered an effect of woman’s childhood on their age of menarche. In addition, the use of birth year as a control variable took care of the effect that events in infancy can have on long-term outcomes, such as the age of menarche (Sunder, 2019), whereas controlling for the non-genetic factors such as altitude of living and districts accounted for the potential effect on the age of menarche due to variability in geographical conditions such as temperature and altitude of living (Shaw et al., 2018).

The third assumption of monotonicity states that all people who are affected by a given instrument are affected by it in the same way (Angrist et al., 1996), meaning absence of “defiers” whose treatment status would be affected in the “wrong” direction (Bärnighausen et al., 2017). This study included woman who got married only on or after the year she had her menarche, which rules out the possibility of presence of “defiers” in this study, thus the assumption of monotonicity is satisfied in this IV estimation study.

2.2.5 *Ethics statement*

Prior to conducting the 2019-2021 National Family Health Survey, ethical approval was obtained by the International Institute for Population Sciences from an independent ethics review committee constituted by the Ministry of Health and Family Welfare, Government of India. This research complies with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Thus, no separate ethical approval was required for this study.

2.3 Results

2.3.1 *Descriptive statistics*

The sample included in the analysis had the minimum age of menarche as 7 years, and the maximum age of menarche of 24 years (**Figure 2.2**); the mean age of marriage for the women who had her menarche by the age of 7 years was 18 years.

Figure 2.2. Relationship between age of menarche marriage (in completed years) and mean age at marriage (in completed years).

Table 2.1 provides summary statistics of BMI, thinness, overweight including obesity, and weight of 71,832 women. The mean BMI for overall population is 2119.4 (95% confidence interval or CI: 2116.7, 2122.1) or 21.2 kg/m^2 and mean weight is 487.6 (95% CI; 486.9, 488.3) or 48.8 kg. Nearly 23.3% (95% CI: 23.0%, 23.6%) and 24.9% (24.6%, 25.2%) women were estimated to be underweight and overweight, including obesity, respectively. The burden of thinness and overweight including obesity among woman who reached their age of menarche by ≤10 years was 16.6% and 32.5%, respectively. With increasing age of marriage, a monotonous decrease in the burden of underweight was registered and the burden of overweight including obesity among women who got married on or after 21 years of their age was 30.3% (95% CI: 29.6%, 31.1%). **Table 2.2** represents the mean/prevalence of WHR, WHR≥0.85 cm, WC, WC> 80 cm, and HC. Overall, the mean of WHR is 0.859 cm (95% CI: 0.858 cm, 0.860 cm) and 54.9% (95% CI: 54.5%, 55.2%) women had WHR of ≥0.85 cm. The mean WC was 75.5 cm (95% CI: 75.4 cm, 75.6 cm) and 31.2% (95% CI: 30.9%, 31.5%) women had WC of >80 cm. The mean HC of sampled population was 87.8 cm (95% CI: 87.7 cm, 87.9 cm). With increasing age of menarche, a monotonous decrease in WHR was registered. The highest burden of WHR of ≥0.85 cm and WC >80 cm was noticed among women who got married on or after 21 years of their age.

Table 2.1. Mean/ percentage of women with their measured body mass index (BMI), thinness, overweight including obesity, and weight, by background characteristics.

	Sample	BMI, mean (95% CI)	Thinness, % (95% CI)	Overweight including obesity, % (95% CI)	Weight, mean (95% CI)
Age of menarche (in years)					
≤10	554	2216.5 (2177.6, 2255.4)	16.6 (13.5, 20.2)	32.5 (28.4, 37.0)	503.8 (494.5, 513.1)
11-13	38,242	2123.5 (2119.7, 2127.2)	23.4 (23.0, 23.8)	25.5 (25.1, 26.0)	486.1 (485.2, 487.1)
14	21,069	2118.3 (2113.5, 2123.1)	22.9 (22.3, 23.4)	24.3 (23.7, 24.8)	489.0 (487.8, 490.2)
≥15	11,967	2104.7 (2098.3, 2111.1)	24.2 (23.5, 25.0)	23.8 (23.1, 24.6)	489.2 (487.6, 490.8)
Age of marriage (in years)					
≤14	2,460	2089.5 (2076.1, 2103.0)	26.6 (25.0, 28.3)	23.5 (22.0, 25.1)	474.0 (470.8, 477.3)
15-16	10,024	2091.9 (2085.0, 2098.7)	26.3 (25.5, 27.1)	22.6 (21.8, 23.3)	476.0 (474.4, 477.7)
17-18	22,964	2099.3 (2094.7, 2103.9)	24.8 (24.3, 25.3)	22.6 (22.1, 23.1)	481.7 (480.5, 482.8)
19-20	21,887	2123.8 (2118.9, 2128.7)	22.9 (22.4, 23.5)	25.3 (24.7, 25.9)	490.5 (489.3, 491.7)
≥21	14,497	2174.3 (2167.9, 2180.6)	18.5 (17.9, 19.2)	30.3 (29.6, 31.1)	504.9 (503.3, 506.5)
Height (in centimeter)					
<145	9,076	2136.2 (2128.0, 2144.4)	22.5 (21.7, 23.4)	26.0 (25.1, 26.8)	427.6 (426.1, 429.1)
145-149.9	18,896	2108.5 (2103.6, 2113.5)	23.2 (22.7, 23.8)	23.3 (22.8, 23.9)	461.0 (459.9, 462.1)
150-154.9	24,336	2127.7 (2123.2, 2132.2)	22.4 (21.9, 22.9)	25.3 (24.8, 25.8)	494.3 (493.2, 495.3)
155-159.9	13,819	2117.9 (2111.8, 2124.1)	23.8 (23.1, 24.5)	25.5 (24.8, 26.2)	523.3 (521.7, 524.8)
≥160	5,705	2096.3 (2086.3, 2106.3)	27.9 (26.8, 29.0)	25.3 (24.2, 26.4)	557.6 (555.0, 560.3)
Religion					
Hinduism	58,784	2108.8 (2106.0, 2111.7)	24.1 (23.8, 24.4)	23.8 (23.5, 24.2)	484.8 (484.1, 485.5)
Islam	7,366	2174.9 (2166.9, 2182.8)	19.2 (18.4, 20.0)	30.8 (29.9, 31.8)	502.1 (500.1, 504.0)
Christian	3,417	2199.4 (2177.0, 2221.9)	18.0 (16.0, 20.2)	31.6 (29.1, 34.2)	505.7 (500.1, 511.2)
Others	2,265	2153.1 (2132.5, 2173.8)	21.3 (19.2, 23.5)	27.4 (25.2, 29.8)	502.1 (496.8, 507.4)
Social group					
Others	10,825	2173.7 (2166.8, 2180.6)	20.0 (19.3, 20.7)	30.8 (30.0, 31.6)	505.8 (504.1, 507.5)
OBC	30,892	2132.7 (2128.7, 2136.7)	22.0 (21.6, 22.5)	26.0 (25.6, 26.5)	492.5 (491.5, 493.5)
ST	13,503	2027.3 (2020.6, 2033.9)	29.7 (28.7, 30.6)	15.7 (14.9, 16.5)	462.2 (460.6, 463.9)
SC	16,612	2100.0 (2094.9, 2105.1)	25.1 (24.5, 25.7)	23.0 (22.4, 23.6)	478.0 (476.8, 479.3)
Type of place of residence					
Urban	12,228	2207.3 (2200.9, 2213.6)	18.4 (17.8, 19.0)	34.1 (33.4, 34.8)	511.8 (510.3, 513.4)
Rural	59,604	2094.0 (2091.1, 2096.9)	24.8 (24.4, 25.1)	22.3 (21.9, 22.6)	480.6 (479.9, 481.3)
Wealth index					
Poorest	17,722	2008.7 (2004.2, 2013.1)	30.8 (30.1, 31.4)	13.4 (12.9, 13.9)	451.1 (450.0, 452.2)
Poorer	18,089	2072.3 (2067.4, 2077.3)	25.9 (25.3, 26.6)	20.1 (19.5, 20.7)	471.8 (470.6, 473.0)
Middle	15,674	2135.6 (2129.8, 2141.4)	22.4 (21.8, 23.1)	26.4 (25.7, 27.1)	492.5 (491.1, 493.9)
Richer	12,644	2193.7 (2187.2, 2200.2)	18.4 (17.8, 19.1)	33.0 (32.2, 33.7)	512.4 (510.8, 514.0)
Richest	7,703	2268.9 (2260.1, 2277.7)	13.9 (13.3, 14.7)	40.2 (39.2, 41.2)	537.9 (535.7, 540.1)
Household size					
<4	11,721	2137.3 (2130.4, 2144.1)	21.8 (21.1, 22.6)	26.6 (25.8, 27.4)	489.3 (487.6, 491.0)
4-5	25,458	2131.2 (2126.6, 2135.9)	22.9 (22.4, 23.4)	26.2 (25.7, 26.8)	490.4 (489.2, 491.5)
≥6	34,653	2105.0 (2101.3, 2108.7)	24.2 (23.8, 24.6)	23.4 (23.0, 23.8)	485.1 (484.2, 486.0)
Total	71,832	2119.4 (2116.7, 2122.1)	23.3 (23.0, 23.6)	24.9 (24.6, 25.2)	487.6 (486.9, 488.3)

All sample counts are unweighted.
CI: confidence interval, OBC: other backward classes, SC: scheduled caste, ST: scheduled tribe

Table 2.2. Mean/ percentage of women with their measured waist circumference (WC) WC >80 cm, hip circumference (HC), waist-to-hip ratio (WHR), and WHR ≥0.85 cm, by background characteristics.

	Sample	WHR, mean (95% CI)	WHR ≥0.85 cm, % (95% CI)	WC, mean (95% CI)	WC >80 cm, % (95% CI)	HC, mean (95% CI)
Age of menarche (in years)						
≤10	547	0.876 (0.865, 0.887)	60.9 (56.3, 65.2)	78.4 (76.8, 80.0)	37.6 (33.3, 42.1)	89.3 (88.2, 90.4)
11-13	38,160	0.863 (0.862, 0.864)	57.1 (56.6, 57.6)	75.7 (75.6, 75.8)	31.7 (31.2, 32.1)	87.7 (87.6, 87.8)
14	21,023	0.857 (0.856, 0.858)	53.4 (52.7, 54.0)	75.3 (75.2, 75.5)	30.7 (30.1, 31.3)	87.9 (87.8, 88.0)
≥15	11,939	0.851 (0.849, 0.853)	50.1 (49.2, 51.0)	74.9 (74.7, 75.1)	30.4 (29.6, 31.2)	88.0 (87.8, 88.2)
Age of marriage (in years)						
≤14	2,459	0.856 (0.852, 0.860)	53.5 (51.6, 55.3)	74.2 (73.8, 74.6)	26.3 (24.8, 28.0)	86.8 (86.4, 87.2)
15-16	10,019	0.858 (0.856, 0.860)	55.0 (54.1, 55.9)	74.6 (74.4, 74.8)	27.9 (27.1, 28.8)	86.9 (86.7, 87.0)
17-18	22,909	0.857 (0.856, 0.858)	53.9 (53.3, 54.5)	74.9 (74.7, 75.0)	29.3 (28.7, 29.9)	87.3 (87.2, 87.4)
19-20	21,838	0.859 (0.858, 0.861)	55.1 (54.4, 55.7)	75.7 (75.6, 75.9)	32.2 (31.6, 32.8)	88.1 (87.9, 88.2)
≥21	14,444	0.863 (0.861, 0.865)	56.4 (55.6, 57.2)	77.1 (76.9, 77.3)	36.4 (35.6, 37.2)	89.3 (89.1, 89.4)
Height (in centimeter)						
<145	9,065	0.861 (0.860, 0.863)	55.5 (54.5, 56.5)	72.3 (72.1, 72.5)	21.2 (20.4, 22.1)	83.9 (83.7, 84.0)
145-149.9	18,859	0.860 (0.859, 0.861)	55.5 (54.8, 56.2)	74.1 (73.9, 74.2)	26.1 (25.5, 26.8)	86.1 (85.9, 86.2)
150-154.9	24,255	0.860 (0.858, 0.861)	55.5 (54.9, 56.1)	76.0 (75.9, 76.1)	32.4 (31.8, 33.0)	88.4 (88.2, 88.5)
155-159.9	13,778	0.856 (0.855, 0.858)	53.1 (52.3, 53.9)	77.2 (77.0, 77.4)	37.7 (36.9, 38.5)	90.2 (90.0, 90.3)
≥160	5,712	0.857 (0.855, 0.860)	53.4 (52.2, 54.7)	78.7 (78.4, 79.0)	43.2 (41.9, 44.4)	91.8 (91.6, 92.1)
Religion						
Hinduism	58,657	0.857 (0.856, 0.857)	53.5 (53.1, 53.9)	75.1 (75.0, 75.2)	30.0 (29.6, 30.3)	87.6 (87.5, 87.7)
Islam	7,347	0.873 (0.871, 0.875)	63.3 (62.3, 64.2)	77.6 (77.3, 77.8)	38.0 (37.0, 39.0)	88.8 (88.6, 89.0)
Christian	3,403	0.868 (0.863, 0.872)	57.4 (54.6, 60.1)	77.7 (77.0, 78.4)	36.3 (33.7, 39.0)	89.4 (88.8, 90.0)
Others	2,262	0.869 (0.864, 0.874)	60.0 (57.4, 62.5)	77.0 (76.3, 77.7)	35.8 (33.4, 38.4)	88.4 (87.9, 88.9)
Social group						
Others	10,813	0.864 (0.862, 0.865)	57.4 (56.5, 58.2)	77.3 (77.1, 77.5)	37.2 (36.4, 38.1)	89.5 (89.3, 89.7)
OBC	30,793	0.857 (0.856, 0.858)	54.0 (53.4, 54.5)	75.6 (75.5, 75.8)	32.4 (31.9, 32.8)	88.2 (88.1, 88.3)
ST	13,493	0.853 (0.851, 0.855)	53.2 (52.2, 54.3)	72.5 (72.3, 72.7)	19.9 (19.1, 20.8)	85.0 (84.8, 85.2)
SC	16,570	0.861 (0.860, 0.863)	55.5 (54.8, 56.2)	75.2 (75.1, 75.4)	30.1 (29.4, 30.7)	87.3 (87.1, 87.4)
Type of place of residence						
Urban	12,166	0.864 (0.862, 0.865)	57.6 (56.8, 58.3)	77.7 (77.5, 77.9)	39.1 (38.4, 39.9)	90.0 (89.8, 90.1)
Rural	59,503	0.858 (0.857, 0.859)	54.1 (53.7, 54.5)	74.8 (74.7, 74.9)	28.9 (28.6, 29.3)	87.2 (87.1, 87.3)
Wealth index						
Poorest	17,704	0.858 (0.857, 0.860)	54.6 (53.8, 55.3)	72.6 (72.5, 72.8)	20.7 (20.1, 21.3)	84.6 (84.4, 84.7)
Poorer	18,069	0.859 (0.858, 0.860)	54.7 (54.0, 55.4)	74.3 (74.2, 74.5)	26.9 (26.3, 27.6)	86.5 (86.3, 86.6)
Middle	15,632	0.859 (0.857, 0.860)	54.0 (53.3, 54.8)	75.8 (75.7, 76.0)	32.5 (31.8, 33.2)	88.3 (88.1, 88.4)
Richer	12,600	0.857 (0.856, 0.859)	54.3 (53.5, 55.1)	77.3 (77.1, 77.5)	38.6 (37.8, 39.4)	90.1 (89.9, 90.2)
Richest	7,664	0.864 (0.862, 0.866)	58.3 (57.3, 59.3)	79.5 (79.3, 79.8)	45.1 (44.1, 46.1)	92.1 (91.9, 92.3)
Household size						
<4	11,665	0.863 (0.861, 0.865)	56.6 (55.8, 57.5)	76.0 (75.8, 76.3)	33.4 (32.6, 34.3)	88.0 (87.9, 88.2)
4-5	25,404	0.861 (0.860, 0.862)	56.3 (55.7, 56.9)	75.8 (75.6, 75.9)	31.9 (31.3, 32.4)	87.9 (87.8, 88.0)
≥6	34,600	0.856 (0.855, 0.857)	53.3 (52.8, 53.8)	75.1 (75.0, 75.2)	30.0 (29.5, 30.4)	87.7 (87.6, 87.8)
Total	71,669	0.859 (0.858, 0.860)	54.9 (54.5, 55.2)	75.5 (75.4, 75.6)	31.2 (30.9, 31.5)	87.8 (87.7, 87.9)

All sample counts are unweighted.
CI: confidence interval, cm: centimeter, OBC: other backward classes, SC: scheduled caste, ST: scheduled tribe

2.3.2 *Effects of age at marriage on nutritional status*

Table 2.3 represents the causal effect of the age of marriage on select indictors of nutritional status of woman aged 15-24 years. One unit increase in the age of marriage could lead to 59.5 unit decrease in BMI (95% CI: -75.0, -43.9), p<0.001]. One year increase in age of marriage could lead to nearly 2 percentage points increase in thinness [0.02 (95% CI: 0.004, 0.038), p=0.016], 6 percentage points decrease in overweight including obesity [-0.06 (95% CI: -0.08, -0.47), p<0.001], and 12.3 unit decrease in weight [-12.3 (95% CI: -15.8, -8.8), p<0.001]. In case of WC and HC, one year increase in the age of marriage could result into 0.004 unit decrease in WHR [-0.004 (95% CI: -0.008, -0.0005), p=0.025], 3 percentage points decrease in WHR ≥0.85 cm [-0.03 (95% CI: -0.05, -0.01), p=0.001], 1.35 unit decrease in WC, 4 percentage point decrease in WC>80 cm [-0.04 (95% CI: -0.06, -0.02), p<0.001], and 1.12 unit decrease in HC [-1.12 (95% CI: -1.52, -0.73), p<0.001].

Table 2.3. Causal effect of age of marriage on nutritional status of women aged 15-24 years.

		2SLS	
	OLS β (95% CI), *p*	**First stage** β (95% CI), *p*, [F-statistic]	**Second stage** β (95% CI), *p*
Sample: 71,832			
BMI	-3.58 (-4.86, -2.30), <0.001	0.17 (0.16, 0.19), <0.001, [570]	-59.5 (-75.0, -43.9), <0.001
Thinness	-0.001 (-0.002, 0.001), 0.249	0.17 (0.16, 0.19), <0.001, [570]	0.02 (0.004, 0.038), 0.016
Overweight including obesity	-0.004 (-0.006, -0.003), <0.001	0.17 (0.16, 0.19), <0.001, [570]	-0.06 (-0.08, -0.47), <0.001
Weight	-0.79 (-1.08, -0.50), <0.001	0.17 (0.16, 0.19), <0.001, [570]	-12.3 (-15.8, -8.8), <0.001
Sample: 71,669			
WHR	0.0009 (0.0006, 0.0012), <0.001	0.17 (0.16, 0.19), <0.001, [568]	-0.004 (-0.008, -0.0005), 0.025
WHR ≥0.85 cm	0.004 (0.002, 0.006), <0.001	0.17 (0.16, 0.19), <0.001, [568]	-0.03 (-0.05, -0.01), 0.001
WC	0.01 (-0.03, 0.05), 0.675	0.17 (0.16, 0.19), <0.001, [568]	-1.35 (-1.83, -0.88), <0.001
Waist >80 cm	-0.00002 (-0.00163, 0.00160), 0.985	0.17 (0.16, 0.19), <0.001, [568]	-0.04 (-0.06, -0.02), <0.001
HC	-0.08 (-0.12, -0.05), <0.001	0.17 (0.16, 0.19), <0.001, [568]	-1.12 (-1.52, -0.73), <0.001

The control variables include mother's height (except for BMI, thinness, and overweight including obesity), religion, social group, type of place of residence, wealth index, household size, and cluster altitude (in meters).
All specifications also include birth-year of women and district fixed effects. F-statistic are adjusted for clusters on districts.
β: coefficient, BMI: body mass index, CI: confidence interval, cm: centimeter, HC: hip circumference, OLS: ordinary least square, p: level of significance, WC: waist circumference, WHR: waist-to-hip ratio, 2SLS: two-stage least squares method.

2.3.3 *Potential mechanisms*

Our study demonstrates that with one year increase in the age of marriage among woman aged 15-24 years could lead to decreased BMI, overweight including obesity, and weight, whereas it could increase their thinness. Similarly, with increased age of marriage, WHR, WHR ≥0.85 cm, WC, WC >80 cm, and HC tend to decrease. Literature suggests that the adverse impact of the age of marriage on a woman's nutritional status might be mediated by the woman's bargaining power and her preferences regarding investment on themselves (Yount et al., 2018; Wodon et al., 2017). We test if this is true for Indian young women. Women's bargaining power in a household could be expressed in terms of their autonomy and women exercising their autonomy are less likely to experience malnutrition (Kadiyalaet al., 2014). In the Indian context, we define autonomy "as the control women have over their own lives – the extent to which they have an equal voice with their husbands in matters affecting themselves and their families, control over material and other resources, access of knowledge and information, the authority to make independent decisions, freedom from constraints on physical mobility, and the ability to forge equitable power relationship withing families (Jejeebhoy and Sathar, 2001)."

To test if women's age of marriage could affect their later life nutritional status, it is essential to examine if the age of marriage could affect women's autonomy. Any relationship between the age of marriage and women's autonomy could be interpreted as having a relation between autonomy and nutritional status as well, as empirically demonstrated in earlier studies (Chari et al., 2017; Sunder, 2019). NFHS-5 collects information on various dimensions of women's agency in decision-making within the household. A sub-sample of currently married women was asked about the person responsible for decision making on three aspects of their daily life: i) the person who usually decides on woman's own health care, ii) the person who usually decides on large household purchases, and iii) the person who usually decides on visits to relatives. The possible responses were coded into five categories, namely respondent herself, her husband, respondent and husband jointly, someone else in household, and other. The women who responded to be solely responsible for decision making were defined as women having liberty in decision making (Sunder, 2019; Chol et al., 2019). In addition, we also constructed two variables representing spousal characteristics: spousal age gap (age of the wife minus the age of husband) and spousal education gap (years of education of wife minus years of education of husband) as indicators being strong predictors of women autonomy (Jejeebhoy and Sathar, 2001). Findings are presented in **Table 2.4**. Of the five indicators of woman's autonomy, only spousal gap in years of education was found to be affected by the age of marriage – one year increase in age of marriage among woman aged 15-24 years could yield 0.43 additional years of education (95% CI: 0.05, 0.80), *p*: 0.025 among women as compared to their husband.

Table 2.4. Potential mechanism: impact of age of marriage on indicators of woman's autonomy.

	2SLS		**Sample**
	First stage β (95% CI), *p*, [F-statistic]	**Second stage** β (95% CI), *p*	
Spousal age gap	0.18 (0.15, 0.22), <0.001, [96]	0.16 (-0.17, 0.48), 0.336	10,761
Spousal education gap	0.19 (0.15, 0.22), <0.001, [97]	0.43 (0.05, 0.80), 0.025	10,715
Own healthcare	0.19 (0.15, 0.22), <0.001, [96]	-0.009 (-0.033, 0.014), 0.449	10,761
Large household purchases	0.19 (0.15, 0.22), <0.001, [96]	0.009 (-0.011, 0.031), 0.376	10,761
Visiting family or relatives	0.19 (0.15, 0.22), <0.001, [96]	0.004 (-0.015, 0.024), 0.671	10,761

The control variables include mother's height, religion, social group, type of place of residence, wealth index, household size, and cluster altitude (in meters).
All specifications also include birth-year of women and district fixed effects. F-statistic are adjusted for clusters on districts.
β: coefficient, CI: confidence interval, OLS: ordinary least square, p: level of significance, 2SLS: two-stage least squares method.

2.3.4 *Robustness check*

A rigorous checking for robustness is essential for findings to be considered stable and affected by definitional changes and other variations. We conducted three robustness checks to support our findings. First, we did not limit our analysis to the women who had achieved their age of menarche between 11 and 16 years of age, as was in the first study conducted in Bangladesh, which used the age of menarche as an IV (Field and Ambrus, 2008). However, we replicated our analysis (**Table 2.5**) for this age group of menarche to examine if the direction of findings changes. We did not find any change in the direction, except that the effect of age of marriage on WHR appeared statistically non-significant (p = 0.108).

Table 2.5. Robustness check: Impact of age of marriage on nutritional status of woman, considering age of marriage aged 11-16 years.

	2SLS	
	First stage β (95% CI), *p,* [F-statistic]	**Second stage** β (95% CI), *p*
Sample: 70,255		
BMI	0.17 (0.15, 0.18), <0.001, [409]	-0.66.8 (-86.3, -0.47.4), <0.001
Thinness	0.17 (0.15, 0.18), <0.001, [409]	0.02 (0.001, 0.043), 0.034
Overweight including obesity	0.17 (0.15, 0.18), <0.001, [409]	-0.08 (-0.099, -0.057), <0.001
Weight	0.17 (0.15, 0.18), <0.001, [406]	-13.7 (-18.1, -9.3), <0.001
Sample: 70, 099		
WHR	0.17 (0.15, 0.18), <0.001, [410]	-0.004 (-0.008, 0.001), 0.108
WHR ≥0.85 cm	0.17 (0.15, 0.18), <0.001, [410]	-0.02 (-0.049, -0.001), 0.043
WC	0.17 (0.15, 0.18), <0.001, [410]	-1.46 (-2.01, -0.91), <0.001
Waist >80 cm	0.17 (0.15, 0.18), <0.001, [410]	-0.05 (-0.07, -0.03), <0.001
HC	0.17 (0.15, 0.18), <0.001, [410]	-1.28 (-1.77, -0.79), <0.001

The control variables include mother's height (except for BMI, thinness, and overweight including obesity), religion, social group, type of place of residence, wealth index, household size, and cluster altitude (in meters). All specifications also include birth-year of women and district fixed effects. F-statistic are adjusted for clusters on districts.

β: coefficient, BMI: body mass index, CI: confidence interval, cm: centimeter, HC: hip circumference, p: level of significance, WC: waist circumference, WHR: waist-to-hip ratio, 2SLS: two-stage least squares method.

Secondly, an alternate definition of the age of marriage was developed using different cut-offs – women who got married at <21 years, <18 years, and <14 years, which were estimated to be 81.3%, and 33.6%, and 1.2% respectively (estimated by authors using NFHS-5 data). To check the robustness, similar instrumental variable strategy was deployed to compare the finding where the age of marriage was used as a continuous variable and the finding where the age of marriage was used as a dichotomous variable (if women got married before the age of 21, 18, and 14, this was coded as 1, otherwise as 0). Findings on the impact of alternate definition of the age of marriage on woman's nutritional status (**Table 2.6**) corroborates findings from the main analysis (**Table 2.3**), which is suggestive of model stability.

Table 2.6. Robustness check: different definitions of age of marriage (<21 years, <18 years, and <14 years).

	<21 years β (95% CI), *p*	<18 years β (95% CI), *p*	<14 years β (95% CI), *p*
Sample: 71,832			
BMI	1152.4 (708.7,1596.2), <0.001	330.6 (242.7, 418.6), <0.001	1348.5 (966.0, 1731.0), <0.001
Thinness	-0.40 (-0.75, -0.06), 0.021	-0.12 (-0.21, -0.02), 0.016	-0.47 (-0.87, -0.08), 0.018
Overweight including obesity	1.25 (0.76, 1.73), <0.001	0.36 (0.26, 0.46), <0.001	1.46 (1.04, 1.88), <0.001
Weight	236.4 (141.9, 331.0), <0.001	68.6 (48.6, 88.7), <0.001	279.1 (192.9, 365.2), <0.001
Sample: 71,669			
WHR	0.080 (0.005, 0.155), 0.036	0.02 (0.003, 0.044), 0.026	0.09 (0.01, 0.18), 0.026
WHR ≥0.85 cm	0.62 (0.21, 1.04), 0.003	0.18 (0.07, 0.29), 0.001	0.74 (0.29, 1.19), 0.001
WC	25.8 (13.9, 37.6), <0.001	7.54 (4.85, 10.22), <0.001	30.6 (19.5, 41.7), <0.001
Waist >80 cm	0.81 (0.40, 1.22), <0.001	0.24 (0.13, 0.34), <0.001	0.96 (0.54, 1.38), <0.001
HC	21.4 (11.7, 31.2), <0.001	6.27 (4.02, 8.52), <0.001	25.4 (16.1, 34.8), <0.001

The control variables include mother's height (except for BMI, thinness, and overweight including obesity), religion, social group, type of place of residence, wealth index, household size, and cluster altitude (in meters).
All specifications also include birth-year of women and district fixed effects. F-statistic are adjusted for clusters on districts.
β: coefficient, BMI: body mass index, CI: confidence interval, cm: centimeter, HC: hip circumference, OLS: ordinary least square, p: level of significance, WC: waist circumference, WHR: waist-to-hip ratio, 2SLS: two-stage least squares method.

Finally, as this study deals with several outcome events of interest to test if the age of marriage affects them, a multiple-hypothesis testing analysis was undertaken to test the possibility of spurious p value. The values were reassessed and adjusted using Romano-Wolf method (**Table 2.7**).

Table 2.7. Robustness check: multiple hypothesis testing using Romano-Wolf method.

	Regular *p* value*	Adjusted *p* value from Romano-Wolf method**
BMI	<0.001	0.010
Thinness	0.016	0.010
Overweight including obesity	<0.001	0.010
Weight	<0.001	0.010
WHR	0.025	0.010
WHR ≥0.85 cm	0.001	0.010
WC	<0.001	0.010
Waist >80 cm	<0.001	0.010
HC	<0.001	0.010

* *p* values are from second stage of 2SLS estimator (Table 2.3)
** *p* values are estimated from Romano-Wolf method, specifying age of menarche as instrumental variables, while adjusting for control variables. The *p* values indicate effect of age of marriage on indictors of child nutrition.
BMI: body mass index, cm: centimeter, HC: hip circumference, p: level of significance, WC: waist circumference, WHR: waist-to-hip ratio

The Romano-Wolf procedure, a simultaneous testing method, follows a resampling algorithm and applies studentized bootstrap replications to test multiple hypotheses (Clarke et al. 2020; Romano and Wolf, 2016; Romano and Wolf, 2005). Findings indicate that the p value of <0.05 in main findings (**Table 2.3**) remains intact after the adjustment with Romano-wolf hypothesis testing, which is indicative of robustness of main findings.

2.4 Discussion

Using a nationally representative 2019-2021 National Family Health Survey dataset, we designed a quasi-experimental study to assess the causal effect of the age of marriage among young women (aged 15-24 years) on total nine indicators of their nutritional status. We used information on their age of menarche as an instrumental variable and applied 2SLS estimator to attain the study objective. This is the first study which estimated the impact of the age of marriage on a comprehensive set of indicators of nutritional status of young Indian women and our findings could objectively help programme and policy makers and donors to prioritize the intervention needed to mitigate the negative effect of low age of marriage on the nutritional status of young women in India.

Findings revealed that one year increase in the age of marriage could lead to decrease in BMI, weight, and overweight including obesity, whereas increasing the age of marriage could lead to increased burden of underweight. We searched for existing studies which tried to evaluate the impact of the age of marriage among women aged 15-24 years on their nutritional status, but we could not find any. However, a recent study (Goli et al., 2015) used 2015-2016 NFHS data and showed that girls married under-age were twice as likely to be undernourished as those married at age ≥25 years. This study was merely an attempt to explore the association. Young married women are the most vulnerable with their early marriage as they transit through a critical period of physical growth and biological maturity. Undernourished adolescents are likely to attain a shorter adult stature than expected and they face an increased risk of health complications in future (Marphatia et al., 2017). In the case of effects of age of marriage on indicators for waist and hip circumferences, findings revealed that one year increase in the age of marriage could negatively affect WHR, WHR ≥0.85 cm, WC, WC>80 cm, and HC. These findings indicate that with increased age of marriage, women aged 15-24 years are less likely to accumulate abdominal obesity. This finding corroborates the findings on BMI and weight.

In this study we attempted to explore the potential mechanism through which age of marriage among young women might affect their nutritional status. We found that increased age of marriage could yield 0.43 additional years of education among women, as compared to their husband. Earlier studies have documented that more educated women are likely to marry higher quality (Abramitzky et al., 2011), and as the age of marriage falls with the increasing gap in years of education, women are more likely to take part in decision making, which could perhaps prevent them from gaining BMI, weight, and abdominal obesity. However, the effect of women's autonomy on increased burden of underweight demands further exploration: if it is the negative unintentional effect of their effort to regulate their bodyweight.

The findings from this study should be interpreted considering its possible limitations. First, most of the information collected in NFHS-5 are recall-based, which might not be free from recall errors or/and social desirability bias. Second, this study analyzed the effect of age of marriage among young Indian mothers aged 15-24 years, thus the findings should be assumed for this age group only and should not be interpreted for women in the reproductive age group (aged 15-49 years). Despite these limitations, it is the first study to estimate the effect of age of marriage on a comprehensive set of indicators of nutritional status of young women and the findings were verified with a range of robustness check. For future research on using age of menarche as an IV to estimate effect of age of marriage on nutritional status of adolescent women, few suggestions may be considered. First, it would be essential to revisit the conceptual validity of age of menarche as an IV, as it might be the case that age of menarche is just reducing the measurement error while causal effect of age of marriage on adolescent nutrition are not captured. Second, this study shows that IV coefficients are much larger than OLS coefficients, which also requires further investigation if age of menarche is a good IV for the study. Third, it would be interesting to stratify the study by socio-economic status of adolescents while capturing state-wise heterogeneity. Fourth and final, even if age of menarche as an IV is valid by some statistical measure and relevant, it may not necessarily identify the average treatment effect (ATE) or the average treatment effect on the treated (ATET); it has probably identified the local average treatment effect (LATE), defined as the average treatment effect on the complier subpopulation. If this is the case of this study, future studies should also focus on investigating validity of age of menarche as an IV.

India houses the largest number of child brides in the world, which calls for a focused and effective intervention that would not only prevent adverse health outcome of child brides but will also make necessary arrangements to prevent poor health of their children as well. Indian Parliament has passed the bill of increasing legal age of marriage for women form 18 years to 21 years, but whether it would remove the deep-rooted social maladies around child marriage remains doubtful. This study has confirmed the concerted efforts needed by the Government of India to prevent child marriage and to mitigate the negative effect of the age of marriage on the nutritional status of young women. For example, if our study reveals that with increased age of marriage, young Indian women tend to be thin/ underweight, and an intervention may be designed targeting young women for their bodyweight monitoring. Failing to prevent child marriage and its adverse consequences would hamper achieving SDG Target 5.3 of eliminating "all harmful practices, such as child, early and forced marriage…," putting lives of millions of women, and their nutritional status, in danger.

3 Estimated effect of vitamin A supplementation on anaemia and anthropometric failure of Indian children†

RAJESH KUMAR RAI

ABSTRACT

India has an unacceptably high burden of vitamin A deficiency (VAD) among children aged 6-59 months. To mitigate VAD and its adverse effects on child health, the Indian government runs a nationwide vitamin A supplementation (VAS) programme. However, the effect of VAS in reducing child morbidity and mortality remains inconclusive and has been debated globally. In this paper, we estimate the effect of VAS on two indicators of child nutrition - anaemia (categorized into any anaemia, and mild/moderate anaemia) and anthropometric failure (categorized into stunting, wasting, and underweight) among children aged 6-59 months. Using the nationally representative 2015-2016 National Family Health Survey dataset from India, we estimated household and mother fixed-effects of VAS on select types of child anaemia and anthropometric failure. Findings from both the household fixed-effects and mother fixed-effects analysis showed that VAS does not influence any types of childhood anaemia and anthropometric failure in India. We discussed the findings considering existing literature and possible limitations of the study. Infirm association of Vitamin A on anaemia and anthropometric failure is probably indicative of targeted VAS intervention, as opposed to universal VAS programme.

Keywords: Vitamin A, anaemia, micronutrients, undernutrition, Epidemiology, Public Health

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3.1 Introduction

Vitamin A deficiency (VAD), measured as a plasma or serum retinol concentration of <0.70 μmol/L (micromole/ liter), is considered a major public health problem among children aged 6-59 months (World Health Organization, 2011). In 2013, nearly 29% of children were estimated to have VAD in 138 low-and-middle-income countries (Stevens et al., 2015). VAD is associated with morbidity and mortality from common childhood infections and is the world's leading preventable cause of childhood blindness (World Health Organization, 2011). Even mild, subclinical deficiency may increase the risk for respiratory and diarrheal infections among children, decrease growth rates, slow bone development, and decrease the likelihood of survival from serious illness (World Health Organization, 2011, Imdad et al., 2017; Tanumihardjo et al., 2016; Imdad et al., 2011). Earlier studies have confirmed the pathways through which VAD could cause anaemia (Gamble et al., 2006; Semba et al., 2002), and VAS could be an effective strategy to treat anaemia among children (Mwanri et al., 2000). The effects of VAD on anthropometric failure have also been studied (Ssentongo et al., 2020; Amaya-Castellanos et al., 2002) whereas moderate-to-severe VAD, marked by xerophthalmia, was estimated to impair normal physical growth among children (West et al., 1997). However, with growing research, the effect of universal VAS in mitigating childhood mortality and morbidity has been questioned.

To combat VAD, the World Health Organization (WHO) devised a guideline (World Health Organization, 2011) of vitamin A supplementation (VAS) for the population where the prevalence of night blindness is 1% or higher among children 24–59 months of age or where the prevalence of VAD is 20% or higher among infants and children aged 6–59 months. WHO recommended that infants aged 6-11 months should receive 100 000 IU or international units (30 mg RE or milligram retinol equivalent) of vitamin A once and children aged 12-59 months should receive 200 000 IU (60 mg RE) of vitamin A every 4–6 months. However, this recommendation of universal periodic VAS has been debated and challenged (Fawzi and Wang, 2021; West et al., 2015), and the most recent evidence questions the effect of VAS in reducing child deaths, whereas most deaths from measles and diarrhea appeared to be preventable in the present time (Fawzi and Wang, 2021; Mason et al., 2018). Thus, the effects of universal VAS programme on child health remains inconclusive, which demands further evidence to understand the need for universal periodic VAS in improving child health.

India's population suffers from a high burden of micronutrient deficiency, with an estimated VAD of 19% (95% confidence interval: 9%-29%) (Venkatesh et al., 2021). With a population of over 124 million children aged 6-59 months, India also runs a nationwide public VAS programme (Ministry of Health & Family Welfare, 2006). India adopted the VAS guideline developed by WHO and total nine oral doses of VAS was recommended for all children by their fifth birthday (Ministry of Health & Family Welfare, 2006). The Integrated Child Development Services (ICDS) programme established under the Department of Women and Child Development was tasked with periodic distribution of VAS doses to children to prevent VAD (Ministry of Health & Family Welfare, 2006). However, in line with the ongoing debate about the need and effectiveness of VAS programmes globally, this debate has also grown in India (Reddy et al., 2021; Greiner et al., 2019; Sareen and Kapil, 2016; Kapil and Sachdev, 2013). A recent study (Reddy et al., 2021) used the Comprehensive National Nutrition Survey (CNNS) data of children aged 1-5 years and concluded that national prevalence of VAD is 15.7% and a targeted approach (as opposed to universal) of VAS intervention was recommended considering India's progress in reduction of infant and child mortality, immunization coverage, and recent initiation of oil and milk fortification with vitamin A. However, these conclusions implied reasonable doubts about existing research findings and a careful interpretation of findings was urged (Fawzi and Wang, 2021). Responding to the CNNS based study (Reddy et al., 2021, a group of researchers welcomed the use of improved targeting or prioritization of VAS delivery to population groups at higher risk of VAD (Hasman et al., 2021), whereas a letter to the Editor (Sheftel et al., 2021) pointed out the insufficiency of evidence for proposing targeting in vitamin A supplementation strategy. The effectiveness of VAS was also questioned by the Deworming and Enhanced Vitamin A supplementation (DEVTA) study, a cluster-randomized trial, the largest program evaluation of universal VAS, conducted in the state of Uttar Pradesh in India, which found no benefits on all-cause or cause-specific mortality (Awasthi et al., 2013).

Therefore, while need of universal periodic VAS intervention among children in India has been questioned, it is worth exploring if there is any estimated impact of VAS on child health using the latest publicly available nationally representative data. Using appropriate MeSH (Medical Subject Headings) terms, we searched for the existing literature on this issue in India and found no recent national study has to date tried to assess the effect of VAS on various child health indicators in India. To fill this evidence gap, using a nationally representative dataset from India, we set-up a fixed-effects (household- and-mother-fixed effects) study design to estimate the relationship of VAS with childhood anaemia (categorized into any anaemia, and mild/moderate anaemia), and anthropometric failure (categorized into stunting, wasting, and underweight), among children aged 6-59 months in India. In context of availability of its first national estimates of VAD among children aged 1-5 years (Awasthi et al., 2013; Ministry of Health and Family Welfare et al., 2019), this study will be a timely effort and could be a significant research contribution for discussion about the need for universal periodic VAS programmes to correct childhood anaemia and anthropometric failure in India.

3.2 Methods

3.2.1 *Dataset*

The dataset used for this study was retrieved from the fourth wave of nationally representative cross-sectional standard Demographic and Health Survey of India, commonly known as the 2015-2016 National Family Health Survey (or NFHS-4) (International Institute for Population Sciences and ICF, 2017). Financially supported by the Ministry of Health and Family Welfare, NFHS-4 provides information on population, health, and nutrition for 37 state/ union territories of India, credibly used by programme and policy makers to guide national public health policy. NFHS-4 used the 2011 Census of India sampling frame and adopted a two-stage stratified sampling design to select the primary sampling unit (PSU) in rural (villages) and urban areas (CEB or Census Enumeration Blocks). Within each rural stratum, villages were selected from the sampling frame with probability proportional to size (PPS). In each stratum, six approximately equal substrata were created by crossing three substrata, each created based on the estimated number of households in each village, with two substrata, each created based on the percentage of the population belonging to scheduled castes (SCs) and scheduled tribes (STs). CEBs in urban areas were sorted according to the percentage of the SC/ST population in each CEB, and sample CEBs were selected with PPS sampling. With an over 97% household response rate, total 601,509 households were selected to interview 699, 686 women and 112, 122 men in NFHS-4. More about the sampling procedure can be obtained from its published report (International Institute for Population Sciences and ICF, 2017).

We used the children recode file of NFHS-4 having information for 259,627 children. On behalf of children born in the five years preceding the survey date, mothers responded and helped NFHS-4 gather information on child mortality, child nutrition, childhood diseases and several other child health indicators. It is worth mentioning that unlike the earlier three rounds of NFHS, NFHS-4 covers information on large number of children helped in setting-up this study. To select the final sample eligible for the household-and-mother-fixed-effects analysis, a four-stage sample recruiting method was followed. At stage I, all outcome variables and control variables (VAS and other variables) were constructed. In stage II, all the observation of children aged <6 months and >59 months of age were dropped from the dataset, keeping children aged 6-59 months for the analysis. Stage III involved the computation of unique identification numbers for all households and all mothers, and selected households which had at least two children for the analysis of household fixed-effects, and for mother fixed-effects we developed a dataset with mothers who had at least two children. Finally, stage IV included preparation of the dataset which included only households or mothers whose children had differing status in receiving VAS. Once the dataset is finalized, a total number of 21,475 and 21,021 children were found to be eligible for running household-fixed-effects analysis for anaemia and anthropometric failures, respectively. On the other hand, for analyzing mother fixed-effects, a total of 16,676, and 16,298 children were included to analyze anaemia and anthropometric failures, respectively.

3.2.2 *Outcome events*

A total of five outcome events were analyzed. They are anaemia (categorized into any anaemia, and mild/ moderate anaemia) and anthropometric failure (categorized into stunting, wasting, and underweight). Indian children experience a high prevalence of anaemia (58.6% as in 2015-2016) and little improvement has been recorded in the last decade (Rai et al., 2021). WHO guidelines (World Health Organization, 2017) classify a hemoglobin (Hb) level of <11 grams/ deciliter or g/dl as having any anaemia, whereas Hb of 7-10.9 g/dl is defined as mild/ moderate anaemia. NFHS-4 provides Hb estimates of children adjusted for the altitude of their residence. Using HemoCue Hb 201+ analyzer, NFHS-4 measured Hb level from the capillary blood sample of children aged 6-59 months. After excluding biologically implausible values, anthropometric failure (stunting, wasting, and underweight) were computed. Stunting was defined as <-2 standard deviations from median height for age of the reference population; wasting was defined as <-2 standard deviations from median weight for height of the reference population, and underweight was defined as <-2 standard deviations from median weight for age of the reference population (WHO Multicenter Growth Reference Study Group, 2006). For child anthropometry, "SECA 874 U digital scale" was used for weighing, "SECA 213 Stadiometer" for measuring height, and "SECA 417 Infantometer" was used for measuring the length of children under 2 years or less than 85 cm. NFHS-4 reported that 38.4%, 21%, and 35.8% of children under-five were stunted, wasted, and underweight, respectively (International Institute for Population Sciences and ICF, 2017).

3.2.3 *Vitamin A supplementation (VAS) and other control variables*

As a primary control variable, the information on VAS was used. In NFHS-4, women were asked about each living child born in 2011 or later – "within the last six months, was (the child) given a vitamin A dose?" A sample of vitamin A dose was shown to respondents to minimize recall errors. As stated earlier, children aged between 6 months and 59 months are expected to receive nine doses of VAS in total (World Health Organization, 2011). Although NFHS-4 does not include the number of VAS doses a child received, the information on receipt of VAS in the six months preceding the survey date indicates if the receipt of VAS is timely and one may expect that child receiving timely VAS will have better health than children who did not receive any VAS six months preceding the survey date. As estimated from NFHS-4 data, nearly 58.6% children aged 6-59 months received VAS dose, which is a threefold increase in VAS from NFHS 2005-2006 (International Institute for Population Sciences and ICF, 2017).

Apart from the primary variable of interest, a set of variables representing child characteristics were used. They are – if the child belonged to women who had twin/multiple births, age of the children, sex, birth order, and if the children received any benefit from *anganwadi* centers (meaning "courtyard shelter"). In NFHS-4, mothers were asked – "during the last 12 months, has (your child) received any benefits from the *anganwadi* center?" Any benefits included supplementary food, growth monitoring, immunizations, health check-ups or education. The Indian government established *anganwadi* centers (AWC) in 1975 as part of the Integrated Child Development Services (ICDS) programme to combat hunger and malnutrition among women and children. India currently has over 1.3 million operational AWC managed by an *anganwadi* worker (Rai et al., 2022). Aside from other responsibilities of *Anganwadi* workers for children, the 2013 National Food Security Act (NFSA) mandated take home ration (THR) or morning snack and hot cooked meal to children aged 6 months to six years at AWCs (Ministry of Law and Justice, 2013). This information on services from AWCs is useful for this study to understand whether exposure to such social security programmes could help strengthen childhood nutrition.

Guided by existing literature (Vollmer et al., 2017; Corsi et al., 2015; Subramanian et al., 2010; Ozaltin et al., 2010; Subramanian et al., 2009; Kundu et al., 2021), a set of variables representing maternal characteristics was also constructed. They are mother's age at first birth, mother's education, maternal body mass index (BMI), tobacco and alcohol use of mothers, if the mother was pregnant or breastfeeding at the time of the survey, if the mother lives with husband/partner, and diabetes and hypertension status of mothers. Maternal BMI for the Indian population (weight in kilograms divided by the square of height in meters) was constructed as per WHO guidelines (WHO Expert Consultation, 2004). Individuals with blood glucose level of ≥141 milligrams per deciliter or mg/dl or those on medication for diabetes were defined as diabetic (International Institute for Population Sciences and ICF, 2017). Individuals were defined as hypertensive if their systolic blood pressure level reading was ≥140 millimeters of mercury or mmHg, or diastolic blood pressure reading was ≥90 mmHg, or if they were on medication to mitigate hypertension (International Institute for Population Sciences and ICF, 2017).

The variable presenting three doses of diphtheria pertussis and tetanus (DPT3) immunization was also constructed to control for variation in receipt of vaccination over time, despite most of the unobserved heterogeneity removed by using household- and mother-fixed-effects (Bogler et al., 2019; Anekwe et al., 2015), while assessing the effect of VAS. It is worth mentioning that inclusion of additional control variables helped control for intrahousehold variability of child health as one household may house more than one mother.

3.2.4 *Statistical approach*

To assess the relationship of VAS with childhood anaemia and anthropometric failure, this study opted for conditional logistic regression, adjusted for household or mother fixed-effects. Fixed-effects design, is the generalization of difference-in-difference designs, and individuals can be measured under different treatment statuses but are nested within a larger level, allowing for control of all observed and unobserved factors common among all individuals belonging to the same entity (here it is same mother or same household) (Bärnighausen et al., 2017). For example: in cross-sectional analysis, controlling for all factors that are shared by siblings, such as having the same household / family (Bogler et al., 2019) or same mother (Bogler et al., 2019; Anekwe et al., 2015). For this study, the conditional logistic (household fixed-effects) regression was specified as below:

$$Y_{ih} = \beta_0 + \beta_1 V_{ih} + \beta_2 X_{ih}^{child} + \beta_3 X_{ih}^{moth} + \delta_h + \varepsilon_{ih}$$

Y_{ih} is the select outcome event of child i in household h. V_{ih} is child i's receipt of VAS and β_1 is the main parameter of interest: the association between receipt of VAS child health outcome. X_{ih}^{child} is a vector containing child-specific control variables including DPT vaccination status, X_{ih}^{moth} is a vector containing mother-specific control variable, δ_h is the household-fixed-effects, and ε_{ih} is the error term. In mother fixed-effects regressions, the vector of mother-specific control variables is dropped and δ_h counts as the mother fixed-effects, whereas h represents the mother instead of the household for all variables in the regression models.

To run the above specified regression, we computed all the outcome events as binary terms – '1' in case of anaemia, mild/moderate anaemia, stunting, wasting, and underweight, otherwise coded as '0'. For each outcome event, we ran two models – model I included the variables representing children and/or mother characteristics without controlling the effect of DPT3, whereas model II controlled the effect of DPT3, and we repeated this analysis with household-fixed-effects and mother fixed-effects. It is worth mentioning that while running the regression models, either for household or mother fixed-effects, the observation was dropped if the model did not find enough variation for outcome events for the same household or same mother. For example: running the household fixed-effects for anaemia included 21,475 observations, but 11,453 sample were excluded automatically from the regression model. This process may lead to a biased estimate (Greene, 2004). However, using conditional logistic regression instead of unconditional logistic regression helped minimize the bias, and the estimates are deemed robust (Katz, 2001). Prior to running conditional logistic regression models, we examined the distribution of the sample in the analytical model to understand the presence of sample selection bias. Except counts, appropriate sample weighting was used to run the analysis. The statistical software Stata version 14 (StataCorp., 2015) was used to execute the analysis, and 'svy' suite available with Stata was applied for all estimation, rendering robust estimates with reliable standard error.

3.2.5 *Ethics statement*

The 2015-2016 National Family Health Survey (NFHS-4) was conducted under the stewardship of the Ministry of Health and Family Welfare (MoHFW), Government of India, and the International Institute for Population Sciences, Mumbai, acted as the nodal agency for executing NFHS-4. Prior to the survey, ethical approval was obtained from an ethics review committee instituted by MoHFW. NFHS-4 dataset is available to the public for the use of researchers, with all participant identifiers removed. Thus, no separate ethical clearance was required for this study.

3.3 Results

Table 3.1 displays the descriptive statistics of the sample included for household fixed-effects. Nearly half of the sample selected for anaemia and anthropometric failure had received VAS. Nearly equal proportion of male or female participants were included. Most mothers had their first child between the age of 18 and 24 years. Nearly 29% of mothers were underweight (BMI of < 18.5 kg/m^2). Nearly 6% and 1% mothers were tobacco and alcohol users. Nearly 3% mothers were diabetic, and 1% of all mothers included were hypertensive. Over 77% of all children received all three doses of DPT vaccinations.

Table 3.1. Sample distribution of child health indicators by receipt of vitamin A supplementation (VAS) and background characteristics of mothers and their children.

	Anaemia, Prop. (SD)	Anthropometric failure, Prop. (SD)
Received VAS		
No	0.50 (0.002)	0.50 (0.002)
Yes	0.50 (0.002)	0.50 (0.002)
Twin/ multiple birth		
No	0.99 (0.001)	0.99 (0.001)
Yes	0.01 (0.001)	0.01 (0.001)
Age (years)		
0	0.15 (0.003)	0.16 (0.003)
1	0.23 (0.004)	0.23 (0.004)
2	0.19 (0.003)	0.19 (0.003)
3	0.21 (0.003)	0.21 (0.003)
4	0.22 (0.003)	0.21 (0.003)
Sex		
Male	0.50 (0.005)	0.49 (0.005)
Female	0.50 (0.005)	0.51 (0.005)
Birth order		
1	0.32 (0.004)	0.33 (0.004)
2	0.36 (0.003)	0.37 (0.003)
3	0.17 (0.003)	0.17 (0.003)
≥4	0.14 (0.004)	0.14 (0.004)
Received benefits from *Anganwadi* Centre		
No	0.41 (0.006)	0.41 (0.006)
Yes	0.59 (0.006)	0.59 (0.006)
Mother's age at first birth (years)		
<18	0.14 (0.005)	0.14 (0.005)
18-24	0.75 (0.006)	0.75 (0.006)

25-30	0.10 (0.004)	0.10 (0.004)
≥31	0.01 (0.002)	0.01 (0.002)
Maternal education		
No education	0.33 (0.006)	0.32 (0.006)
Primary	0.16 (0.005)	0.16 (0.005)
Secondary or higher	0.51 (0.007)	0.52 (0.007)
Maternal BMI (kg/m^2)		
<18.5	0.29 (0.006)	0.29 (0.006)
18.5-22.9	0.50 (0.007)	0.49 (0.007)
≥23.0	0.22 (0.006)	0.22 (0.006)
Maternal tobacco use		
Non-user	0.94 (0.003)	0.94 (0.003)
User	0.06 (0.003)	0.06 (0.003)
Maternal alcohol use		
Non-user	0.99 (0.001)	0.99 (0.001)
User	0.01 (0.001)	0.01 (0.001)
Currently pregnant		
No/ unsure	0.92 (0.003)	0.92 (0.003)
Yes	0.08 (0.003)	0.08 (0.003)
Currently breastfeeding		
No	0.23 (0.006)	0.23 (0.006)
Yes	0.77 (0.006)	0.77 (0.006)
Has husband/ partner		
No	0.01 (0.001)	0.01 (0.001)
Yes	0.99 (0.001)	0.99 (0.001)
Maternal diabetes status		
Non-diabetic	0.97 (0.002)	0.97 (0.002)
Diabetic	0.03 (0.002)	0.03 (0.002)
Maternal hypertension status		
Non-hypertensive	0.99 (0.001)	0.99 (0.001)
Hypertensive	0.01 (0.001)	0.01 (0.001)
Received three doses of DPT vaccinations		
No	0.23 (0.005)	0.23 (0.005)
Yes	0.77 (0.005)	0.77 (0.005)
n	21,475	21,021

Proportion may not add to 1 due to rounding.
BMI: body mass index, DPT: diphtheria pertussis and tetanus, n: sample, Prop.: proportion, SD: Standard Deviation

Tables 3.2 and 3.3 represent the findings from household fixed-effects showing the effect of VAS and other control variables on anaemia (any anaemia, and mild/ moderate anaemia), and anthropometric failure (stunting, wasting, and underweight, respectively. Both for model I (without adjustment of DPT3) and model II (with adjustment of DPT3), the result from household-fixed-effects showed that VAS has no effect on anaemia or anthropometric failure. **Tables S3.1, and S3.2 (online supplementary tables)** tested the effects of mother fixed-effects on anaemia (any anaemia, and mild/ moderate anaemia), and anthropometric failure (stunting, wasting, and underweight), respectively. Like household-fixed-effects, mother fixed-effects did not show any effects of VAS on childhood anaemia and anthropometric failure. Online supplementary **Table S3.3, and Table S3.4** furnish the distribution of the analytical sample included in household- fixed-effects by status of childhood anaemia and anthropometric failure, and sample distribution appeared reasonably comparable, thus reducing the probability of sample selection bias.

Table 3.2. Household fixed-effects regression of anaemia (any anaemia, and moderate/mild anaemia) on receipt of vitamin A supplementation (VAS) and control variables.

	Any anaemia				Moderate/mild anaemia			
	Model I OR (95% CI)	p	Model II OR (95% CI)	p	Model I OR (95% CI)	p	Model II OR (95% CI)	p
Received VAS								
No	1.00		1.00		1.00		1.00	
Yes	1.02 (0.91-1.13)	0.782	1.01 (0.91-1.13)	0.803	1.01 (0.91-1.11)	0.900	1.01 (0.91-1.11)	0.897
Twin/ multiple birth								
No	1.00		1.00		1.00		1.00	
Yes	1.22 (0.64-2.33)	0.539	1.22 (0.64-2.34)	0.541	0.95 (0.51-1.77)	0.875	0.95 (0.51-1.77)	0.876
Age (years)								
0	1.00		1.00		1.00		1.00	
1	1.13 (0.91-1.41)	0.276	1.13 (0.91-1.40)	0.285	1.04 (0.84-1.28)	0.722	1.04 (0.84-1.28)	0.720
2	0.73 (0.60-0.89)	0.002	0.73 (0.60-0.88)	0.001	0.72 (0.60-0.87)	0.001	0.72 (0.60-0.87)	0.001
3	0.43 (0.35-0.53)	<0.001	0.43 (0.35-0.53)	0.001	0.46 (0.38-0.56)	<0.001	0.46 (0.38-0.56)	<0.001
4	0.32 (0.26-0.40)	<0.001	0.32 (0.26-0.40)	<0.001	0.35 (0.28-0.43)	<0.001	0.35 (0.28-0.43)	<0.001
Sex								
Male	1.00		1.00		1.00		1.00	
Female	0.92 (0.80-1.05)	0.228	0.92 (0.80-1.05)	0.227	0.94 (0.82-1.07)	0.332	0.94 (0.82-1.07)	0.332
Birth order								
1	1.00		1.00		1.00		1.00	
2	1.06 (0.92-1.23)	0.411	1.06 (0.92-1.23)	0.413	1.07 (0.93-1.23)	0.351	1.07 (0.93-1.23)	0.350
3	1.12 (0.90-1.39)	0.299	1.12 (0.90-1.39)	0.301	1.14 (0.92-1.40)	0.233	1.14 (0.92-1.40)	0.233
≥4	1.19 (0.88-1.61)	0.268	1.19 (0.88-1.60)	0.270	1.14 (0.85-1.52)	0.378	1.14 (0.85-1.52)	0.377
Received benefits from *Anganwadi* Centre								
No	1.00		1.00		1.00		1.00	
Yes	0.98 (0.82-1.16)	0.793	0.98 (0.82-1.16)	0.792	0.98 (0.83-1.16)	0.839	0.98 (0.83-1.16)	0.839
Mother's age at first birth (years)								
<18	1.00		1.00		1.00		1.00	
18-24	0.86 (0.60-1.23)	0.397	0.86 (0.60-1.22)	0.395	0.89 (0.63-1.25)	0.508	0.89 (0.63-1.26)	0.508
25-30	0.83 (0.51-1.34)	0.444	0.83 (0.51-1.34)	0.443	0.87 (0.55-1.39)	0.570	0.87 (0.55-1.39)	0.570
≥31	0.80 (0.23-2.77)	0.729	0.80 (0.23-2.75)	0.725	0.67 (0.19-2.31)	0.521	0.67 (0.19-2.31)	0.522
Maternal education								
No education	1.00		1.00		1.00		1.00	
Primary	0.73 (0.50-1.08)	0.117	0.73 (0.50-1.08)	0.117	0.77 (0.53-1.11)	0.163	0.77 (0.53-1.11)	0.163

Secondary or higher	0.83 (0.60-1.14)	0.255	0.83 (0.60-1.14)	0.255	0.84 (0.62-1.15)	0.276	0.84 (0.62-1.15)	0.276
Maternal BMI (kg/m^2)								
<18.5	1.00		1.00		1.00		1.00	
18.5-22.9	1.10 (0.84-1.43)	0.488	1.10 (0.84-1.43)	0.493	1.05 (0.82-1.36)	0.688	1.05 (0.82-1.36)	0.687
≥23.0	1.20 (0.82-1.76)	0.354	1.20 (0.82-1.75)	0.357	1.12 (0.78-1.61)	0.548	1.12 (0.78-1.61)	0.547
Maternal tobacco use								
Non-user	1.00		1.00		1.00		1.00	
User	1.28 (0.65-2.49)	0.475	1.28 (0.65-2.49)	0.472	1.34 (0.70-2.58)	0.382	1.34 (0.70-2.58)	0.382
Maternal alcohol use								
Non-user	1.00		1.00		1.00		1.00	
User	1.74 (0.20-14.79)	0.614	1.74 (0.20-14.83)	0.614	1.70 (0.21-13.61)	0.615	1.70 (0.21-13.60)	0.615
Currently pregnant								
No/ unsure	1.00		1.00		1.00		1.00	
Yes	1.41 (1.02-1.95)	0.039	1.41 (1.02-1.95)	0.039	1.53 (1.12-2.10)	0.008	1.53 (1.12-2.10)	0.008
Currently breastfeeding								
No	1.00		1.00		1.00		1.00	
Yes	1.21 (0.93-1.57)	0.163	1.20 (0.93-1.57)	0.166	1.26 (0.98-1.62)	0.076	1.26 (0.98-1.63)	0.076
Has husband/ partner								
No	1.00		1.00		1.00		1.00	
Yes	1.33 (0.62-2.89)	0.465	1.33 (0.61-2.88)	0.470	1.28 (0.60-2.72)	0.524	1.28 (0.60-2.72)	0.523
Maternal diabetes status								
Non-diabetic	1.00		1.00		1.00		1.00	
Diabetic	1.13 (0.57-2.25)	0.731	1.13 (0.57-2.25)	0.730	1.04 (0.53-2.07)	0.903	1.04 (0.53-2.07)	0.903
Maternal hypertension status								
Non-hypertensive	1.00		1.00		1.00		1.00	
Hypertensive	1.81 (0.62-5.28)	0.276	1.81 (0.62-5.28)	0.275	1.89 (0.67-5.38)	0.231	1.89 (0.67-5.38)	0.231
Received three doses of DPT vaccinations	nm				nm			
No			1.00				1.00	
Yes			1.03 (0.85-1.24)	0.793			0.99 (0.83-1.20)	0.954
n (included in the model)	10,022		10,022		10,464		10,464	
n (dropped from the model)	11,453		11,453		11,011		11,011	

nm: not included in the model
BMI: body mass index, CI: confidence interval, DPT: diphtheria pertussis and tetanus, n: sample, OR: odds ratio, p: level of significance

Table 3.3. Household fixed-effects regression of anthropometric failure (stunting, wasting, and underweight) on receipt of vitamin A supplementation (VAS) and control variables.

	Stunting				Wasting				Underweight			
	Model I OR (95% CI)	p	Model II OR (95% CI)	p	Model I OR (95% CI)	p	Model II OR (95% CI)	p	Model I OR (95% CI)	p	Model II OR (95% CI)	p
Received VAS												
No	1.00		1.00		1.00		1.00		1.00		1.00	
Yes	1.00 (0.91-1.10)	0.957	1.00 (0.91-1.10)	0.959	0.96 (0.86-1.08)	0.501	0.97 (0.86-1.08)	0.560	1.01 (0.92-1.11)	0.885	1.02 (0.92-1.12)	0.729
Twin/ multiple birth												
No	1.00		1.00		1.00		1.00		1.00		1.00	
Yes	1.21 (0.51-2.84)	0.667	1.21 (0.51-2.86)	0.659	2.23 (0.82-6.08)	0.117	2.27 (0.84-6.12)	0.104	1.11 (0.55-2.21)	0.776	1.12 (0.56-2.22)	0.747
Age (years)												
0	1.00		1.00		1.00		1.00		1.00		1.00	
1	3.60 (2.92-4.44)	<0.001	3.64 (2.95-4.49)	<0.001	0.68 (0.55-0.84)	<0.001	0.69 (0.55-0.85)	0.001	1.61 (1.31-1.99)	<0.001	1.65 (1.34-2.03)	<0.001
2	4.33 (3.49-5.36)	<0.001	4.37 (3.51-5.44)	<0.001	0.40 (0.32-0.51)	<0.001	0.41 (0.32-0.52)	<0.001	1.69 (1.38-2.07)	<0.001	1.73 (1.41-2.13)	<0.001
3	4.29 (3.46-5.33)	<0.001	4.33 (3.49-5.37)	<0.001	0.42 (0.33-0.53)	<0.001	0.43 (0.34-0.54)	<0.001	1.86 (1.50-2.290	<0.001	1.90 (1.54-2.350	<0.001
4	3.04 (2.42-3.81)	<0.001	3.06 (2.43-3.84)	<0.001	0.36 (0.28-0.47)	<0.001	0.37 (0.28-0.47)	<0.001	1.68 (1.34-2.10)	<0.001	1.71 (1.36-2.14)	<0.001
Sex												
Male	1.00		1.00		1.00		1.00		1.00		1.00	
Female	1.00 (0.89-1.14)	0.939	1.00 (0.89-1.13)	0.962	0.87 (0.75-1.01)	0.065	0.87 (0.75-1.010	0.065	0.99 (0.88-1.12)	0.867	0.98 (0.87-1.11)	0.802
Birth order												
1	1.00		1.00		1.00		1.00		1.00		1.00	
2	1.32 (1.14-1.52)	<0.001	1.31 (1.14-1.52)	<0.001	1.01 (0.86-1.20)	0.895	1.01 (0.85-1.20)	0.898	1.12 (0.97-1.29)	0.125	1.12 (0.97-1.29)	0.133
3	1.54 (1.23-1.93)	<0.001	1.54 (1.23-1.92)	<0.001	1.16 (0.89-1.50)	0.266	1.16 (0.89-1.50)	0.272	1.43 (1.14-1.80)	0.002	1.43 (1.14-1.79)	0.002
≥4	2.42 (1.76-3.34)	<0.001	2.42 (1.75-3.34)	<0.001	1.11 (0.77-1.60)	0.570	1.11 (0.77-1.59)	0.587	2.05 (1.50-2.82)	<0.001	2.05 (1.49-2.81)	<0.001
Received benefits from *Anganwadi* Centre												
No	1.00		1.00		1.00		1.00		1.00		1.00	
Yes	0.85 (0.71-1.02)	0.074	0.85 (0.71-1.02)	0.078	1.10 (0.91-1.34)	0.335	1.11 (0.91-1.35)	0.317	0.98 (0.83-1.16)	0.802	0.99 (0.83-1.17)	0.892
Mother's age at first birth (years)												

<18	1.00		1.00		1.00		1.00		1.00		1.00	
18-24	1.09 (0.76-1.57)	0.645	1.08 (0.75-1.56)	0.662	1.70 (1.01-2.85)	0.044	1.71 (1.03-2.85)	0.040	1.33 (0.91-1.94)	0.135	1.33 (0.92-1.94)	0.132
25-30	1.38 (0.78-2.45)	0.273	1.37 (0.77-2.45)	0.280	2.48 (1.23-5.00)	0.011	2.52 (1.26-5.05)	0.009	2.31 (1.23-4.34)	0.009	2.29 (1.22-4.32)	0.010
≥31	1.65 (0.55-4.98)	0.375	1.64 (0.54-4.94)	0.381	0.94 (0.25-3.57)	0.926	0.95 (0.25-3.58)	0.935	1.14 (0.31-4.26)	0.842	1.12 (0.30-4.16)	0.870
Maternal education												
No education	1.00		1.00		1.00		1.00		1.00		1.00	
Primary	0.87 (0.57-1.32)	0.507	0.87 (0.57-1.33)	0.525	1.25 (0.75-2.07)	0.396	1.24 (0.75-2.07)	0.398	0.99 (0.63-1.57)	0.976	1.01 (0.64-1.58)	0.977
Secondary or higher	1.07 (0.75-1.53)	0.711	1.07 (0.75-1.53)	0.710	1.15 (0.73-1.81)	0.536	1.15 (0.73-1.81)	0.542	1.02 (0.70-1.48)	0.925	1.02 (0.70-1.49)	0.921
Maternal BMI (kg/m^2)												
<18.5	1.00		1.00		1.00		1.00		1.00		1.00	
18.5-22.9	1.03 (0.78-1.36)	0.818	1.04 (0.78-1.37)	0.806	0.72 (0.51-1.02)	0.063	0.72 (0.51-1.02)	0.063	0.85 (0.63-1.13)	0.259	0.85 (0.63-1.13)	0.262
≥23.0	0.64 (0.43-0.96)	0.032	0.65 (0.43-0.96)	0.032	0.85 (0.54-1.33)	0.469	0.84 (0.53-1.33)	0.463	0.74 (0.48-1.14)	0.178	0.75 (0.49-1.15)	0.182
Maternal tobacco use												
Non-user	1.00		1.00		1.00		1.00		1.00		1.00	
User	1.12 (0.64-1.95)	0.692	1.11 (0.63-1.93)	0.722	1.12 (0.49-2.55)	0.792	1.11 (0.48-2.53)	0.812	0.92 (0.44-1.95)	0.837	0.93 (0.44-1.93)	0.836
Maternal alcohol use												
Non-user	1.00		1.00		1.00		1.00		1.00		1.00	
User	0.16 (0.03-0.92)	0.040	0.16 (0.03-0.92)	0.040	1.67 (0.16-17.60)	0.671	1.62 (0.15-17.13)	0.688	0.67 (0.15-2.97)	0.601	0.65 (0.14-2.93)	0.573
Currently pregnant												
No/ unsure	1.00		1.00		1.00		1.00		1.00		1.00	
Yes	1.06 (0.71-1.59)	0.777	1.06 (0.70-1.59)	0.784	1.46 (0.95-2.25)	0.085	1.45 (0.94-2.24)	0.090	0.96 (0.66-1.40)	0.849	0.96 (0.66-1.40)	0.836
Currently breastfeeding												
No	1.00		1.00		1.00		1.00		1.00		1.00	
Yes	1.33 (1.00-1.76)	0.046	1.33 (1.01-1.76)	0.046	1.04 (0.75-1.43)	0.818	1.04 (0.75-1.43)	0.829	1.40 (1.05-1.86)	0.022	1.40 (1.05-1.86)	0.021
Has husband/ partner												
No	1.00		1.00		1.00		1.00		1.00		1.00	

Yes	1.18 (0.46-3.06)	0.729	1.19 (0.46-3.08)	0.723	2.94 (0.75-11.59)	0.122	2.96 (0.76-11.58)	0.119	1.47 (0.73-2.96)	0.283	1.50 (0.74-3.02)	0.257
Maternal diabetes status												
Non-diabetic	1.00		1.00		1.00		1.00		1.00		1.00	
Diabetic	1.47 (0.64-3.38)	0.367	1.47 (0.64-3.39)	0.361	1.30 (0.58-2.92)	0.524	1.30 (0.58-2.94)	0.522	1.18 (0.47-2.96)	0.724	1.18 (0.47-2.96)	0.717
Maternal hypertension status												
Non-hypertensive	1.00		1.00		1.00		1.00		1.00		1.00	
Hypertensive	0.68 (0.25-1.82)	0.443	0.69 (0.26-1.84)	0.461	2.21 (0.73-6.72)	0.160	2.22 (0.73-6.71)	0.159	1.04 (0.37-2.87)	0.946	1.04 (0.38-2.87)	0.936
Received three doses of DPT vaccinations	nm				nm				nm			
No			1.00				1.00				1.00	
Yes			0.93 (0.77-1.13)	0.466			0.90 (0.72-1.13)	0.373			0.82 (0.68-0.99)	0.038
n (included in the model)	9,393		9,393		6,187		6,187		8,500		8,500	
n (dropped from the model)	11,628		11,628		14834		14834		12,521		12,521	

nm: not included in the model
BMI: body mass index, CI: confidence interval, DPT: diphtheria pertussis and tetanus, n: sample, OR: odds ratio, p: level of significance

3.4 Discussion

India, with a population of over 1.3 billion, has a high burden of micronutrient deficiencies among children, and VAD is one among them (Venkatesh et al., 2021; Gonmei and Toteja, 2018). To mitigate VAD, India adopted the WHO guideline for VAS (World Health Organization, 2011) and recommends a universal periodic dose of vitamin A for children aged 6-59 months to prevent child mortality and morbidity including infections (Ministry of Health and Family Welfare, 2006). However, researchers, donors and policy makers have questioned the VAS programme and recommended a targeted approach to VAS may be introduced instead of universal VAS (Reddy et al., 2021; Greiner et al., 2019; Sareen and Kapil, 2016; Kapil and Sachdev, 2013). In the wake of this debate of universal versus targeted approaches to VAS, using nationally representative 2015-2016 National Family Health Survey data (International Institute for Population Sciences and ICF, 2017), this study took on a (household and mother) fixed-effects study design to assess the effect of VAS on anaemia and anthropometric failure among children 6-59 months.

Findings from both household-and-mother-fixed-effects revealed that VAS was not associated with anaemia status (categorized into any anaemia, and mild/ moderate anaemia), and anthropometric failure (categorized into stunting, wasting, and underweight. These findings resonate with the recent body of evidence including systematic reviews. A systematic review (Chen et al., 2008) suggested that positive effects of VAS appear limited to populations with acute and chronic under nutrition, and India suffers from high burdens of growth failure (Local Burden of Disease Child Growth Failure Collaborators, 2020), anaemia (Rai et al., 2021), and micronutrient deficiencies (Ministry of Health and Family Welfare et al., 2019). Another systematic review which included 16 studies from India suggested that VAS has no effect on incidence of respiratory disease or hospitalizations due to diarrhea or pneumonia (Imdad et al., 2017). A recent meta-analysis of Indian studies also concluded that children aged 6-59 months who received VAS had no survival benefits (Thomas et al., 2022). All these studies support the findings of this study that universal periodic doses of VAS may not be useful in preventing anaemia, anthropometric failure, and childhood infections in India.

The findings of this study should be interpreted considering its limitations. First, this study analyzed VAS among children aged 6-59 months, whereas the Government of India encourages VAS for children aged 9-59 months (Ministry of Health and Family Welfare, 2006). The purpose of analyzing the age group 6-59 months was to have a global perspective as per the guideline developed by WHO. However, we ran the analysis for children aged 9-59 months (data not shown separately) and the findings did not differ from the analysis for children aged 6-59 months. Second, for grouping the anaemia level, we could not consider severe anaemia (Hb <7 g/dl) as a potential outcome measure because of reasonably low sample size to run the analysis. Third, similar reasoning applies for excluding childhood diarrhea, and acute respiratory infections (ARI) from the analysis. Fourth, our fixed-effects model relies on variation in VAS status among siblings and includes only observations from households, or mothers, with more than one child, excluding children with families with one child. This process reduces the sample size, and it may affect the representativeness of the sample. However, this should not raise concerns about the findings because apart from controlling for observed and unobserved heterogeneity, the regression models also controlled for underlying maternal factors which could affect the outcome of interest (WHO Expert Consultation, 2004).

Fifth, due to the unavailability of the information on VAS status of children reported dead during the survey, this study could not estimate the effect of VAS on child mortality. Sixth, although it is not the objective of the study, for an execution point of view of VAS programme in India, the future study may explore the possible reasons on why, within a household or child belonged to same mother, one child received VAS while another did not. Seventh, most information collected on children are based on mother's recall, thus one cannot completely rule out the possibility of recall errors or social desirability bias. Finally, the findings of this study must be treated as the estimated effect which has potential of undermining true effect of VAS on child nutrition. Simply put, absence of estimated effect of VAS on child health indicators are not always indicative of true effects.

Despite these limitations, this study is the first of its kind to use nationally representative data to estimate that universal periodic VAS may not be an effective strategy to mitigate select childhood nutrition and diseases, which could be suggestive of targeted VAS intervention. If universal VAS is not helping to improve childhood nutrition and diseases, targeted VAS programme might not only be a cost-effective strategy, but it will also be less of a burden on India's public health system.

Table S3.1. Mother fixed-effects regression of anaemia (any anaemia, and moderate/mild anaemia) on receipt of vitamin A supplementation (VAS) and control variables.

	Any anaemia				Moderate/mild anaemia			
	Model I OR (95% CI)	p	Model II OR (95% CI)	p	Model I OR (95% CI)	p	Model II OR (95% CI)	p
Received VAS								
No	1.00		1.00		1.00		1.00	
Yes	1.04 (0.92-1.18)	0.534	1.04 (0.92-1.19)	0.511	1.03 (0.92-1.16)	0.587	1.04 (0.92-1.17)	0.553
Twin/ multiple birth								
No	1.00		1.00		1.00		1.00	
Yes	1.74 (0.77-3.93)	0.180	1.75 (0.78-3.90)	0.173	1.28 (0.59-2.75)	0.532	1.28 (0.60-2.74)	0.519
Age (years)								
0	1.00		1.00		1.00		1.00	
1	1.18 (0.90-1.54)	0.239	1.18 (0.90-1.55)	0.225	1.07 (0.83-1.38)	0.617	1.07 (0.83-1.38)	0.582
2	0.90 (0.69-1.17)	0.415	0.90 (0.70-1.17)	0.432	0.87 (0.68-1.12)	0.286	0.88 (0.69-1.13)	0.305
3	0.56 (0.42-0.74)	<0.001	0.56 (0.42-0.75)	<0.001	0.58 (0.44-0.77)	<0.001	0.58 (0.44-0.77)	<0.001
4	0.48 (0.34-0.69)	<0.001	0.48 (0.34-0.69)	<0.001	0.50 (0.36-0.71)	<0.001	0.50 (0.36-0.71)	<0.001
Sex								
Male	1.00		1.00		1.00		1.00	
Female	0.90 (0.75-1.07)	0.214	0.90 (0.75-1.07)	0.216	0.90 (0.76-1.06)	0.198	0.90 (0.76-1.06)	0.200
Birth order								
1	1.00		1.00		1.00		1.00	
2	1.33 (1.07-1.66)	0.011	1.33 (1.07-1.66)	0.010	1.33 (1.07-1.64)	0.009	1.33 (1.07-1.64)	0.009
3	1.94 (1.30-2.90)	0.001	1.95 (1.30-2.90)	0.001	1.88 (1.29-2.76)	0.001	1.89 (1.29-2.76)	0.001
≥4	2.94 (1.58-5.46)	0.001	2.94 (1.58-5.46)	0.001	2.55 (1.41-4.61)	0.002	2.55 (1.41-4.61)	0.002
Received benefits from *Anganwadi* Centre								
No	1.00		1.00		1.00		1.00	
Yes	0.93 (0.74-1.16)	0.512	0.93 (0.74-1.16)	0.503	0.95 (0.77-1.18)	0.642	0.95 (0.77-1.17)	0.630
Received three doses of DPT vaccinations	nm				nm			
No			1.00				1.00	
Yes			0.94 (0.74-1.21)	0.637			0.93 (0.74-1.18)	0.546
n (included in the model)	7,077		7,077		7,395		7,395	
n (dropped from the model)	9,599		9,599		9,281		9,281	

nm: not included in the model

BMI: body mass index, CI: confidence interval, DPT: diphtheria pertussis and tetanus, n: sample, OR: odds ratio, p: level of significance

Table S3.2. Mother fixed-effects regression of anthropometric failure (stunting, wasting, and underweight) on receipt of vitamin A supplementation (VAS) and control variables.

	Stunting				Wasting				Underweight			
	Model I OR (95% CI)	p	Model II OR (95% CI)	p	Model I OR (95% CI)	p	Model II OR (95% CI)	p	Model I OR (95% CI)	p	Model II OR (95% CI)	p
Received VAS												
No	1.00		1.00		1.00		1.00		1.00		1.00	
Yes	1.02 (0.91-1.15)	0.694	1.03 (0.92-1.15)	0.663	0.92 (0.80-1.05)	0.226	0.92 (0.80-1.05)	0.231	1.02 (0.92-1.14)	0.685	1.03 (0.92-1.15)	0.609
Twin/ multiple birth												
No	1.00		1.00		1.00		1.00		1.00		1.00	
Yes	0.86 (0.28-2.62)	0.792	0.86 (0.28-2.63)	0.796	2.63 (0.76-9.09)	0.125	2.65 (0.77-9.08)	0.120	0.85 (0.37-1.96)	0.703	0.86 (0.37-1.96)	0.713
Age (years)												
0	1.00		1.00		1.00		1.00		1.00		1.00	
1	4.55 (3.53-5.85)	<0.001	4.56 (3.54-5.88)	<0.001	0.76 (0.58-1.00)	0.047	0.76 (0.58-1.00)	0.053	2.01 (1.58-2.57)	<0.001	2.03 (1.59-2.60)	<0.001
2	6.67 (5.00-8.90)	<0.001	6.69 (4.99-8.95)	<0.001	0.39 (0.29-0.52)	<0.001	0.39 (0.29-0.53)	<0.001	2.11 (1.63-2.75)	<0.001	2.14 (1.64-2.79)	<0.001
3	7.65 (5.47-10.68)	<0.001	7.66 (5.48-10.71)	<0.001	0.42 (0.30-0.61)	<0.001	0.43 (0.30-0.61)	<0.001	2.49 (1.83-3.40)	<0.001	2.52 (1.85-3.44)	<0.001
4	6.32 (4.24-9.44)	<0.001	6.34 (4.24-9.46)	<0.001	0.34 (0.23-0.52)	<0.001	0.35 (0.23-0.53)	<0.001	2.38 (1.65-3.44)	<0.001	2.40 (1.66-3.46)	<0.001
Sex												
Male	1.00		1.00		1.00		1.00		1.00		1.00	
Female	1.02 (0.88-1.18)	0.813	1.02 (0.88-1.18)	0.820	0.86 (0.72-1.03)	0.102	0.86 (0.72-1.03)	0.103	0.96 (0.83-1.12)	0.633	0.96 (0.83-1.12)	0.611
Birth order												
1	1.00		1.00		1.00		1.00		1.00		1.00	
2	2.19 (1.72-2.79)	<0.001	2.19 (1.72-2.78)	<0.001	0.89 (0.69-1.16)	0.398	0.89 (0.69-1.16)	0.398	1.33 (1.06-1.68)	0.014	1.33 (1.06-1.68)	0.015
3	3.99 (2.57-6.21)	<0.001	3.99 (2.57-6.20)	<0.001	1.10 (0.68-1.77)	0.700	1.10 (0.68-1.77)	0.702	2.09 (1.37-3.18)	0.001	2.07 (1.36-3.17)	0.001
≥4	8.53 (4.24-17.17)	<0.001	8.53 (4.24-17.16)	<0.001	1.13 (0.55-2.34)	0.732	1.13 (0.55-2.34)	0.737	3.29 (1.71-6.33)	<0.001	3.28 (1.70-6.32)	<0.001
Received benefits from *Anganwadi* Centre												
No	1.00		1.00		1.00		1.00		1.00		1.00	
Yes	0.76 (0.61-0.96)	0.019	0.76 (0.61-0.96)	0.019	1.23 (0.96-1.57)	0.097	1.23 (0.96-1.58)	0.095	0.93 (0.75-1.16)	0.541	0.94 (0.75-1.16)	0.556

Received three doses of DPT vaccinations	nm			nm			nm		
No		1.00			1.00			1.00	
Yes		0.97 (0.78-1.22)	0.813		0.97 (0.73-1.28)	0.807		0.90 (0.71-1.13)	0.345
n (included in the model)	6,619	6,619		4,345	4,345		5,844	5,844	
n (dropped from the model)	9,679	9,679		11,953	11,953		10,454	10,454	

nm: not included in the model
BMI: body mass index, CI: confidence interval, DPT: diphtheria pertussis and tetanus, n: sample, OR: odds ratio, p: level of significance

Table S3.3. Sample distribution (sample included to estimate household fixed-effects) of anaemia status among children who received vitamin A versus children who did not receive vitamin A by select characteristics of children.

	Presence of any anaemia		Absence of any anaemia		Presence of moderate/mild anaemia		Absence of moderate/mild anaemia	
	vitamin A received	vitamin A not received	vitamin A received	vitamin A not received	vitamin A received	vitamin A not received	vitamin A received	vitamin A not received
Twin/ multiple birth								
No	98.1	98.6	98.6	99.1	98.2	98.6	98.5	98.8
Yes	1.9	1.4	1.4	0.9	1.9	1.4	1.5	1.2
Age (years)								
0	14.6	27.9	9.3	12.7	14.8	27.2	9.5	12.9
1	38.8	22.6	18.8	8.8	37.9	21.8	20.6	9.6
2	24.2	16.6	19.6	13.1	23.9	16.4	19.7	13.7
3	12.6	15.9	25.7	26.8	13.2	16.7	24.8	26.6
4	9.8	17.1	26.6	38.6	10.3	17.9	25.5	37.3
Sex								
Male	51.1	51.5	47.0	48.1	50.6	51.5	47.7	48.2
Female	48.9	48.5	53.0	51.9	49.4	48.5	52.3	51.8
Birth order								
1	21.4	27.5	37.9	43.4	21.7	28.4	36.8	42.7
2	41.6	37.6	33.3	31.9	41.6	36.8	33.8	31.9
3	21.6	18.5	15.8	13.9	21.4	18.3	15.8	14.2
≥4	15.4	16.4	13.0	10.7	15.3	16.5	13.6	11.2
Received benefits from *Anganwadi* Centre								
No	36.6	45.8	41.0	48.0	37.1	45.9	41.0	48.1
Yes	63.4	54.2	59.0	51.96	62.9	54.1	59.0	51.9
n	2,785	2,359	2,249	2,629	2,874	2,489	2,386	2,715

n: sample

Table S3.4. Sample distribution (sample included to estimate household fixed-effects) of anthropometric failure among children who received vitamin A versus children who did not receive vitamin A by select characteristics of children.

	Stunted		Not stunted		Wasted		Not wasted		Underweight		Not underweight	
	vitamin A received	vitamin A not received	vitamin A received	vitamin A not received	vitamin A received	vitamin A not received	vitamin A received	vitamin A not received	vitamin A received	vitamin A not received	vitamin A received	vitamin A not received
Twin/ multiple birth												
No	98.5	99.1	98.3	98.9	98.3	98.5	98.4	99.3	98.0	98.4	97.6	99.0
Yes	1.5	0.9	1.7	1.1	1.7	1.5	1.6	0.8	2.0	1.6	2.4	1.0
Age (years)												
0	6.2	11.7	19.1	30.3	19.9	33.5	8.4	14.5	10.0	17.2	14.7	24.1
1	29.5	18.4	27.9	12.4	35.3	19.5	23.4	11.6	29.2	16.6	28.1	13.7
2	26.8	20.1	17.5	12.4	18.6	12.7	24.0	19.0	22.3	18.0	21.1	14.6
3	22.4	26.8	17.6	17.6	14.8	17.7	24.2	26.1	22.0	23.6	18.4	21.4
4	15.0	23.0	17.9	27.4	11.5	16.7	20.0	28.8	16.6	24.6	17.6	26.2
Sex												
Male	50.1	48.4	48.4	51.3	56.8	51.6	49.2	47.9	50.9	46.6	49.5	47.9
Female	49.9	51.6	51.6	48.7	43.2	48.4	50.9	52.1	49.1	53.4	50.5	52.1
Birth order												
1	29.7	33.6	29.8	33.3	24.1	29.1	35.6	39.2	29.3	34.8	32.2	32.6
2	35.9	34.1	36.2	35.5	37.8	37.2	33.7	32.8	34.2	32.8	35.9	37.1
3	17.7	16.4	20.2	17.6	20.2	19.2	17.1	13.9	18.6	17.3	19.0	15.8
≥4	16.7	15.9	13.8	13.7	17.9	14.5	13.7	14.1	17.9	15.1	13.0	14.5
Received benefits from *Anganwadi* Centre												
No	36.1	47.3	36.2	42.4	29.1	41.0	35.8	43.2	33.3	45.7	36.4	42.4
Yes	63.9	52.8	63.8	57.6	70.9	59.0	64.2	56.9	66.7	54.3	63.6	57.6
n	2,490	2,161	2,236	2,506	1,429	1,382	1,662	1,714	2,156	2,025	2,118	2,201

n: sample

4 Association of parental characteristics with offspring anthropometric failure, anaemia and mortality in India[‡]

RAJESH KUMAR RAI, S V SUBRAMANIAN, and SEBASTIAN VOLLMER

ABSTRACT

This study used a wide range of information on parental sociodemographic, physical and behavioural characteristics as well as on the presence of non-communicable diseases among parents and examined the association of these attributes with anthropometric failure, anaemia and mortality of their children aged 0-59 months. Findings revealed that children of fathers aged 30-39 years were less likely to experience anthropometric failure and anaemia; however, survival of children of fathers below 18 years at marriage could be threatened. Parental education had protective association with children's anthropometric failure, anaemia and under-five mortality. With increasing maternal height, children had lower odds of anthropometric failure and under-five mortality. Tobacco use by mothers was associated with increase in under-five mortality, and children with diabetic fathers had higher odds of under-five mortality.

Keywords: anthropometric failure, child anaemia, child mortality, social determinants of health, India

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4.1 Introduction

Evolutionary biologists have extensively studied the importance of parental characteristics in shaping their offspring's health and the pathways through which this relationship operates (Wells et al., 2017). The pathways start with children's intrauterine exposure, maternal exposure during pregnancy, followed by parents' choices about the amount and quality of healthcare their children receive, the food they eat, the amount of emotional support they are provided and the quality of the environment in which they live (Cutler et al., 2008; Bauman et al., 2006; Case and Paxson, 2002). These choices are often conditioned by parents' material resources, knowledge of health practices and programmes, their own health behaviour and the characteristics of the communities they live in (Case and Paxson, 2002; Case et al., 2002).

As a first step of this study, a literature search on PubMed/MEDLINE bibliographic database was conducted using appropriate Medical Subject Headings (MeSH) terms to learn about the existing studies on the relationship between parental characteristics and offspring's health, with a focus on India. While searching relevant literature, emphasis was laid on studies which analysed parental sociodemographic and behavioural characteristics, and parental health status and their effects on offspring health. Of sociodemographic characteristics, the literature search suggested that child marriage of girls (married before age 18) in India was associated with increased risk of offspring morbidity and mortality (Kumar et al., 2021a; Fall et al., 2015; Finlay et al., 2011; Raj et al., 2010). When it comes to child marriage of boys, the literature is rather scarce. Child marriage of boys is likely to constrain their access to education and opportunities for career advancement (Gastón et al., 2019), which could potentially limit their earnings and their access to healthcare and healthcare information. A study analysed Demographic and Health Survey (DHS) data from India and concluded that children (aged 12-59 months) of younger parents (aged 15-24 years at the time of survey) had elevated risk of anaemia, stunting and incomplete immunization (Puri et al., 2020). A longitudinal study for over 15 years (Perez-Alvarez and Favara, 2019) on a total of 12,000 children from Ethiopia, India (from the states of Andhra Pradesh and Telangana), Peru and Vietnam revealed that children born to early mothers are shorter for their age and perform poorer in mathematics tests. A research collaboration of five birth cohorts from low- and middle-income countries, such as Brazil, Guatemala, India, Philippines and South Africa, found that maternal age of ≤19 years was associated with increased risk of low birthweight, preterm birth and stunting among children of 2 years of age (Fall et al., 2015). Using cross-sectional data from 118 DHSs conducted in 55 countries (between 1990 and 2008), a study found that mothers below the age of 27-29 years had elevated risks for infant mortality in first-born children and stunting, diarrhoea and anaemia in all children (Finlay et al., 2011).

Recent studies have demonstrated that children of uneducated parents are more likely to experience poor health outcomes as compared to children with educated parents in India (Kumar et al., 2021b; Puri et al., 2020; Srivastava and Upadhyay, 2022). Studies have also found that maternal education has a protective association with double burden of malnutrition (Patel et al., 2020) and triple burden of malnutrition among their children (Kumar et al., 2021a; Kumar et al., 2021b). A global systematic review and meta-analysis (Balaj et al. 2021) found that not only illiteracy but also lower maternal and paternal education are risk factors for child mortality, whereas an analysis of 80 DHS datasets from 62 countries revealed that higher maternal and paternal educational levels were associated with lower childhood anthropometric failures (Vollmer et al., 2017). While research about the stronger effects of education of either parent remains inconclusive, researchers have urged to count on both maternal and paternal education for improving the health of the offspring (Balaj et al. 2021; Vollmer et al., 2017). Like parental education, parental employment is also an indicator of financial security, which is often conditioned by education of a certain level. A recent study documented that if both parents are employed, their children were less likely to have incomplete immunization; however, no association with childhood anaemia and stunting was found (Puri et al., 2020). Children with mothers employed in professional jobs had better health status as compared to children whose mothers were employed in agricultural and manual (skilled and unskilled) jobs (Shajan and Sumalatha, 2020).

The association of parental phenotypic traits such as height, weight and body mass index (BMI) with children's health has also been widely studied. Using DHS data from India, a study documented that increased height of both parents was associated with decreased odds of childhood stunting (Gupta et al., 2022). In the wake of the debate around intrauterine influences on child nutrition, a study used nationally representative data from India and found that higher values of maternal and paternal BMIs were associated with higher values of offspring BMI (Corsi et al., 2015). However, while comparing the effect sizes of maternal and paternal BMIs, no consistent differences were found in the strength of these parental associations with the BMI of the offspring. This finding resonates with an earlier study which found that a one unit increase of maternal BMI was associated with lower relative risk of childhood stunting, wasting and underweight (Subramanian et al., 2010). Another study used data from 109 DHSs of 54 countries and showed that a 1 cm increase in maternal height was associated with decreased risk of offspring mortality, underweight and stunting in infancy and childhood (Özaltin et al., 2010). In line with these studies, Subramanian et al. (2009) documented that an increased maternal height of 1 cm was inversely associated with child mortality, stunting, wasting, underweight and childhood anaemia in India.

Of behavioural characteristics, parental use of tobacco could be detrimental to the offspring's health (Zhuge et al., 2020; Caleyachetty et al., 2014). Exposure of unborn children to maternal smoking during pregnancy or second-hand smoke is linked to birth defects, stillbirths, preterm births and infant deaths (Nicoletti et al., 2014; Leonardi-Bee et al., 2011). Newborns and young children who are exposed to tobacco smoke in their immediate environment are at increased risk of asthma, respiratory infections and meningococcal disease, leading to increased mortality (Faber et al., 2017). In addition, tobacco consumption among adults comes with significant cost to families, contributing to hunger and food insecurity for both children and adults in both higher-income and lower-income countries (World Health Organization, 2021). Many households are impoverished by the cost of smoking, diverting spending away from basic household expenses with an increased risks of catastrophic health expenditure (Semba et al., 2007). A cross-sectional study utilizing data from eight South Asian and South East Asian countries documented that child death was associated with smoking by both parents, parental use of smokeless tobacco and use of any tobacco (Bhatta and Glantz, 2019). Like tobacco use, alcohol misuse or problematic drinking behaviour of parents is associated with poor child health, cognitive development, behavioural problems in younger children and a range of problematic behaviours in adolescence such as absence from school, substance abuse and teenage pregnancy (Huq et al., 2021; Jose and Cherayi, 2020).

Consumption of alcohol prior to and during pregnancy could lead to an increased risk of adverse birth outcomes such as low birthweight and preterm birth (Nykjaer et al., 2014). A study conducted among young Swedish males revealed that paternal alcohol consumption was associated with increased risk of offspring mortality (Landberg et al., 2018).

The presence of non-communicable diseases (NCDs) such as diabetes mellitus and hypertension (elevated blood pressure) among parents could also lead to poor offspring health. While diabetes and hypertension could affect both rich and poor, parental NCDs could be an indication of inaccessibility to good healthcare practices or insufficient healthcare information. A study conducted in the United States concluded that maternal diabetes prior to or during pregnancy was associated with poorer glycaemic control and β-cell function among their children (Chernausek et al., 2016). Using 8,301 mother-offspring pairs, a study concluded that maternal diabetes is associated with high blood pressure late in childhood, demonstrating the role of children's body mass in the pathway of this association (Miranda et al., 2019). Like diabetes, parental hypertension is associated with poor child health outcomes (Miliku et al., 2016), and pathways through which it affects child health could be genetic as well (Uehara et al., 1998).

From this overview, it is evident that the majority of published studies had measured a specific indicator of child's health and its association with a limited range of parental characteristics, which limits our understanding of this issue. For example, one drawback of earlier studies in India is that none of them examined the presence of NCDs among parents and its relationship with offspring health. Against this evidence gap, using a nationally representative cross-sectional dataset from India, a comprehensive set of information on parental sociodemographic, physical and behavioural characteristics, and on the presence of NCDs among parents was employed to examine whether these parental attributes were associated with anthropometric failure, anaemia and mortality of their children aged 0-59 months. Findings from this study could be useful in devising a strategy for mitigating the burden of anthropometric failure, anaemia and mortality among children aged under 5 in India.

4.2 Methods

4.2.1 *Study Design and Data*

This study used data from the nationally representative fourth wave of the standard Demographic and Health Survey (DHS) of India, commonly known as the 2015-2016 National Family Health Survey or NFHS-4 (International Institute for Population Sciences and ICF, 2017). Health statistics from NFHS-4 are used extensively to guide district, state and national public health policy in India. NFHS-4 is cross-sectional and covers 640 districts from 37 states or union territories. India's 2011 Census sampling frame was used to select primary sampling units (PSUs) in rural and urban areas, and NFHS-4 adopted a stratified two-stage sampling design. From the predefined sampling frame, PSUs were identified as villages in rural areas and Census Enumeration Blocks (CEBs) in urban areas. Within each rural stratum, villages were selected from the sampling frame with probability proportional to size (PPS). In each stratum, six approximately equal substrata were created by crossing three substrata, each created based on the number of households in each village, with two substrata, each created based on the percentage of the population belonging to Scheduled Castes (SCs) and Scheduled Tribes (STs). In urban areas, CEBs were sorted according to the percentage of the SC/ST population in each CEB, and sample CEBs were selected with the PPS sampling method. NFHS-4 had a household response rate of 97.6%. The NFHS-4 sampled 699,686 women aged 15-49 years and 112,122 men aged 15-54 years residing in 601,509 households for the interview. Further details about the sampling procedure of NFHS-4 can be reviewed from its published report (International Institute for Population Sciences and ICF, 2017).

A dataset with parent–child dyads was prepared by merging three separate datasets with information on children, men and all household members. The purpose of merging these datasets was to have a single dataset with information of parents (both father and mother) linked to their offspring. Using appropriate merging identifiers, the household member dataset was merged with men's dataset at the first stage; and at the second stage, the merged dataset from the first stage was re-merged with the children's file. The children's file had information for 259,627 children aged 0–59 months (247,743 living children and 11,884 deceased children). Upon merging required datasets (children, men and all household members), 33,047 children aged 0–59 months were identified with information on both parents. Among these children aged 0–59 months, 28,952 children were eligible for calculating anthropometric failure, whereas 27,265 children aged 6–59 months were measured for childhood anaemia. As a final sample included in the analysis, 25,429 under-five children were found eligible for analysing anthropometric failure, and 28,693 for under-five mortality, whereas 24,022 children aged 6–59 months were eligible to be included for analysing anaemia. Derivation of sample size is presented schematically as an online supplement (**Figure S4.1**). Samples included in the analysis were compared with the samples excluded from the analysis for three outcome events (anthropometric failure, anaemia and under-five mortality) by selected socio-economic characteristics of children to assess the possible extent of sample selection bias in this study.

4.2.2 *Outcome Variables: Anthropometric Failure, Anaemia and Under-Five Mortality*

Outcome events were chosen in two stages. At stage I, the association with parental characteristics was analysed for three outcome events—any anthropometric failure, anaemia and under-five mortality, and they were labelled as primary outcome measures. At stage II, as complementary outcome measures, anthropometric failure was categorized into underweight, stunting, wasting, severe underweight, severe stunting and severe wasting; anaemia was further analysed for mild–moderate anaemia and severe anaemia; and in addition to under-five mortality, neonatal mortality and postneonatal mortality were also investigated. All complementary outcome measures were tested for their association with parental characteristics; findings are available in the online supplement.

While any anthropometric failure and mortality were measured among children aged 0–59 months, the measure of anaemia was restricted to children aged 6–59 months in NFHS-4. Children identified as being either stunted, wasted or underweight were defined as having any anthropometric failure. Guided by the methodology developed by the World Health Organization (WHO Multicentre Growth Reference Study Group, 2006), stunting was defined as <–2 standard deviations from median height for age of the reference population; wasting was defined as <–2 standard deviations from median weight for height of the reference population; and underweight was defined as <–2 standard deviations from median weight for age of the reference population. Severe stunting, severe wasting and severe underweight were defined as <–3 standard deviations from median height for age, weight for height and weight for age of the reference population, respectively (WHO Multicentre Growth Reference Study Group, 2006). For child anthropometry, in NFHS-4, the 'SECA 874 U digital scale' was used for weighing, the 'SECA 213 Stadiometer' was used for measuring height and the 'SECA 417 Infantometer' was used for measuring the length of children under 2 years or less than 85 cm (International Institute for Population Sciences, 2014). Children aged 6–59 months diagnosed with haemoglobin level (recorded in grams/decilitre or g/dl) of <11.0 g/dl were defined as anaemic, whereas children diagnosed with haemoglobin level of 7.0–10.9 g/dl and haemoglobin level of <7.0 g/dl were defined as mild to moderate or severe anaemia, respectively (World Health Organization, 2011). NFHS-4 provides Hb estimates of children adjusted for the altitude of their residence (ICF, 2018; Sullivan et al., 2008). Using HemoCue Hb 201+ machines, NFHS-4 measured Hb levels from a capillary blood sample of children aged 6–59 months. Death of a child during the first 28 days of life was defined as neonatal mortality, deaths between 28 and 364 days of life were considered as postneonatal mortality, and death of children between birth and their fifth birthday were defined as under-five mortality. Information on mortality was based on recall of age at death from mothers for all children ever born. Detailed protocols about obtaining data for child anthropometry and child biomarkers were presented in the clinical anthropometric biochemical manual of NFHS-4 (International Institute for Population Sciences, 2014).

4.2.3 *Predictors: Parental Characteristics and Covariables*

Parental characteristics were divided into four categories, namely sociodemographic, physical and behavioural characteristics, and presence of selected NCDs. Sociodemographic characteristics included age group (15–29, 30–39 and ≥40 years), age at marriage (<18, 18–20, 21–25 and ≥26 years), education (no or incomplete primary, primary or incomplete secondary and secondary or higher), years of schooling and employment (unemployed, non-manual, agricultural and manual/others). Physical characteristics included person's height (<145, 145–149.9, 150–154.9, 155–159.9 and ≥160 cm) and body mass index (BMI in kilogram per metre squared: <17.00, 17.00–18.49, 18.50–23.49, 23.50–24.99, 25.00–29.99 and ≥30.00). Behavioural characteristics of parents included current use of tobacco (non-user and user) and alcohol (non-user and user), whereas presence of NCDs among parents included their clinically diagnosed hypertension (non-hypertensive and hypertensive) and diabetes status (non-diabetic and diabetic).

In addition, maternal age at birth (<17, 17–19, 20–24, 25–29 and 30–49 years), child's age (0, 1, 2, 3 and 4 years), child's sex (male and female), child's birth order (first, second, third, fourth and fifth or higher), area of residence (urban and rural), religion (Hinduism, Islam, Christianity and Sikhism or others), social group (SCs, STs, Other Backward Classes and Others), wealth index and state of residence (non-high focus group states and high focus group states) were included as potential predictors. Inclusion and computation of the variables was guided by a range of existing literature focused on assessing the effect of parental characteristics on health of their children in India and other low- and middle-income countries (Kumar et al., 2021a; Kumar et al., 2021b; Puri et al., 2020; Patel et al., 2020; Vollmer et al., 2017; Rai et al., 2017; Sinha et al., 2016; Corsi et al., 2015; Subramanian et al., 2010; Özaltin et al., 2010; Subramanian et al., 2009). More about the construction and definition of variables in NFHS-4 can be obtained from the DHS recode manual VII (ICF, 2018).

As per the Constitution of India, social groups such as the SCs, STs and the so-called Other Backward Classes are historically, socially and economically disadvantaged populations; the ‘Others’ category represents the population that has historically been more privileged (Rai et al., 2022). Wealth index was calculated by NFHS-4 based on household assets and durables (Vyas and Kumaranayake, 2006). Due to both high fertility and high mortality indicators, nine states are regarded as high focus group states in need of special attention; these are Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, Rajasthan, Uttarakhand, Uttar Pradesh and Assam (Rai et al., 2022). BMI was calculated by dividing the weight in kilograms by the height in meters squared (kg/m^2). To measure the status of diabetes, random blood glucose was measured. Individuals with a blood glucose level of ≥141 milligrams per decilitre or those on medication for diabetes were defined as diabetic (Geldsetzer et al., 2018). Individuals were defined as hypertensive if their systolic blood pressure level reading was ≥140 millimetres of mercury (mmHg), or diastolic blood pressure reading was ≥90 mmHg, or if they were on medication to control hypertension (Geldsetzer et al., 2018). For measuring adult BMI, a SECA 874 U digital scale was used to measure weight, whereas the SECA 213 Stadiometer was used for measuring the height of adults. The standardized protocol for measuring capillary blood sample for glucose level, and measurement of blood pressure were presented in the clinical anthropometric biochemical manual of NFHS-4 (International Institute for Population Sciences, 2014).

4.2.4 *Statistical Analysis*

The sample included in the analysis was compared with the sample excluded from the analysis for all three outcome events—anthropometric failure, anaemia and under-five mortality, for select background characteristics of children (sex of children, education of mother, age at birth of mothers, sex of the household head, social group and wealth index) using a chi-squared test of independence to assess the presence of sample selection bias. Variance inflation factor (VIF) was estimated to assess the presence of multicollinearity among predictor variables for all primary and complementary outcome measures, and a VIF of more than 5 against a predictor variable was considered as multicollinear (Chatterjee and Hadi, 2013). Weighted multivariable logistic regression was used to understand the association between parental characteristics and all primary (any anthropometric failure, any anaemia and under-five mortality) and complementary outcome measures (underweight, stunting, wasting, severe underweight, severe stunting, severe wasting, mild-moderate anaemia, severe anaemia, neonatal mortality and postneonatal mortality). For each outcome event, three separate multivariable regression analyses were conducted. Model I was adjusted for paternal characteristics, Model II included maternal characteristics and Model III was adjusted for parental (both father and mother) characteristics. All regression models were adjusted for paternal or/and maternal characteristics and potential socio-economic predictors—maternal age at birth, child age (for modelling anthropometric failure and anaemia only), sex, birth order, area of residence, religion, social group, wealth index and states of residence. Appropriate sample weights, available with the NFHS-4 dataset, were used. Analysis was performed using the ‘svy’ suite available with statistical software Stata version 14 (StataCorp, 2015).

4.3 Results

Guided by the existing literature, the socioeconomic characteristics for assessing sample selection bias were sex of the child, education of mother, age at birth of mother, sex of the household head, social group and wealth index (**Table S4.1**), and the sample selected for the analysis was not different ($p > 0.05$) from the sample excluded due to ineligibility, indicating the absence of sample selection bias. **Table 4.1** represents the sample distribution of the sample selected for anthropometric failure, anaemia and under-five mortality by characteristics of children.

Table 4.1. Sample distribution of children selected to measure their anthropometric failure (aged 0-59 months), anaemia status (aged 6-59 months), and mortality (aged 0-59 months), by parental characteristics and other covariates.

	Anthropometric failure n (weighted %, or mean)	**Anaemia n (weighted %, or mean)**	**Mortality n (weighted %, or mean)**
Parental current age (in years)			
Father			
15-29	38.6 (9,649)	37.1 (8,831)	38.7 (10,930)
30–39	51.1 (12,865)	52.1 (12,329)	50.8 (14,416)
≥40	10.3 (2,915)	10.7 (2,862)	10.5 (3,347)
Mother			
15-29	73.4 (17,805)	72.4 (16,594)	73.1 (20,075)
30–39	24.5 (6,952)	25.3 (6,753)	24.6 (7,823)
≥40	2.1 (672)	2.3 (675)	2.3 (795)
Parental age at marriage (years)			
Father			
<18	8.3 (2,150)	8.3 (2,051)	8.3 (2,453)
18-20	21.3 (5,560)	21.3 (5,282)	21.4 (6,316)
21-25	41.9 (10,462)	41.7 (9,887)	42.1 (11,822)
≥26	28.5 (7,257)	28.7 (6,802)	28.2 (8,102)
Mother			
<18	37.2 (8,916)	37.5 (8,537)	37.3(10,135)
18-20	36.8 (9,156)	36.7 (8,639)	36.6 (10,324)
21-25	21.9 (5,923)	21.8 (5,518)	22.0 (6,652)
≥26	4.1 (1,434)	4.0 (1,328)	4.1 (1,582)
Parental education			
Father			
No or incomplete primary	23.7 (6,222)	24.0 (5,937)	24.4 (7,202)
Primary or incomplete secondary	53.4 (13,527)	53.5 (12,781)	52.9 (15,186)
Secondary or higher	22.9 (5,680)	22.5 (5,304)	22.7 (6,305)
Mother			
No or incomplete primary	34.1 (9,197)	34.4 (8,798)	34.7 (10,546)
Primary or incomplete secondary	46.6 (11,740)	46.4 (11,028)	46.1 (13,169)
Secondary or higher	19.3 (4,492)	19.2 (4,196)	19.2 (4,978)
Parental years of schooling (mean, SE)			
Father	7.7 (0.0)	7.7 (0.0)	7.7 (0.0)
Mother	6.6 (0.0)	6.5 (0.0)	6.5 (0.0)
Parental employment			
Father			
Unemployed	6.5 (1,542)	6.5 (1,460)	6.6 (1,771)
Non-manual	25.5 (6,128)	25.2 (5,754)	25.3 (6,845)
Agricultural	33.5 (9,236)	33.9 (8,766)	33.8 (10,485)
Manual /others	34.6 (8,523)	34.4 (8,042)	34.4 (9,592)
Mother			
Unemployed	76.3 (19,004)	75.5 (17,791)	76.1 (21,410)
Non-manual	4.6 (1,300)	4.7 (1,245)	4.7 (1,472)
Agricultural	13.3 (3,658)	13.7 (3,549)	13.5 (4,170)
Manual /others	5.9 (1,467)	6.1 (1,437)	5.7 (1,641)

Parental height (in cm)			
Father			
<145	0.6 (106)	0.6 (106)	0.6 (135)
145-149.9	1.7 (492)	1.8 (479)	1.8 (579)
150-154.9	7.4 (1,961)	7.6 (1,938)	7.6 (2,276)
155-159.9	18.9 (5,022)	19.2 (4,747)	19.0 (5,694)
≥160	71.4 (17,848)	70.8 (16,752)	70.9 (20,009)
Mother			
<145	11.9 (2,983)	12.0 (2,845)	12.3 (3,466)
145-149.9	26.0 (6,676)	26.0 (6,309)	26.3 (7,585)
150-154.9	34.2 (8,674)	34.2 (8,170)	33.9 (9,717)
155-159.9	20.1 (5,179)	19.9 (4,861)	19.8 (5,767)
≥160	7.8 (1,917)	7.9 (1,837)	7.7 (2,158)
Parental height (mean, SE)			
Father	163.6 (0.4)	163.5 (0.5)	163.5 (0.4)
Mother	151.7 (0.4)	151.7 (0.4)	151.7 (0.4)
Parental BMI			
Father			
<17.00	5.3 (1,230)	5.2 (1,163)	5.3 (1,397)
17.00–18.49	11.5 (2,877)	11.2 (2,660)	11.5 (3,230)
18.50–23.49	51.7 (13,832)	51.8 (13,088)	52.2 (15,687)
23.50–24.99	11.9 (3,024)	12.0 (2,877)	11.8 (3,401)
25.00–29.99	16.9 (3,851)	16.9 (3,642)	16.6 (4,293)
≥30.00	2.8 (615)	2.9 (592)	2.7 (685)
Mother			
<17.00	9.8 (2,276)	10.1 (2,225)	9.9 (2,589)
17.00–18.49	15.5 (3,817)	15.5 (3,614)	15.5 (4,286)
18.50–23.49	50.7 (13,601)	50.2 (12,760)	50.8 (15,404)
23.50–24.99	8.5 (2,115)	8.6 (2,006)	8.6 (2,397)
25.00–29.99	12.3 (2,887)	12.3 (2,714)	12.0 (3,200)
≥30.00	3.2 (733)	3.2 (703)	3.2 (817)
Parental BMI (mean, SE)			
Father	22.09 (2.4)	22.10 (2.5)	22.07 (2.3)
Mother	15.17 (0.4)	15.17 (0.4)	15.17 (0.4)
Parental tobacco use			
Father			
Non-user	43.1 (9,993)	42.7 (9,391)	43.1 (11,264)
User	56.9 (15,436)	57.3 (14,631)	56.9 (17,429)
Mother			
Non-user	94.2 (22,804)	94.0 (21,517)	93.9 (25,680)
User	5.8 (2,625)	6.0 (2,505)	6.1 (3,013)
Parental alcohol use			
Father			
Non-user	63.4 (15,432)	63.3 (14,574)	63.4 (17,407)
User	36.6 (9,997)	36.7 (9,448)	36.6 (11,286)
Mother			
Non-user	98.9 (24,882)	98.9 (23,487)	98.9 (28,049)
User	1.1 (547)	1.1 (535)	1.1 (644)
Parental diabetes status			
Father			
Non-diabetic	92.9 (23,676)	92.8 (22,325)	92.9 (26,698)
Diabetic	7.1 (1,753)	7.2 (1,697)	7.1 (1,995)
Mother			
Non-diabetic	96.2 (24,516)	96.0 (23,119)	96.2 (27,648)
Diabetic	3.8 (913)	4.0 (903)	3.8 (1,045)
Parental hypertension status			
Father			
Non-hypertensive	96.0 (24,309)	95.9 (22,955)	96.0 (27,433)
Hypertensive	4.0 (1,120)	4.1 (1,067)	4.0 (1,260)
Mother			

Non-hypertensive	99.0 (25,081)	99.0 (23,702)	98.9 (28,286)
Hypertensive	1.0 (348)	1.1 (320)	1.1 (407)
Maternal age at birth (years)			
<17	6.2 (1,428)	6.4 (1,387)	6.3 (1,654)
17–19	30.0 (7,399)	30.0 (7,061)	29.7 (8,341)
20–24	49.7 (12,550)	49.5 (11,814)	49.8 (14,181)
25–29	12.1 (3,316)	12.0 (3,079)	12.1 (3,693)
30–49	2.1 (736)	2.1 (681)	2.2 (824)
Child age (years)			
0	17.2 (4,478)	10.2 (2,456)	na
1	20.1 (5,088)	21.9 (5,249)	na
2	20.0 (5,137)	22.0 (5,341)	na
3	21.9 (5,489)	23.5 (5,626)	na
4	20.8 (5,237)	22.4 (5,350)	na
Child sex			
Male	51.2 (13,130)	51.8 (12,495)	51.9 (14,952)
Female	48.8 (12,299)	48.2 (11,527)	48.1 (13,741)
Child's birth order			
First	36.9 (8,904)	37.1 (8,442)	36.8 (10,022)
Second	32.8 (7,994)	32.5 (7,505)	32.5 (8,933)
Third	15.7 (4,226)	15.8 (4,002)	15.7 (4,759)
Fourth	7.4 (2,133)	7.4 (2,017)	7.5 (2,431)
Fifth or higher	7.3 (2,172)	7.3 (2,056)	7.6 (2,548)
Area of residence			
Urban	29.7 (6,607)	29.6 (6,234)	29.4 (7,372)
Rural	70.3 (18,822)	70.4 (17,788)	70.6 (21,321)
Religion			
Hindu	81.6 (19,126)	81.8 (18,110)	81.7 (21,603)
Islam	13.3 (3,280)	13.2 (3,085)	13.1 (3,678)
Christian	2.2 (2,005)	2.3 (1,882)	2.3 (2,285)
Sikhs	1.4 (456)	1.4 (413)	1.4 (498)
Other/missing	1.5 (562)	1.4 (532)	1.5 (629)
Social group			
Others	20.0 (4,604)	20.2 (4,362)	19.8 (5,087)
Scheduled castes	21.9 (5,041)	21.8 (4,786)	21.8 (5,705)
Scheduled tribes	11.4 (5,462)	11.4 (5,102)	11.7 (6,259)
Other backward classes	46.7 (10,322)	46.7 (9,772)	46.8 (11,642)
Wealth index			
Poorest	22.8 (6,207)	22.9 (5,908)	23.1 (7,130)
Poorer	21.3(5,792)	21.4 (5,495)	21.4 (6,608)
Middle	21.3 (5,286)	21.2 (4,962)	21.2 (5,907)
Richer	18.4 (4,331)	18.4 (4,069)	18.4 (4,824)
Richest	16.2 (3,813)	16.1 (3,588)	15.9 (4,224)
States			
Non-high focus group states	48.3 (10,738)	48.9 (10,230)	48.4 (12,124)
High focus group states	51.7 (14,691)	51.1 (13,792)	51.6 (16,569)
Total	25,429	24,022	28,693

All *n* are un-weighted
BMI: Body Mass Index (kg/m^2), SE: Standard Error; na: not included in the analysis

Of the total sample, over 50% of fathers were aged 30–39 years, whereas over 70% mothers were from the 15–29 age group. Most fathers got married between ages 21 and 25, in contrast to mothers who typically got married under 18 years of age. Over 20% of fathers had either no education or completed primary education, whereas the proportion of mothers in the same group was more than 30%. Around 6% of fathers were unemployed, while over 75% mothers were unemployed. Most parents had a BMI of 18.50–23.49 kg/m^2. Use of tobacco and alcohol among fathers was higher than among mothers, as was the proportion of having diabetes and hypertension.

Tables 4.2–4.4 represent associations between parental characteristics and any anthropometric failure, any anaemia and under-five mortality measured as odds ratio (OR) with a 95% confidence interval (CI). VIFs for all predictor variables were <5, indicating a low probability of multicollinearity (results not shown separately). Interpretation and discussion of findings focus on models which included both parents' characteristics (that is Model III), unless mentioned otherwise. This strategy of interpretation followed the consensus that both parents' characteristics generally have a joint effect on their offspring's health. Findings revealed that as compared to fathers aged 15–29 years, children of fathers aged 30–39 years were less likely to have any anthropometric failure or any anaemia (OR = 0.87, CI = 0.77–0.97 and OR = 0.88, CI = 0.79–0.98, respectively), and a similar association was observed for Model I which adjusted only paternal characteristics. Compared to fathers who got married before 18 years of age, children born to fathers who were married between ages 18 and 25 years had lower odds of under-five mortality. Parental education appeared to be a protective factor for all three primary outcomes—any anthropometric failure, any anaemia and under-five mortality. This association was also found in Models I and II, which independently controlled for paternal and maternal characteristics, respectively. With increasing maternal height, children had lower odds of any anthropometric failure and were less likely to experience under-five mortality. This association was also found after controlling for maternal characteristics only (Model II). Increased BMI of fathers (18.50 through ≥30 kg/m^2) and mothers was associated with lower anthropometric failure, whereas mothers' BMI (18.50 through 29.99 kg/m^2) was associated with lower odds of anaemia. Use of tobacco by mothers was associated with increased under-five mortality (OR = 1.50, CI = 1.17–1.91), as evident from Model II (adjusted for maternal characteristics) and Model III (adjusted for parental characteristics). Children of fathers with diabetes had higher odds of under-five mortality (OR = 1.36, CI = 1.01–1.82), which was also found in Model I. Children born to mothers with hypertension had lower odds (OR = 0.69, CI = 0.51–0.94) of any anthropometric failure (Model III), which was also found in Model II. The analyses of complementary outcome measures are presented in online supplements—underweight (**Table S4.2**), stunting (**Table S4.3**), wasting (**Table S4.4**), severe underweight (**Table S4.5**), severe stunting (**Table S4.6**), severe wasting (**Table S4.7**), mild–moderate anaemia (**Table S4.8**), severe anaemia (**Table S4.9**), neonatal mortality (**Table S4.10**) and postneonatal mortality (**Table S4.11**). To reiterate, the complementary analyses have been supplied to understand the role of parental characteristics on various stages of any anthropometric failure, any anaemia and under-five mortality of their children.

Table 4.2. Association between parental characteristics and any anthropometric failure (aged 0-59 months).

Parental characteristics	**Number** children with any anthropometric failure**, n**		**Model I** [α]		**Model II** [β]		**Model III** [¥]			
			Father		**Mother**		**Father**		**Mother**	
	Father	**Mother**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**
Age (in years)										
15-29	5,563	9,919	1.00		1.00		1.00		1.00	
30–39	6,902	3,730	0.85 (0.76-0.95)	0.004	0.93 (0.82-1.05)	0.241	0.87 (0.77-0.97)	0.016	0.95 (0.83-1.09)	0.489
≥40	1,585	401	0.74 (0.61-0.89)	0.001	0.93 (0.70-1.24)	0.627	0.80 (0.65-0.97)	0.025	0.96 (0.70-1.31)	0.781
Age at marriage (years)										
<18	1,362	5,448	1.00		1.00		1.00		1.00	
18-20	3,416	5,162	0.95 (0.82-1.09)	0.443	1.02 (0.92-1.13)	0.685	0.97 (0.84-1.11)	0.641	1.04 (0.93-1.15)	0.514
21-25	5,884	2,887	0.93 (0.81-1.07)	0.295	0.99 (0.87-1.14)	0.912	0.94 (0.81-1.08)	0.393	1.04 (0.90-1.20)	0.600
≥26	3,388	553	0.84 (0.71-1.00)	0.049	0.85 (0.66-1.11)	0.229	0.89 (0.75-1.06)	0.199	0.92 (0.70-1.20)	0.540
Education										
None or incomplete primary	4,098	6,065	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	7,540	6,168	0.89 (0.80-0.98)	0.021	0.78 (0.71-0.85)	<0.001	0.96 (0.87-1.06)	0.441	0.82 (0.75-0.91)	<0.001
Secondary or higher	2,412	1,817	0.73 (0.64-0.84)	<0.001	0.66 (0.57-0.77)	<0.001	0.85 (0.74-0.98)	0.025	0.76 (0.65-0.89)	0.001
Employment										
Unemployed	827	10,292	1.00		1.00		1.00		1.00	
Non-manual	2,830	620	1.05 (0.89-1.25)	0.539	1.02 (0.85-1.24)	0.804	1.11 (0.93-1.31)	0.241	1.04 (0.85-1.25)	0.723
Agricultural	5,536	2,271	1.12 (0.95-1.31)	0.170	1.02 (0.91-1.13)	0.784	1.15 (0.98-1.35)	0.083	0.98 (0.88-1.10)	0.740
Manual/others	4,857	867	1.04 (0.89-1.23)	0.595	1.05 (0.88-1.25)	0.564	1.07 (0.91-1.26)	0.399	1.03 (0.86-1.22)	0.760
Height (in cm)										
<145	82	2,177	1.00		1.00		1.00		1.00	
145-149.9	344	4,193	0.78 (0.36-1.70)	0.535	0.66 (0.57-0.76)	<0.001	0.84 (0.38-1.87)	0.668	0.69 (0.60-0.80)	<0.001
150-154.9	1,364	4,652	0.75 (0.36-1.57)	0.448	0.53 (0.46-0.60)	<0.001	0.82 (0.38-1.77)	0.618	0.57 (0.49-0.65)	<0.001
155-159.9	3,192	2,303	0.61 (0.29-1.26)	0.181	0.39 (0.34-0.46)	<0.001	0.71 (0.33-1.51)	0.373	0.43 (0.37-0.50)	<0.001
≥160	9,068	725	0.39 (0.19-0.80)	0.011	0.28 (0.23-0.34)	<0.001	0.49 (0.23-1.04)	0.064	0.32 (0.27-0.38)	<0.001
BMI										
<17.00	842	1,599	1.00		1.00		1.00		1.00	
17.00–18.49	1,904	2,428	0.90 (0.73-1.11)	0.329	0.77 (0.66-0.90)	0.001	0.94 (0.77-1.16)	0.589	0.79 (0.68-0.92)	0.003
18.50–23.49	7,935	7,605	0.67 (0.56-0.81)	<0.001	0.61 (0.53-0.69)	<0.001	0.75 (0.62-0.90)	0.002	0.64 (0.56-0.73)	<0.001

23.50–24.99	1,465	1,016	0.55 (0.44-0.68)	<0.001	0.53 (0.44-0.63)	<0.001	0.63 (0.51-0.78)	<0.001	0.57 (0.48-0.69)	<0.001
25.00–29.99	1,656	1,150	0.58 (0.47-0.71)	<0.001	0.47 (0.39-0.57)	<0.001	0.69 (0.56-0.85)	<0.001	0.52 (0.43-0.63)	<0.001
≥30.00	248	252	0.43 (0.32-0.60)	<0.001	0.34 (0.26-0.44)	<0.001	0.55 (0.39-0.75)	<0.001	0.38 (0.29-0.50)	<0.001
Tobacco use										
Non-user	5,015	12,525	1.00		1.00		1.00		1.00	
User	9,035	1,525	1.10 (1.01-1.20)	0.029	1.11 (0.97-1.29)	0.134	1.07 (0.99-1.17)	0.103	1.06 (0.92-1.23)	0.409
Alcohol use										
Non-user	8,410	13,720	1.00		1.00		1.00		1.00	
User	5,640	330	0.99 (0.91-1.07)	0.767	0.87 (0.65-1.17)	0.360	0.97 (0.89-1.05)	0.409	0.89 (0.66-1.20)	0.447
Diabetes status										
Non-diabetic	13,170	13,612	1.00		1.00		1.00		1.00	
Diabetic	880	438	0.89 (0.76-1.04)	0.143	0.85 (0.69-1.04)	0.120	0.91 (0.77-1.07)	0.263	0.89 (0.72-1.10)	0.287
Hypertension status										
Non-hypertensive	13,529	13,890	1.00		1.00		1.00		1.00	
Hypertensive	521	160	1.11 (0.92-1.35)	0.289	0.70 (0.51-0.95)	0.020	1.10 (0.90-1.34)	0.361	0.69 (0.51-0.94)	0.018

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

[α] Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

[β] Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

[¥] Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table 4.3. Association between parental characteristics and any anaemia (aged 6-59 months).

Parental characteristics	**Number of** children with any anaemia, **n**		**Model I** $^{\alpha}$		**Model II** $^{\beta}$		**Model III** $^{¥}$			
			Father		**Mother**		**Father**		**Mother**	
	Father	**Mother**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**
Age (in years)										
15-29	5,569	9,964	1.00		1.00		1.00		1.00	
30–39	6,965	3,738	0.86 (0.77-0.96)	0.008	0.92 (0.82-1.04)	0.186	0.88 (0.79-0.98)	0.021	0.95 (0.83-1.07)	0.390
≥40	1,536	368	0.83 (0.69-1.00)	0.045	0.94 (0.71-1.24)	0.659	0.85 (0.70-1.03)	0.103	0.95 (0.70-1.29)	0.761
Age at marriage (years)										
<18	1,280	5,195	1.00		1.00		1.00		1.00	
18-20	3,271	5,150	1.01 (0.87-1.17)	0.928	1.04 (0.94-1.16)	0.427	1.00 (0.86-1.16)	0.964	1.05 (0.94-1.17)	0.376
21-25	5,934	3,055	1.00 (0.86-1.15)	0.966	0.86 (0.75-0.99)	0.030	1.00 (0.86-1.16)	0.961	0.90 (0.78-1.05)	0.174
≥26	3,585	670	0.85 (0.71-1.00)	0.056	0.88 (0.68-1.14)	0.321	0.88 (0.74-1.05)	0.160	0.95 (0.73-1.24)	0.723
Education										
No or incomplete primary	3,775	5,626	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	7,456	6,232	0.86 (0.78-0.95)	0.003	0.85 (0.77-0.94)	0.001	0.89 (0.80-0.98)	0.024	0.89 (0.81-0.98)	0.022
Secondary or higher	2,839	2,212	0.76 (0.67-0.87)	<0.001	0.70 (0.60-0.81)	<0.001	0.84 (0.73-0.97)	0.017	0.76 (0.65-0.89)	0.001
Employment										
Unemployed	867	10,463	1.00		1.00		1.00		1.00	
Non-manual	3,176	611	0.97 (0.82-1.15)	0.729	1.10 (0.91-1.34)	0.313	0.99 (0.83-1.17)	0.891	1.10 (0.90-1.33)	0.350
Agricultural	5,217	2,139	0.96 (0.82-1.13)	0.629	1.08 (0.97-1.21)	0.148	0.95 (0.81-1.12)	0.561	1.08 (0.97-1.21)	0.158
Manual/others	4,810	857	0.96 (0.82-1.14)	0.667	1.06 (0.89-1.26)	0.546	0.97 (0.82-1.14)	0.670	1.06 (0.89-1.26)	0.527
Height (in cm)										
<145	61	1,704	1.00		1.00		1.00		1.00	
145-149.9	303	3,759	1.30 (0.66-2.57)	0.449	0.95 (0.83-1.09)	0.498	1.35 (0.68-2.68)	0.398	0.96 (0.84-1.10)	0.593
150-154.9	1,169	4,725	1.34 (0.71-2.56)	0.366	0.99 (0.87-1.13)	0.876	1.40 (0.73-2.70)	0.307	1.00 (0.88-1.14)	0.995
155-159.9	2,827	2,830	1.14 (0.61-2.16)	0.676	0.95 (0.82-1.10)	0.516	1.20 (0.63-2.29)	0.571	0.97 (0.84-1.12)	0.639
≥160	9,710	1,052	1.16 (0.62-2.18)	0.639	0.91 (0.76-1.09)	0.324	1.23 (0.65-2.34)	0.525	0.94 (0.78-1.12)	0.487
BMI										
<17.00	734	1,496	1.00		1.00		1.00		1.00	
17.00–18.49	1,726	2,303	1.19 (0.97-1.46)	0.090	0.87 (0.74-1.01)	0.072	1.21 (0.99-1.48)	0.066	0.88 (0.76-1.03)	0.121
18.50–23.49	7,741	7,375	1.03 (0.86-1.23)	0.739	0.79 (0.69-0.91)	0.001	1.07 (0.89-1.28)	0.458	0.81 (0.71-0.93)	0.002
23.50–24.99	1,623	1,073	0.98 (0.80-1.21)	0.866	0.72 (0.60-0.87)	0.001	1.03 (0.84-1.27)	0.765	0.74 (0.62-0.90)	0.002

25.00–29.99	1,932	1,438	0.91 (0.74-1.12)	0.366	0.77 (0.64-0.92)	0.003	0.96 (0.78-1.19)	0.720	0.80 (0.67-0.95)	0.013
≥30.00	314	385	0.94 (0.68-1.29)	0.707	0.81 (0.61-1.06)	0.127	0.98 (0.71-1.36)	0.919	0.86 (0.66-1.13)	0.292
Tobacco use										
Non-user	5,517	12,843	1.00		1.00		1.00		1.00	
User	8,553	1,227	0.95 (0.87-1.04)	0.268	0.93 (0.80-1.07)	0.281	0.94 (0.86-1.03)	0.203	0.92 (0.80-1.06)	0.276
Alcohol use										
Non-user	8,708	13,768	1.00		1.00		1.00		1.00	
User	5,362	302	0.93 (0.86-1.01)	0.105	0.83 (0.61-1.11)	0.209	0.93 (0.86-1.02)	0.118	0.84 (0.62-1.13)	0.247
Diabetes status										
Non-diabetic	13,128	13,558	1.00		1.00		1.00		1.00	
Diabetic	942	512	1.01 (0.86-1.17)	0.940	1.00 (0.78-1.28)	0.981	1.01 (0.87-1.17)	0.918	1.01 (0.79-1.29)	0.929
Hypertension status										
Non-hypertensive	13,498	13,891	1.00		1.00		1.00		1.00	
Hypertensive	572	179	1.18 (0.97-1.42)	0.096	1.16 (0.85-1.57)	0.355	1.17 (0.97-1.42)	0.098	1.16 (0.85-1.58)	0.342

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

[α] Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

[β] Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

[¥] Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table 4.4. Association between parental characteristics and under-five mortality (aged 0-59 months).

Parental characteristics	Number under-five mortality, n		Model I [α]		Model II [β]		Model III [¥]			
			Father		Mother		Father		Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	508	886	1.00		1.00		1.00		1.00	
30–39	628	395	0.95 (0.77-1.18)	0.651	1.01 (0.81-1.27)	0.918	0.94 (0.76-1.17)	0.587	0.99 (0.76-1.28)	0.912
≥40	204	59	1.30 (0.91-1.87)	0.153	1.25 (0.72-2.17)	0.426	1.27 (0.84-1.91)	0.252	0.94 (0.51-1.72)	0.840
Age at marriage (years)										
<18	126	538	1.00		1.00		1.00		1.00	
18-20	335	477	1.29 (0.99-1.69)	0.062	1.08 (0.88-1.32)	0.460	1.35 (1.03-1.76)	0.029	1.06 (0.87-1.30)	0.542
21-25	588	273	1.37 (1.06-1.78)	0.016	1.13 (0.85-1.50)	0.393	1.43 (1.10-1.87)	0.008	1.25 (0.94-1.66)	0.127
≥26	291	52	0.88 (0.64-1.23)	0.461	1.20 (0.68-2.11)	0.523	0.90 (0.64-1.27)	0.558	1.47 (0.83-2.59)	0.183
Education										
No or incomplete primary	473	646	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	681	558	0.68 (0.57-0.81)	<0.001	0.75 (0.62-0.91)	0.003	0.72 (0.60-0.87)	<0.001	0.82 (0.68-0.99)	0.040
Secondary or higher	186	136	0.56 (0.42-0.74)	<0.001	0.61 (0.42-0.90)	0.012	0.62 (0.45-0.86)	0.004	0.73 (0.48-1.13)	0.163
Employment										
Unemployed	86	936	1.00		1.00		1.00		1.00	
Non-manual	260	67	0.89 (0.63-1.27)	0.537	1.13 (0.76-1.68)	0.549	0.93 (0.65-1.32)	0.671	1.13 (0.77-1.67)	0.536
Agricultural	525	249	0.78 (0.56-1.09)	0.140	1.11 (0.89-1.37)	0.353	0.79 (0.57-1.10)	0.160	1.11 (0.89-1.39)	0.363
Manual/others	469	88	0.80 (0.57-1.13)	0.205	0.95 (0.71-1.26)	0.719	0.82 (0.59-1.16)	0.260	0.91 (0.68-1.23)	0.546
Height (in cm)										
<145	7	227	1.00		1.00		1.00		1.00	
145-149.9	34	406	0.77 (0.29-2.08)	0.612	0.88 (0.69-1.11)	0.281	0.80 (0.29-2.21)	0.667	0.89 (0.70-1.14)	0.350
150-154.9	97	414	0.62 (0.24-1.57)	0.311	0.70 (0.55-0.87)	0.002	0.64 (0.25-1.69)	0.371	0.71 (0.56-0.89)	0.003
155-159.9	284	221	0.74 (0.30-1.86)	0.528	0.64 (0.49-0.85)	0.002	0.81 (0.31-2.08)	0.661	0.66 (0.50-0.88)	0.004
≥160	918	72	0.69 (0.28-1.70)	0.417	0.61 (0.40-0.93)	0.020	0.78 (0.31-1.98)	0.605	0.64 (0.42-0.97)	0.036
BMI										
<17.00	82	139	1.00		1.00		1.00		1.00	
17.00–18.49	179	202	0.95 (0.65-1.36)	0.763	0.94 (0.70-1.25)	0.673	0.96 (0.66-1.39)	0.813	0.97 (0.72-1.29)	0.827
18.50–23.49	762	716	0.85 (0.62-1.16)	0.307	0.92 (0.72-1.18)	0.533	0.87 (0.63-1.21)	0.412	0.96 (0.75-1.23)	0.733
23.50–24.99	125	126	0.62 (0.42-0.93)	0.021	1.33 (0.92-1.92)	0.128	0.66 (0.44-0.99)	0.043	1.40 (0.97-2.03)	0.076

25.00–29.99	164	120	0.75 (0.51-1.10)	0.142	0.89 (0.62-1.27)	0.517	0.77 (0.52-1.13)	0.183	0.93 (0.65-1.34)	0.701
≥30.00	28	37	0.90 (0.46-1.77)	0.754	1.08 (0.67-1.73)	0.760	0.93 (0.47-1.84)	0.836	1.13 (0.69-1.83)	0.627
Tobacco use										
Non-user	468	1,140	1.00		1.00		1.00		1.00	
User	872	200	1.03 (0.85-1.24)	0.765	1.51 (1.18-1.92)	0.001	1.00 (0.83-1.20)	0.987	1.50 (1.17-1.91)	0.001
Alcohol use										
Non-user	812	1,292	1.00		1.00		1.00		1.00	
User	528	48	0.93 (0.79-1.100	0.400	1.13 (0.66-1.91)	0.658	0.91 (0.77-1.08)	0.275	1.16 (0.67-2.01)	0.592
Diabetes status										
Non-diabetic	1,230	1,288	1.00		1.00		1.00		1.00	
Diabetic	110	52	1.34 (1.00-1.80)	0.050	0.94 (0.65-1.36)	0.740	1.36 (1.01-1.82)	0.040	0.91 (0.62-1.32)	0.612
Hypertension status										
Non-hypertensive	1,279	1,319	1.00		1.00		1.00		1.00	
Hypertensive	61	21	1.03 (0.73-1.45)	0.868	1.04 (0.60-1.81)	0.888	1.02 (0.73-1.44)	0.903	1.02 (0.59-1.76)	0.940

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

$^{\alpha}$ Adjusted for father's characteristics and maternal age at birth, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{\beta}$ Adjusted for mother's characteristics and maternal age at birth, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{¥}$ Adjusted for parental (father and mother) characteristics and maternal age at birth, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

4.4 Discussion

Parental characteristics and their relationship with offspring health have been studied widely, mostly by evolutionary biologists. Public health researchers have attempted to explore if the evolutionary aspect of parent–child relationship could help mitigate some of the most daunting challenges in child health (Wells et al., 2017). Existing studies on the role of parental characteristics on offspring health in India have tested a limited range of information on parental attributes and often tested limited indicators of child health. To address this knowledge gap, this study used a nationally representative cross-sectional NFHS-4 dataset to expand and understand the role of additional parental characteristics on the health of their children aged 0–59 months. Three primary outcome measures were analysed—any anthropometric failure, anaemia and under-five mortality; the discussion of this article has focused on these primary outcome measures, while complementary analyses were supplied for further understanding and review of the issue.

Findings of this study should be interpreted considering a range of limitations. First, interpretation should be assumed as an association and should not imply any causality. Second, most of the information on parental characteristics were self-reported by parents, and mothers responded on behalf of their children; thus, there is a chance of recall errors and/or social desirability bias. Third, some studies have questioned the measurement error of HemoCue device (Karakochuk et al., 2019). Therefore, a cautious interpretation of the reported haemoglobin levels is suggested. Finally, for the measurement of clinical anthropometric biochemical indicators such as height, weight, anaemia, diabetes mellitus and hypertension, all precautions were taken to ensure precision of measurement with stringent monitoring (International Institute for Population Sciences, 2014). However, one cannot exclude the possibility of measurement error. Future studies on this issue should focus on analysing robust cohort data to estimate the effects of parental characteristics on the health of their children.

This study revealed that with father's higher age, children were less likely to experience any anthropometric failure and any anaemia (for age group 30–39 years). This association is consistent with an earlier study which showed that older fathers were more likely to be involved in their children's healthcare (Moore and Kotelchuck, 2004), thus reducing the odds of morbidity among children. The analysis also revealed that children born to fathers who got married at age <18 years had higher likelihood of mortality. Although the adverse effects of low maternal age at marriage on child mortality (Raj et al., 2010) have been studied widely, the adverse effects of a father's low age at marriage on under-five mortality in India remain understudied. To our knowledge, no empirical studies were available to show the detrimental effect of <18 years of age at marriage of fathers on offspring health in India (Jejeebhoy, 2019). The role of parental education on child health has been studied globally. Our analysis showed that parental education had a protective association with any anthropometric failure, any anaemia and under-five mortality. Parental education is a proxy indicator for economic opportunities and appropriate health knowledge to take care of their own health and the health of their children (Aslam and Kingdon, 2012). Earlier studies on India and other low- and middle-income countries have shown that paternal education is important for reduction in child undernutrition (Vollmer et al., 2017), and educated parents are more likely to ensure better nutrition for their children (Alderman and Headey, 2017).

Furthermore, our analysis revealed that with increasing maternal height, children had lower odds of any anthropometric failure and were less likely to experience under-five mortality. This finding is consistent with studies conducted in India (Subramanian et al., 2009) and in 54 low- and middle-income countries (Özaltin et al., 2010). Earlier studies on the association between parental BMI and child health (undernutrition) demonstrated that intergenerational associations in nutritional status were not driven by maternal intrauterine influences (Subramanian et al., 2010). Similarly, findings of this study suggest that increased BMI of fathers (18.50 through ≥30) and mothers was associated with lower anthropometric failure, whereas mothers' BMI (18.50 through 29.99) was associated with lower odds of anaemia.

Of behavioural lifestyle indicators, the results indicate that the use of tobacco by mothers was associated with increased under-five mortality. This finding concurs with studies conducted in sub-Saharan African countries (Akinyemi et al., 2016), Southeast Asian Countries (Andriani et al., 2019) and India, where it was suggested that smoking among mothers could lead to adverse pregnancy outcomes (Suliankatchi and Sinha, 2016). Having NCDs such as diabetes among fathers was associated with increased risk of under-five mortality. Although a genetic disposition could potentially explain the likelihood of poor health outcomes of children of diabetic fathers (van Esch et al., 2010), this finding needs further exploration on all the possible pathways for which this relationship could be true. In addition, our multivariable analysis showing that children born to hypertensive mothers had lower odds of experiencing any anthropometric failure also requires further investigation, and this finding should be interpreted with caution.

4.5 Conclusion

To conclude, this study highlights that early age at marriage (<18 years) among men could be detrimental for the survival of their children. Education of parents was protective for any anthropometric failure, any anaemia and mortality of their children. As maternal height is a protective factor for any anthropometric failure and under-five mortality, this study could be valuable for pre-pregnancy preparation of prospective mothers with relatively shorter height while ensuring that proper nutrition and healthcare is available for children born to mothers with short stature. As use of tobacco by mothers and fathers being diabetic are associated with under-five mortality, a greater focus on mandatory tobacco cessation counselling for women and diabetes control programmes for men could be effective interventions.

Table S4.1. Comparison of distribution between analytical sample and sample excluded from the analysis, by select background characteristics.

	Anthropometric failure		Anaemia		Under-five mortality	
	Analytical sample, %	Excluded sample, %	Analytical sample, %	Excluded sample, %	Analytical sample, %	Excluded sample, %
Child sex	p= 0.851		p= 0.641		p=0.739	
Male	51.2	51.0	51.8	51.1	51.9	51.5
Female	48.8	49.1	48.2	48.9	48.1	48.5
Mother's education	p= 0.625		p= 0.672		p=0.186	
No or incomplete primary	34.1	33.2	34.4	34.5	34.7	33.4
Primary or incomplete secondary	46.6	47.2	46.4	47.4	46.1	45.8
Secondary or higher	19.3	19.6	19.2	18.2	19.2	20.8
Maternal age at birth (years)	p= 0.317		p= 0.262		p=0.536	
<17	6.2	7.8	6.4	7.4	6.3	7.7
17–19	30.0	30.6	30.0	31.8	29.7	30.4
20–24	49.7	46.7	49.5	46.3	49.8	45.7
25–29	12.1	12.6	12.0	12.0	12.1	13.8
30–49	2.1	2.4	2.1	2.5	2.2	2.4
Sex of household head	p= 0.445		p= 0.727		p= 0.633	
Male	92.3	92.9	92.4	92.7	92.4	92.8
Female	7.7	7.1	7.6	7.3	7.6	7.2
Social group	p= 0.054		p= 0.417		p=0.069	
Others	20.0	25.0	20.2	22.2	19.8	25.0
Scheduled castes	21.9	18.5	21.8	19.4	21.8	17.7
Scheduled tribes	11.4	14.1	11.4	14.5	11.7	14.3
Other backward classes	46.7	42.4	46.7	43.9	46.8	43.0
Wealth index	p= 0.216		p= 0.648		p=0.056	
Poorest	22.8	20.6	22.9	21.1	23.1	20.3
Poorer	21.3	22.4	21.4	22.8	21.4	21.3
Middle	21.3	21.1	21.2	21.6	21.2	20.9
Richer	18.4	18.3	18.4	18.5	18.4	17.9
Richest	16.2	17.6	16.1	16.1	15.9	19.6
Total, n	25,429	3,523	24,022	3,243	28,693	4,354

All *n* are un-weighted

p values were obtained from chi-squared test

Table S4.2. Association between parental characteristics and underweight among children aged 0-59 months.

Parental characteristics	Number of underweight children, n		Model 1 [α]		Model 1I [β]		Model III [¥]			
			Father		Mother		Father		Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	3,563	6,355	1.00		1.00		1.00		1.00	
30–39	4,418	2,407	0.90 (0.81-1.00)	0.058	1.00 (0.88-1.14)	0.951	0.94 (0.83-1.05)	0.246	1.02 (0.89-1.17)	0.820
≥40	1,055	274	0.82 (0.68-0.98)	0.030	1.13 (0.85-1.52)	0.397	0.87 (0.71-1.06)	0.178	1.16 (0.84-1.60)	0.360
Age at marriage (years)										
<18	942	3,696	1.00		1.00		1.00		1.00	
18-20	2,287	3,343	0.96 (0.83-1.11)	0.577	1.07 (0.96-1.18)	0.237	0.97 (0.84-1.12)	0.656	1.08 (0.97-1.20)	0.156
21-25	3,786	1,726	0.96 (0.83-1.10)	0.524	1.03 (0.89-1.18)	0.714	0.94 (0.82-1.09)	0.431	1.05 (0.90-1.21)	0.554
≥26	2,021	271	0.91 (0.77-1.08)	0.298	0.80 (0.59-1.07)	0.135	0.96 (0.81-1.15)	0.666	0.82 (0.61-1.12)	0.216
Education										
No or incomplete primary	2,862	4,262	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	4,819	3,812	0.91 (0.82-1.00)	0.053	0.79 (0.73-0.87)	<0.001	0.98 (0.88-1.08)	0.665	0.84 (0.76-0.92)	<0.001
Secondary or higher	1,355	962	0.78 (0.67-0.90)	0.001	0.66 (0.57-0.77)	<0.001	0.91 (0.78-1.06)	0.239	0.75 (0.63-0.89)	0.001
Employment										
Unemployed	512	6,530	1.00		1.00		1.00		1.00	
Non-manual	1,672	353	1.01 (0.84-1.20)	0.947	0.88 (0.72-1.07)	0.192	1.06 (0.89-1.27)	0.482	0.90 (0.74-1.09)	0.266
Agricultural	3,630	1,534	1.20 (1.02-1.41)	0.032	1.02 (0.92-1.14)	0.652	1.23 (1.04-1.44)	0.013	0.98 (0.88-1.09)	0.709
Manual/others	3,222	619	1.12 (0.95-1.32)	0.194	1.12 (0.94-1.32)	0.211	1.15 (0.97-1.35)	0.100	1.07 (0.90-1.28)	0.427
Height (in cm)										
<145	63	1,596	1.00		1.00		1.00		1.00	
145-149.9	237	2,804	0.50 (0.28-0.91)	0.024	0.67 (0.59-0.76)	<0.001	0.53 (0.28-0.98)	0.042	0.69 (0.61-0.79)	<0.001
150-154.9	944	2,912	0.49 (0.28-0.85)	0.011	0.52 (0.46-0.59)	<0.001	0.52 (0.29-0.92)	0.026	0.55 (0.49-0.63)	<0.001
155-159.9	2,175	1,351	0.46 (0.27-0.80)	0.006	0.38 (0.33-0.43)	<0.001	0.53 (0.30-0.94	0.029	0.41 (0.36-0.48)	<0.001
≥160	5,617	373	0.28 (0.16-0.48)	<0.001	0.24 (0.20-0.29)	<0.001	0.35 (0.20-0.61)	<0.001	0.27 (0.22-0.33)	<0.001
BMI										
<17.00	650	1,240	1.00		1.00		1.00		1.00	
17.00–18.49	1,388	1,740	0.83 (0.69-1.01)	0.057	0.71 (0.61-0.82)	<0.001	0.88 (0.73-1.06)	0.188	0.73 (0.63-0.84)	<0.001
18.50–23.49	5,098	4,769	0.58 (0.49-0.69)	<0.001	0.48 (0.42-0.54)	<0.001	0.66 (0.56-0.78)	<0.001	0.50 (0.44-0.57)	<0.001

23.50–24.99	860	581	0.45 (0.37-0.55)	<0.001	0.39 (0.33-0.47)	<0.001	0.54 (0.44-0.66)	<0.001	0.42 (0.35-0.51)	<0.001
25.00–29.99	921	580	0.47 (0.39-0.58)	<0.001	0.32 (0.26-0.39)	<0.001	0.60 (0.49-0.73)	<0.001	0.35 (0.29-0.43)	<0.001
≥30.00	119	126	0.31 (0.22-0.43)	<0.001	0.24 (0.18-0.32)	<0.001	0.41 (0.29-0.57)	<0.001	0.27 (0.20-0.36)	<0.001
Tobacco use										
Non-user	3,081	8,084	1.00		1.00		1.00		1.00	
User	5,955	952	1.13 (1.04-1.24)	0.005	1.06 (0.92-1.23)	0.399	1.10 (1.01-1.20)	0.028	1.01 (0.88-1.17)	0.852
Alcohol use										
Non-user	5,361	8,826	1.00		1.00		1.00		1.00	
User	3,675	210	1.00 (0.92-1.09)	0.995	0.91 (0.68-1.22)	0.525	0.97 (0.89-1.06)	0.488	0.93 (0.69-1.25)	0.616
Diabetes status										
Non-diabetic	8,493	8,758	1.00		1.00		1.00		1.00	
Diabetic	543	278	0.89 (0.76-1.05)	0.170	0.86 (0.69-1.07)	0.174	0.92 (0.78-1.09)	0.341	0.89 (0.71-1.11)	0.307
Hypertension status										
Non-hypertensive	8,708	8,935	1.00		1.00		1.00		1.00	
Hypertensive	328	101	1.23 (1.02-1.49)	0.032	0.82 (0.60-1.12)	0.219	1.23 (1.01-1.49)	0.044	0.81 (0.59-1.11)	0.195

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

[α] Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

[β] Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

[¥] Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table S4.3. Association between parental characteristics and stunting among children aged 0-59 months.

Parental characteristics	Number of stunted children, n		Model 1 [α]		Model 1I [β]		Model III [¥]			
			Father		Mother		Father		Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	3,890	6,935	1.00		1.00		1.00		1.00	
30–39	4,865	2,681	0.87 (0.78-0.97)	0.014	0.85 (0.76-0.96)	0.010	0.91 (0.81-1.01)	0.082	0.87 (0.77-0.99)	0.030
≥40	1,166	305	0.78 (0.66-0.94)	0.008	0.95 (0.72-1.26)	0.731	0.86 (0.71-1.04)	0.126	0.96 (0.71-1.30)	0.788
Age at marriage (years)										
<18	1,031	3,977	1.00		1.00		1.00		1.00	
18-20	2,492	3,635	1.00 (0.87-1.14)	0.945	1.05 (0.95-1.16)	0.350	1.02 (0.89-1.17)	0.820	1.08 (0.97-1.20)	0.148
21-25	4,114	1,933	0.95 (0.83-1.09)	0.456	0.98 (0.85-1.13)	0.793	0.94 (0.82-1.08)	0.408	1.04 (0.90-1.21)	0.577
≥26	2,284	376	0.84 (0.71-1.00)	0.047	0.77 (0.59-1.00)	0.054	0.88 (0.75-1.05)	0.157	0.84 (0.64-1.11)	0.219
Education										
No or incomplete primary	3,058	4,563	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	5,364	4,267	0.90 (0.82-0.99)	0.030	0.78 (0.71-0.86)	<0.001	0.97 (0.88-1.07)	0.531	0.83 (0.75-0.91)	<0.001
Secondary or higher	1,499	1,091	0.72 (0.63-0.82)	<0.001	0.61 (0.53-0.71)	<0.001	0.86 (0.74-0.99)	0.038	0.70 (0.59-0.82)	<0.001
Employment										
Unemployed	580	7,151	1.00		1.00		1.00		1.00	
Non-manual	1,863	425	1.00 (0.85-1.19)	0.955	1.08 (0.90-1.30)	0.405	1.07 (0.90-1.27)	0.417	1.09 (0.91-1.31)	0.354
Agricultural	4,005	1,706	1.04 (0.89-1.22)	0.596	1.02 (0.92-1.14)	0.655	1.09 (0.93-1.27)	0.305	1.00 (0.90-1.11)	0.961
Manual/others	3,473	639	0.99 (0.84-1.16)	0.911	1.07 (0.91-1.25)	0.437	1.03 (0.88-1.20)	0.751	1.04 (0.88-1.22)	0.667
Height (in cm)										
<145	63	1,729	1.00		1.00		1.00		1.00	
145-149.9	264	3,151	0.66 (0.35-1.22)	0.183	0.68 (0.60-0.77)	<0.001	0.74 (0.38-1.44)	0.380	0.70 (0.62-0.80)	<0.001
150-154.9	1,001	3,201	0.60 (0.34-1.06)	0.078	0.52 (0.46-0.58)	<0.001	0.69 (0.38-1.28)	0.241	0.55 (0.48-0.62)	<0.001
155-159.9	2,349	1,446	0.55 (0.31-0.97)	0.039	0.34 (0.30-0.40)	<0.001	0.68 (0.37-1.25)	0.220	0.37 (0.32-0.43)	<0.001
≥160	6,244	394	0.35 (0.20-0.62)	<0.001	0.21 (0.18-0.26)	<0.001	0.48 (0.26-0.87)	0.016	0.24 (0.20-0.29)	<0.001
BMI										
<17.00	628	1,099	1.00		1.00		1.00		1.00	
17.00–18.49	1,373	1,734	0.90 (0.75-1.08)	0.244	0.92 (0.79-1.07)	0.293	0.94 (0.79-1.13)	0.524	0.95 (0.82-1.10)	0.491
18.50–23.49	5,654	5,418	0.71 (0.61-0.84)	<0.001	0.79 (0.69-0.90)	<0.001	0.79 (0.67-0.92)	0.003	0.83 (0.73-0.94)	0.004
23.50–24.99	972	709	0.57 (0.47-0.70)	<0.001	0.71 (0.59-0.85)	<0.001	0.66 (0.54-0.80)	<0.001	0.76 (0.63-0.91)	0.003

25.00–29.99	1,125	786	0.63 (0.52-0.76)	<0.001	0.62 (0.52-0.75)	<0.001	0.74 (0.61-0.89)	0.002	0.67 (0.56-0.81)	<0.001
≥30.00	169	175	0.56 (0.40-0.78)	0.001	0.54 (0.40-0.73)	<0.001	0.67 (0.48-0.95)	0.024	0.59 (0.44-0.80)	0.001
Tobacco use										
Non-user	3,376	8,767	1.00		1.00		1.00		1.00	
User	6,545	1,154	1.16 (1.06-1.26)	0.001	1.05 (0.92-1.20)	0.468	1.13 (1.04-1.23)	0.006	1.01 (0.88-1.16)	0.918
Alcohol use										
Non-user	5,978	9,700	1.00		1.00		1.00		1.00	
User	3,943	221	0.95 (0.88-1.03)	0.253	0.74 (0.55-0.98)	0.034	0.93 (0.86-1.01)	0.086	0.76 (0.57-1.01)	0.062
Diabetes status										
Non-diabetic	9,298	9,599	1.00		1.00		1.00		1.00	
Diabetic	623	322	0.91 (0.78-1.07)	0.245	0.97 (0.78-1.20)	0.776	0.92 (0.78-1.08)	0.311	1.01 (0.81-1.25)	0.930
Hypertension status										
Non-hypertensive	9,544	9,808	1.00		1.00		1.00		1.00	
Hypertensive	377	113	1.27 (1.04-1.55)	0.021	0.75 (0.54-1.04)	0.087	1.25 (1.01-1.55)	0.037	0.73 (0.53-1.02)	0.065

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

$^{\alpha}$ Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{\beta}$ Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{¥}$ Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table S4.4. Association between parental characteristics and wasting among children aged 0-59 months.

Parental characteristics	Number of wasted children, n		Model 1 [α] Father		Model 1I [β] Mother		Model III [¥] Father		Model III [¥] Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	2,127	3,795	1.00		1.00		1.00		1.00	
30–39	2,606	1,370	0.93 (0.82-1.05)	0.258	1.08 (0.93-1.25)	0.334	0.94 (0.83-1.07)	0.325	1.10 (0.93-1.29)	0.278
≥40	570	138	0.89 (0.72-1.10)	0.299	0.98 (0.72-1.32)	0.884	0.90 (0.71-1.15)	0.403	1.01 (0.71-1.42)	0.974
Age at marriage (years)										
<18	470	1,946	1.00		1.00		1.00		1.00	
18-20	1,225	1,973	0.95 (0.81-1.11)	0.537	1.00 (0.89-1.13)	0.989	0.96 (0.82-1.12)	0.581	0.97 (0.86-1.10)	0.662
21-25	2,261	1,171	1.05 (0.90-1.22)	0.537	1.06 (0.90-1.23)	0.496	1.07 (0.91-1.25)	0.398	1.03 (0.88-1.21)	0.722
≥26	1,347	213	1.03 (0.85-1.25)	0.763	1.01 (0.74-1.38)	0.955	1.06 (0.86-1.29)	0.598	1.01 (0.73-1.41)	0.936
Education										
No or incomplete primary	1,491	2,180	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	2,797	2,333	0.98 (0.89-1.09)	0.770	0.89 (0.80-0.99)	0.029	1.02 (0.92-1.14)	0.677	0.91 (0.82-1.01)	0.089
Secondary or higher	1,015	790	0.88 (0.75-1.04)	0.128	0.87 (0.73-1.02)	0.092	0.93 (0.78-1.09)	0.358	0.94 (0.79-1.13)	0.530
Employment										
Unemployed	303	3,944	1.00		1.00		1.00		1.00	
Non-manual	1,109	230	1.03 (0.84-1.25)	0.786	0.88 (0.69-1.12)	0.289	1.02 (0.84-1.25)	0.811	0.89 (0.70-1.12)	0.314
Agricultural	2,047	811	1.20 (1.00-1.44)	0.055	1.01 (0.89-1.14)	0.884	1.18 (0.98-1.41)	0.081	0.99 (0.87-1.12)	0.831
Manual/others	1,844	318	1.13 (0.94-1.36)	0.206	0.90 (0.76-1.08)	0.273	1.13 (0.93-1.36)	0.212	0.89 (0.75-1.07)	0.219
Height (in cm)										
<145	32	711	1.00		1.00		1.00		1.00	
145-149.9	134	1,443	0.79 (0.38-1.63)	0.524	0.92 (0.80-1.06)	0.250	0.74 (0.36-1.53)	0.424	0.95 (0.82-1.09)	0.452
150-154.9	529	1,793	0.71 (0.36-1.40)	0.319	0.90 (0.78-1.03)	0.125	0.67 (0.34-1.31)	0.239	0.95 (0.83-1.09)	0.450
155-159.9	1,149	993	0.54 (0.28-1.05)	0.069	0.87 (0.74-1.03)	0.102	0.51 (0.26-1.00)	0.050	0.94 (0.80-1.10)	0.439
≥160	3,459	363	0.46 (0.24-0.90)	0.023	0.84 (0.68-1.03)	0.096	0.45 (0.23-0.87)	0.017	0.91 (0.74-1.13)	0.405
BMI										
<17.00	333	766	1.00		1.00		1.00		1.00	
17.00–18.49	745	927	0.97 (0.79-1.19)	0.780	0.64 (0.55-0.75)	<0.001	0.99 (0.81-1.22)	0.939	0.65 (0.55-0.76)	<0.001
18.50–23.49	2,945	2,760	0.84 (0.70-1.01)	0.057	0.55 (0.48-0.63)	<0.001	0.90 (0.75-1.08)	0.253	0.56 (0.49-0.64)	<0.001
23.50–24.99	588	346	0.76 (0.61-0.95)	0.017	0.49 (0.40-0.60)	<0.001	0.83 (0.67-1.04)	0.113	0.51 (0.41-0.63)	<0.001

25.00–29.99	607	416	0.73 (0.58-0.92)	0.007	0.45 (0.36-0.56)	<0.001	0.82 (0.66-1.03)	0.091	0.48 (0.39-0.60)	<0.001
≥30.00	85	88	0.47 (0.33-0.68)	<0.001	0.32 (0.22-0.45)	<0.001	0.56 (0.38-0.80)	0.002	0.35 (0.25-0.49)	<0.001
Tobacco use										
Non-user	1,989	4,769	1.00		1.00		1.00		1.00	
User	3,314	534	0.98 (0.88-1.08)	0.661	1.12 (0.95-1.31)	0.169	0.97 (0.87-1.07)	0.530	1.11 (0.95-1.30)	0.195
Alcohol use										
Non-user	3,119	5,162	1.00		1.00		1.00		1.00	
User	2,184	141	1.04 (0.94-1.14)	0.470	1.38 (1.02-1.85)	0.034	1.02 (0.93-1.13)	0.668	1.37 (1.01-1.84)	0.042
Diabetes status										
Non-diabetic	4,979	5,136	1.00		1.00		1.00		1.00	
Diabetic	324	167	0.91 (0.76-1.10)	0.340	1.01 (0.77-1.32)	0.953	0.93 (0.77-1.12)	0.439	1.03 (0.79-1.35)	0.822
Hypertension status										
Non-hypertensive	5,119	5,238	1.00		1.00		1.00		1.00	
Hypertensive	184	65	0.95 (0.75-1.19)	0.632	0.98 (0.68-1.43)	0.934	0.94 (0.75-1.18)	0.612	0.99 (0.68-1.45)	0.974

All *n* are un-weighted
BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio
[α] Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.
[β] Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.
[¥] Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table S4.5. Association between parental characteristics and severe underweight among children aged 0-59 months.

Parental characteristics	Number of children with severe underweight, n		Model 1 [α]		Model 1I [β]		Model III [¥]			
			Father		Mother		Father		Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	1,108	1,959	1.00		1.00		1.00		1.00	
30–39	1,392	772	0.94 (0.81-1.09)	0.392	0.94 (0.77-1.14)	0.516	0.99 (0.85-1.15)	0.849	0.96 (0.78-1.19)	0.727
≥40	334	103	0.79 (0.62-1.02)	0.067	0.98 (0.69-1.37)	0.887	0.82 (0.61-1.11)	0.202	1.10 (0.74-1.64)	0.644
Age at marriage (years)										
<18	312	1,171	1.00		1.00		1.00		1.00	
18-20	751	1,037	1.01 (0.84-1.23)	0.885	1.05 (0.91-1.21)	0.491	1.04 (0.86-1.25)	0.718	1.07 (0.92-1.24)	0.388
21-25	1,195	535	1.00 (0.83-1.21)	0.992	1.14 (0.94-1.38)	0.170	1.00 (0.83-1.21)	0.999	1.18 (0.97-1.43)	0.105
≥26	576	91	0.93 (0.73-1.17)	0.519	0.99 (0.65-1.53)	0.976	0.94 (0.74-1.20)	0.640	1.08 (0.69-1.68)	0.751
Education										
No or incomplete primary	1,033	1,499	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	1,462	1,097	0.88 (0.77-0.99)	0.039	0.80 (0.70-0.91)	<0.001	0.93 (0.82-1.06)	0.297	0.86 (0.75-0.98)	0.027
Secondary or higher	339	238	0.76 (0.61-0.95)	0.014	0.67 (0.52-0.87)	0.002	0.88 (0.70-1.11)	0.275	0.78 (0.60-1.02)	0.073
Employment										
Unemployed	166	1,993	1.00		1.00		1.00		1.00	
Non-manual	431	93	0.86 (0.66-1.12)	0.273	0.68 (0.49-0.93)	0.015	0.91 (0.70-1.18)	0.467	0.68 (0.49-0.93)	0.015
Agricultural	1,182	539	1.09 (0.86-1.37)	0.487	1.10 (0.95-1.26)	0.211	1.08 (0.86-1.36)	0.492	1.06 (0.91-1.23)	0.441
Manual/others	1,055	209	1.05 (0.83-1.31)	0.704	1.03 (0.84-1.27)	0.774	1.06 (0.85-1.33)	0.595	1.00 (0.81-1.24)	0.973
Height (in cm)										
<145	26	597	1.00		1.00		1.00		1.00	
145-149.9	106	930	0.72 (0.37-1.39)	0.321	0.73 (0.62-0.84)	<0.001	0.79 (0.41-1.52)	0.475	0.76 (0.65-0.88)	<0.001
150-154.9	365	855	0.58 (0.31-1.06)	0.078	0.52 (0.45-0.61)	<0.001	0.64 (0.35-1.19)	0.158	0.56 (0.48-0.66)	<0.001
155-159.9	733	356	0.42 (0.23-0.76)	0.004	0.41 (0.33-0.51)	<0.001	0.49 (0.27-0.89)	0.020	0.45 (0.36-0.56)	<0.001
≥160	1,604	96	0.28 (0.16-0.51)	<0.001	0.21 (0.16-0.28)	<0.001	0.36 (0.20-0.65)	0.001	0.25 (0.18-0.33)	<0.001
BMI										
<17.00	242	479	1.00		1.00		1.00		1.00	
17.00–18.49	479	590	0.88 (0.70-1.11)	0.280	0.72 (0.60-0.87)	<0.001	0.93 (0.75-1.17)	0.549	0.74 (0.61-0.88)	0.001
18.50–23.49	1,602	1,441	0.70 (0.58-0.86)	<0.001	0.50 (0.43-0.59)	<0.001	0.81 (0.67-0.99)	0.035	0.52 (0.44-0.61)	<0.001

23.50–24.99	243	146	0.53 (0.41-0.69)	<0.001	0.37 (0.28-0.48)	<0.001	0.65 (0.50-0.84)	0.001	0.39 (0.30-0.51)	<0.001
25.00–29.99	239	145	0.53 (0.40-0.71)	<0.001	0.35 (0.24-0.50)	<0.001	0.67 (0.51-0.89)	0.005	0.39 (0.27-0.54)	<0.001
≥30.00	29	33	0.34 (0.20-0.58)	<0.001	0.27 (0.17-0.43)	<0.001	0.45 (0.26-0.77)	0.004	0.31 (0.20-0.49)	<0.001
Tobacco use										
Non-user	909	2,505	1.00		1.00		1.00		1.00	
User	1,925	329	1.10 (0.97-1.25)	0.128	1.08 (0.90-1.29)	0.431	1.07 (0.94-1.21)	0.320	1.06 (0.88-1.27)	0.562
Alcohol use										
Non-user	1,654	2,761	1.00		1.00		1.00		1.00	
User	1,180	73	0.97 (0.86-1.09)	0.605	1.00 (0.71-1.40)	0.993	0.93 (0.83-1.05)	0.237	1.01 (0.71-1.43)	0.970
Diabetes status										
Non-diabetic	2,669	2,743	1.00		1.00		1.00		1.00	
Diabetic	165	91	0.90 (0.71-1.14)	0.368	1.20 (0.88-1.63)	0.253	0.91 (0.72-1.16)	0.441	1.24 (0.91-1.68)	0.166
Hypertension status										
Non-hypertensive	2,744	2,798	1.00		1.00		1.00		1.00	
Hypertensive	90	36	1.25 (0.91-1.72)	0.162	1.28 (0.87-1.90)	0.215	1.24 (0.89-1.73)	0.195	1.28 (0.84-1.93)	0.249

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

$^{\alpha}$ Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{\beta}$ Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

[¥] Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table S4.6. Association between parental characteristics and severe stunting among children aged 0-59 months.

Parental characteristics	Number of children with severe stunting, n		Model 1 [α]		Model 1I [β]		Model III [¥]			
			Father		Mother		Father		Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	1,659	2,859	1.00		1.00		1.00		1.00	
30–39	2,012	1,159	0.90 (0.79-1.03)	0.113	0.87 (0.75-1.01)	0.070	0.93 (0.82-1.06)	0.305	0.91 (0.78-1.06)	0.208
≥40	484	137	0.74 (0.60-0.92)	0.007	0.90 (0.66-1.22)	0.486	0.78 (0.62-0.98)	0.032	1.03 (0.74-1.44)	0.858
Age at marriage (years)										
<18	484	1,739	1.00		1.00		1.00		1.00	
18-20	1,068	1,523	0.84 (0.71-0.99)	0.038	1.02 (0.90-1.15)	0.783	0.86 (0.73-1.01)	0.058	1.05 (0.93-1.19)	0.414
21-25	1,729	753	0.82 (0.70-0.97)	0.018	0.94 (0.79-1.12)	0.492	0.83 (0.71-0.98)	0.025	0.98 (0.82-1.18)	0.856
≥26	874	140	0.74 (0.61-0.91)	0.003	0.79 (0.57-1.11)	0.175	0.79 (0.65-0.97)	0.022	0.85 (0.60-1.20)	0.362
Education										
No or incomplete primary	1,450	2,154	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	2,150	1,595	0.88 (0.79-0.98)	0.019	0.73 (0.65-0.81)	<0.001	0.95 (0.85-1.06)	0.368	0.78 (0.70-0.87)	<0.001
Secondary or higher	555	406	0.77 (0.65-0.92)	0.003	0.65 (0.54-0.79)	<0.001	0.90 (0.75-1.09)	0.282	0.75 (0.61-0.92)	0.006
Employment										
Unemployed	250	2,967	1.00		1.00		1.00		1.00	
Non-manual	678	158	0.87 (0.71-1.08)	0.211	0.88 (0.67-1.16)	0.366	0.92 (0.75-1.14)	0.453	0.88 (0.67-1.15)	0.344
Agricultural	1,766	758	1.02 (0.84-1.23)	0.870	1.06 (0.93-1.20)	0.388	1.04 (0.86-1.26)	0.683	1.02 (0.90-1.16)	0.777
Manual/others	1,461	272	0.94 (0.77-1.13)	0.507	1.01 (0.83-1.21)	0.958	0.96 (0.80-1.17)	0.705	0.99 (0.82-1.19)	0.894
Height (in cm)										
<145	37	864	1.00		1.00		1.00		1.00	
145-149.9	143	1,366	0.58 (0.32-1.06)	0.076	0.68 (0.59-0.77)	<0.001	0.64 (0.34-1.19)	0.159	0.71 (0.62-0.81)	<0.001
150-154.9	480	1,250	0.43 (0.25-0.74)	0.002	0.48 (0.42-0.55)	<0.001	0.48 (0.27-0.85)	0.012	0.52 (0.45-0.59)	<0.001
155-159.9	1,069	539	0.36 (0.21-0.62)	<0.001	0.40 (0.34-0.47)	<0.001	0.43 (0.25-0.75)	0.003	0.44 (0.37-0.52)	<0.001
≥160	2,426	136	0.25 (0.14-0.42)	<0.001	0.23 (0.18-0.30)	<0.001	0.32 (0.18-0.55)	<0.001	0.26 (0.21-0.34)	<0.001
BMI										
<17.00	269	491	1.00		1.00		1.00		1.00	
17.00–18.49	616	782	1.04 (0.85-1.29)	0.692	1.01 (0.85-1.19)	0.950	1.09 (0.88-1.34)	0.431	1.02 (0.86-1.21)	0.828
18.50–23.49	2,405	2,292	0.88 (0.73-1.06)	0.165	0.83 (0.71-0.96)	0.013	0.96 (0.79-1.16)	0.664	0.85 (0.73-0.99)	0.035

23.50–24.99	389	268	0.71 (0.56-0.89)	0.004	0.77 (0.61-0.96)	0.021	0.81 (0.64-1.02)	0.076	0.80 (0.64-1.01)	0.058
25.00–29.99	420	264	0.74 (0.59-0.94)	0.013	0.61 (0.48-0.78)	<0.001	0.87 (0.68-1.10)	0.238	0.66 (0.52-0.84)	0.001
≥30.00	56	58	0.51 (0.34-0.77)	0.002	0.55 (0.36-0.83)	0.004	0.62 (0.41-0.95)	0.030	0.60 (0.39-0.91)	0.016
Tobacco use										
Non-user	1,292	3,658	1.00		1.00		1.00		1.00	
User	2,863	497	1.20 (1.08-1.34)	0.001	1.12 (0.96-1.32)	0.152	1.17 (1.05-1.30)	0.003	1.09 (0.93-1.28)	0.288
Alcohol use										
Non-user	2,450	4,053	1.00		1.00		1.00		1.00	
User	1,705	102	0.97 (0.88-1.07)	0.576	0.73 (0.55-0.98)	0.038	0.95 (0.86-1.05)	0.308	0.73 (0.54-0.99)	0.045
Diabetes status										
Non-diabetic	3,903	4,029	1.00		1.00		1.00		1.00	
Diabetic	252	126	0.94 (0.77-1.15)	0.527	0.96 (0.73-1.27)	0.786	0.96 (0.78-1.17)	0.664	0.99 (0.75-1.30)	0.917
Hypertension status										
Non-hypertensive	4,013	4,105	1.00		1.00		1.00		1.00	
Hypertensive	142	50	1.19 (0.89-1.57)	0.238	0.87 (0.60-1.25)	0.447	1.18 (0.89-1.57)	0.259	0.84 (0.57-1.23)	0.358

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

[α] Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

[β] Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

[¥] Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table S4.7. Association between parental characteristics and severe wasting among children aged 0-59 months.

Parental characteristics	Number of children with severe wasting, n		Model 1 [α]		Model 1I [β]		Model III [¥]			
			Father		Mother		Father		Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	769	1,363	1.00		1.00		1.00		1.00	
30–39	933	479	0.98 (0.82-1.18)	0.859	1.06 (0.82-1.37)	0.660	0.99 (0.82-1.20)	0.900	1.07 (0.81-1.43)	0.621
≥40	203	63	0.93 (0.66-1.30)	0.666	1.34 (0.87-2.06)	0.184	0.88 (0.58-1.34)	0.543	1.46 (0.84-2.53)	0.177
Age at marriage (years)										
<18	155	705	1.00		1.00		1.00		1.00	
18-20	453	712	1.16 (0.89-1.50)	0.267	0.96 (0.80-1.14)	0.631	1.16 (0.89-1.50)	0.268	0.94 (0.78-1.14)	0.528
21-25	815	417	1.15 (0.89-1.49)	0.273	1.11 (0.88-1.40)	0.366	1.16 (0.90-1.51)	0.253	1.08 (0.85-1.37)	0.523
≥26	482	71	1.23 (0.90-1.67)	0.188	0.78 (0.47-1.32)	0.361	1.25 (0.91-1.72)	0.170	0.78 (0.45-1.34)	0.360
Education										
No or incomplete primary	538	789	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	984	818	1.00 (0.85-1.18)	0.973	0.94 (0.81-1.11)	0.476	1.03 (0.87-1.22)	0.733	0.95 (0.81-1.12)	0.544
Secondary or higher	383	298	1.08 (0.86-1.36)	0.522	1.06 (0.83-1.37)	0.640	1.08 (0.85-1.37)	0.542	1.07 (0.83-1.38)	0.613
Employment										
Unemployed	114	1,419	1.00		1.00		1.00		1.00	
Non-manual	400	91	0.97 (0.72-1.30)	0.820	0.85 (0.60-1.21)	0.373	0.95 (0.71-1.27)	0.727	0.85 (0.59-1.21)	0.355
Agricultural	762	288	1.14 (0.87-1.50)	0.333	1.05 (0.87-1.27)	0.602	1.11 (0.84-1.45)	0.464	1.04 (0.86-1.25)	0.691
Manual/others	629	107	1.01 (0.76-1.33)	0.957	0.81 (0.62-1.06)	0.127	1.00 (0.76-1.32)	0.988	0.83 (0.64-1.09)	0.185
Height (in cm)										
<145	10	233	1.00		1.00		1.00		1.00	
145-149.9	56	524	3.32 (1.38-8.02)	0.008	0.96 (0.77-1.20)	0.748	3.15 (1.31-7.57)	0.011	0.99 (0.80-1.24)	0.946
150-154.9	224	671	3.15 (1.38-7.21)	0.007	0.99 (0.80-1.23)	0.929	2.92 (1.28-6.64)	0.011	1.04 (0.83-1.29)	0.741
155-159.9	413	344	1.93 (0.86-4.36)	0.112	0.98 (0.75-1.28)	0.869	1.81 (0.81-4.06)	0.151	1.04 (0.79-1.36)	0.786
≥160	1,202	133	1.75 (0.78-3.91)	0.175	1.00 (0.70-1.44)	0.989	1.64 (0.73-3.65)	0.228	1.08 (0.75-1.56)	0.665
BMI										
<17.00	105	242	1.00		1.00		1.00		1.00	
17.00–18.49	238	321	1.07 (0.78-1.46)	0.677	0.81 (0.64-1.04)	0.094	1.09 (0.80-1.49)	0.586	0.80 (0.63-1.02)	0.075
18.50–23.49	1,098	1,031	1.16 (0.88-1.53)	0.287	0.73 (0.60-0.90)	0.003	1.21 (0.92-1.60)	0.177	0.73 (0.59-0.90)	0.003

23.50–24.99	216	131	1.02 (0.73-1.42)	0.925	0.67 (0.49-0.92)	0.012	1.07 (0.76-1.51)	0.699	0.68 (0.49-0.93)	0.016
25.00–29.99	215	152	1.00 (0.71-1.42)	0.991	0.65 (0.45-0.95)	0.026	1.08 (0.76-1.53)	0.663	0.67 (0.47-0.97)	0.034
≥30.00	33	28	0.76 (0.45-1.27)	0.293	0.41 (0.23-0.72)	0.002	0.85 (0.50-1.44)	0.539	0.44 (0.25-0.78)	0.005
Tobacco use										
Non-user	712	1,705	1.00		1.00		1.00		1.00	
User	1,193	200	1.05 (0.90-1.23)	0.509	1.30 (1.00-1.69)	0.050	1.04 (0.89-1.22)	0.595	1.28 (0.99-1.65)	0.056
Alcohol use										
Non-user	1,095	1,860	1.00		1.00		1.00		1.00	
User	810	45	0.99 (0.86-1.14)	0.887	1.20 (0.71-2.04)	0.500	0.98 (0.85-1.13)	0.818	1.18 (0.68-2.03)	0.557
Diabetes status										
Non-diabetic	1,799	1,849	1.00		1.00		1.00		1.00	
Diabetic	106	56	0.84 (0.60-1.16)	0.288	0.94 (0.56-1.56)	0.800	0.86 (0.62-1.19)	0.356	0.98 (0.59-1.64)	0.951
Hypertension status										
Non-hypertensive	1,839	1,883	1.00		1.00		1.00		1.00	
Hypertensive	66	22	0.97 (0.66-1.42)	0.857	0.95 (0.55-1.67)	0.868	0.97 (0.66-1.43)	0.883	0.98 (0.56-1.71)	0.933

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

$^{\alpha}$ Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{\beta}$ Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{¥}$ Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table S4.8. Association between parental characteristics and mild-moderate anaemia (aged 6-59 months).

Parental characteristics	Number of children with mild-moderate anaemia, n		Model 1 [α]		Model 1I [β]		Model III [¥]			
			Father		Mother		Father		Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	5,422	9,699	1.00		1.00		1.00		1.00	
30–39	6,784	3,637	0.88 (0.79-0.97)	0.015	0.94 (0.83-1.06)	0.321	0.89 (0.80-0.99)	0.034	0.98 (0.86-1.10)	0.690
≥40	1,490	360	0.81 (0.68-0.98)	0.026	1.01 (0.77-1.32)	0.963	0.81 (0.67-0.99)	0.040	1.07 (0.79-1.44)	0.659
Age at marriage (years)										
<18	1,244	5,063	1.00		1.00		1.00		1.00	
18-20	3,180	5,017	1.02 (0.88-1.18)	0.809	1.03 (0.93-1.14)	0.544	1.01 (0.87-1.17)	0.908	1.03 (0.93-1.15)	0.547
21-25	5,789	2,968	1.02 (0.88-1.17)	0.801	0.85 (0.74-0.98)	0.023	1.02 (0.88-1.18)	0.767	0.90 (0.78-1.03)	0.130
≥26	3,483	648	0.85 (0.72-1.010	0.059	0.84 (0.66-1.09)	0.192	0.89 (0.75-1.06)	0.193	0.92 (0.71-1.19)	0.529
Education										
No or incomplete primary	3,664	5,471	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	7,273	6,074	0.88 (0.80-0.97)	0.011	0.86 (0.78-0.94)	0.001	0.91 (0.82-1.01)	0.070	0.89 (0.81-0.98)	0.017
Secondary or higher	2,759	2,151	0.78 (0.69-0.90)	<0.001	0.73 (0.63-0.85)	<0.001	0.86 (0.74-0.99)	0.030	0.79 (0.67-0.92)	0.003
Employment										
Unemployed	845	10,192	1.00		1.00		1.00		1.00	
Non-manual	3,098	590	0.99 (0.84-1.17)	0.908	1.04 (0.86-1.25)	0.715	1.00 (0.85-1.19)	0.956	1.03 (0.85-1.24)	0.780
Agricultural	5,082	2,088	0.96 (0.83-1.12)	0.638	1.07 (0.96-1.19)	0.239	0.95 (0.82-1.11)	0.546	1.07 (0.96-1.19)	0.231
Manual/others	4,671	826	0.97 (0.83-1.14)	0.717	1.03 (0.86-1.22)	0.760	0.97 (0.83-1.14)	0.708	1.03 (0.87-1.22)	0.734
Height (in cm)										
<145	58	1,666	1.00		1.00		1.00		1.00	
145-149.9	299	3,667	1.38 (0.71-2.69)	0.339	0.95 (0.83-1.08)	0.439	1.43 (0.72-2.81)	0.305	0.96 (0.84-1.09)	0.529
150-154.9	1,148	4,587	1.45 (0.78-2.70)	0.245	0.97 (0.85-1.11)	0.664	1.50 (0.79-2.85)	0.210	0.98 (0.86-1.12)	0.782
155-159.9	2,772	2,755	1.22 (0.66-2.26)	0.524	0.95 (0.82-1.09)	0.459	1.28 (0.68-2.40)	0.443	0.96 (0.83-1.11)	0.583
≥160	9,419	1,021	1.22 (0.66-2.25)	0.521	0.89 (0.75-1.06)	0.200	1.29 (0.69-2.41)	0.426	0.92 (0.77-1.10)	0.340
BMI										
<17.00	716	1,459	1.00		1.00		1.00		1.00	
17.00–18.49	1,680	2,253	1.17 (0.96-1.43)	0.130	0.88 (0.75-1.02)	0.097	1.19 (0.97-1.45)	0.093	0.89 (0.77-1.04)	0.152
18.50–23.49	7,550	7,181	1.03 (0.87-1.23)	0.707	0.80 (0.70-0.91)	0.001	1.08 (0.90-1.28)	0.414	0.82 (0.71-0.93)	0.003

23.50–24.99	1,580	1,038	0.99 (0.81-1.21)	0.918	0.70 (0.58-0.84)	<0.001	1.04 (0.85-1.28)	0.690	0.73 (0.60-0.87)	0.001
25.00–29.99	1,867	1,393	0.90 (0.74-1.11)	0.329	0.77 (0.64-0.91)	0.003	0.96 (0.78-1.18)	0.698	0.80 (0.67-0.95)	0.012
≥30.00	303	372	0.94 (0.68-1.29)	0.697	0.81 (0.61-1.06)	0.124	0.99 (0.72-1.36)	0.938	0.87 (0.66-1.14)	0.304
Tobacco use										
Non-user	5,361	12,496	1.00		1.00		1.00		1.00	
User	8,335	1,200	0.95 (0.87-1.04)	0.299	0.93 (0.81-1.07)	0.318	0.95 (0.87-1.03)	0.230	0.93 (0.81-1.07)	0.316
Alcohol use										
Non-user	8,459	13,399	1.00		1.00		1.00		1.00	
User	5,237	297	0.94 (0.86-1.02)	0.149	0.82 (0.61-1.08)	0.157	0.94 (0.87-1.03)	0.171	0.83 (0.62-1.10)	0.187
Diabetes status										
Non-diabetic	12,779	13,197	1.00		1.00		1.00		1.00	
Diabetic	917	499	1.03 (0.88-1.20)	0.708	0.97 (0.76-1.24)	0.813	1.04 (0.89-1.21)	0.644	0.98 (0.78-1.25)	0.900
Hypertension status										
Non-hypertensive	13,148	13,524	1.00		1.00		1.00		1.00	
Hypertensive	548	172	1.10 (0.91-1.33)	0.332	1.07 (0.79-1.45)	0.667	1.10 (0.91-1.32)	0.336	1.08 (0.80-1.46)	0.624

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

$^{\alpha}$ Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{\beta}$ Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{¥}$ Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table S4.9. Association between parental characteristics and severe anaemia (aged 6-59 months).

Parental characteristics	Number of children with severe anaemia, n		Model 1 $^{\alpha}$		Model 1I $^{\beta}$		Model III $^{¥}$			
			Father		Mother		Father		Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	147	265	1.00		1.00		1.00		1.00	
30–39	181	101	0.78 (0.53-1.14)	0.200	0.71 (0.47-1.07)	0.103	0.82 (0.56-1.22)	0.331	0.61 (0.37-1.02)	0.059
≥40	46	8	1.28 (0.60-2.74)	0.531	0.30 (0.10-0.88)	0.029	1.74 (0.75-4.04)	0.197	0.17 (0.05-0.57)	0.004
Age at marriage (years)										
<18	36	132	1.00		1.00		1.00		1.00	
18-20	91	133	0.84 (0.50-1.43)	0.524	1.17 (0.75-1.84)	0.490	0.84 (0.50-1.41)	0.503	1.29 (0.82-2.01)	0.267
21-25	145	87	0.70 (0.41-1.20)	0.193	1.13 (0.67-1.91)	0.640	0.66 (0.38-1.13)	0.126	1.22 (0.71-2.09)	0.473
≥26	102	22	0.96 (0.51-1.83)	0.908	1.91 (0.73-5.03)	0.189	0.85 (0.46-1.58)	0.613	1.81 (0.71-4.64)	0.217
Education										
No or incomplete primary	111	155	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	183	158	0.71 (0.50-1.03)	0.070	0.96 (0.66-1.41)	0.835	0.70 (0.48-1.01)	0.058	1.08 (0.71-1.65)	0.728
Secondary or higher	80	61	0.68 (0.40-1.15)	0.149	0.44 (0.24-0.80)	0.007	0.80 (0.46-1.40)	0.435	0.49 (0.25-0.96)	0.037
Employment										
Unemployed	22	271	1.00		1.00		1.00		1.00	
Non-manual	78	21	0.71 (0.33-1.52)	0.383	2.40 (1.00-5.76)	0.049	0.76 (0.36-1.59)	0.469	2.47 (1.07-5.71)	0.035
Agricultural	135	51	1.00 (0.52-1.93)	0.992	1.29 (0.86-1.92)	0.221	1.03 (0.54-1.96)	0.923	1.24 (0.82-1.88)	0.304
Manual/others	139	31	0.92 (0.47-1.81)	0.812	1.52 (0.91-2.54)	0.111	0.92 (0.47-1.81)	0.816	1.52 (0.89-2.59)	0.126
Height (in cm)										
<145	3	38	1.00		1.00		1.00		1.00	
145-149.9	4	92	0.42 (0.06-2.97)	0.387	1.13 (0.70-1.83)	0.615	0.43 (0.06-3.01)	0.392	1.11 (0.68-1.80)	0.685
150-154.9	21	138	0.33 (0.06-1.76)	0.194	1.37 (0.86-2.19)	0.180	0.34 (0.07-1.78)	0.203	1.35 (0.85-2.16)	0.208
155-159.9	55	75	0.41 (0.07-2.28)	0.310	1.13 (0.62-2.04)	0.690	0.41 (0.08-2.18)	0.297	1.10 (0.60-2.01)	0.768
≥160	291	31	0.54 (0.11-2.74)	0.456	1.58 (0.81-3.06)	0.177	0.52 (0.10-2.62)	0.430	1.47 (0.76-2.85)	0.254
BMI										
<17.00	18	37	1.00		1.00		1.00		1.00	
17.00–18.49	46	50	1.29 (0.59-2.80)	0.521	0.85 (0.50-1.43)	0.536	1.29 (0.61-2.75)	0.506	0.89 (0.52-1.51)	0.658
18.50–23.49	191	194	0.94 (0.53-1.67)	0.829	0.91 (0.58-1.43)	0.691	0.93 (0.52-1.66)	0.799	0.94 (0.60-1.47)	0.778

23.50–24.99	43	35	0.87 (0.42-1.80)	0.705	1.57 (0.76-3.24)	0.225	0.84 (0.41-1.74)	0.640	1.63 (0.77-3.45)	0.203
25.00–29.99	65	45	1.11 (0.56-2.19)	0.761	1.09 (0.59-2.00)	0.782	1.07 (0.54-2.12)	0.837	1.09 (0.59-2.04)	0.780
≥30.00	11	13	1.04 (0.40-2.68)	0.934	1.06 (0.44-2.53)	0.897	0.95 (0.37-2.46)	0.918	1.03 (0.42-2.50)	0.955
Tobacco use										
Non-user	156	347	1.00		1.00		1.00		1.00	
User	218	27	0.95 (0.69-1.30)	0.744	0.91 (0.55-1.52)	0.728	0.95 (0.70-1.29)	0.749	0.92 (0.55-1.55)	0.765
Alcohol use										
Non-user	249	369	1.00		1.00		1.00		1.00	
User	125	5	0.87 (0.65-1.19)	0.390	1.26 (0.40-3.97)	0.694	0.86 (0.63-1.16)	0.327	1.29 (0.40-4.19)	0.672
Diabetes status										
Non-diabetic	349	361	1.00		1.00		1.00		1.00	
Diabetic	25	13	0.61 (0.37-1.00)	0.049	1.47 (0.67-3.23)	0.335	0.57 (0.33-0.97)	0.039	1.52 (0.69-3.31)	0.297
Hypertension status										
Non-hypertensive	350	367	1.00		1.00		1.00		1.00	
Hypertensive	24	7	2.29 (1.32-3.97)	0.003	2.41 (1.05-5.54)	0.039	2.24 (1.29-3.89)	0.004	2.19 (0.94-5.10)	0.070

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

$^{\alpha}$ Adjusted for father's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{\beta}$ Adjusted for mother's characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{¥}$ Adjusted for parental (father and mother) characteristics and maternal age at birth, child age, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table S4.10. Association between parental characteristics and neonatal mortality (aged 0-59 months).

Parental characteristics	Number of neonatal mortality, n		Model 1 $^{\alpha}$		Model 1I $^{\beta}$		Model III $^{¥}$			
			Father		Mother		Father		Mother	
	Father	**Mother**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**
Age (in years)										
15-29	364	608	1.00		1.00		1.00		1.00	
30–39	398	243	0.93 (0.72-1.21)	0.583	0.99 (0.74-1.32)	0.934	0.94 (0.72-1.23)	0.658	0.95 (0.67-1.34)	0.774
≥40	125	36	1.40 (0.87-2.25)	0.166	1.44 (0.69-3.00)	0.332	1.35 (0.79-2.32)	0.270	1.04 (0.46-2.34)	0.930
Age at marriage (years)										
<18	76	346	1.00		1.00		1.00		1.00	
18-20	216	326	1.29 (0.91-1.84)	0.149	1.15 (0.91-1.47)	0.239	1.34 (0.94-1.91)	0.100	1.13 (0.89-1.43)	0.331
21-25	399	177	1.45 (1.04-2.03)	0.030	1.00 (0.71-1.40)	0.999	1.51 (1.07-2.13)	0.020	1.10 (0.78-1.54)	0.597
≥26	196	38	0.91 (0.60-1.38)	0.654	1.56 (0.82-2.99)	0.178	0.92 (0.59-1.43)	0.718	1.95 (1.02-3.74)	0.044
Education										
No or incomplete primary	301	424	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	461	367	0.72 (0.58-0.91)	0.005	0.76 (0.60-0.96)	0.020	0.77 (0.62-0.96)	0.022	0.82 (0.66-1.03)	0.082
Secondary or higher	125	96	0.60 (0.43-0.85)	0.004	0.72 (0.45-1.14)	0.162	0.65 (0.44-0.96)	0.031	0.87 (0.52-1.46)	0.593
Employment										
Unemployed	55	616	1.00		1.00		1.00		1.00	
Non-manual	180	41	1.09 (0.71-1.68)	0.700	0.98 (0.59-1.61)	0.928	1.12 (0.72-1.74)	0.620	1.01 (0.61-1.65)	0.982
Agricultural	348	173	1.07 (0.70-1.63)	0.761	1.25 (0.97-1.61)	0.090	1.06 (0.70-1.62)	0.775	1.24 (0.95-1.62)	0.107
Manual/others	304	57	1.05 (0.69-1.60)	0.818	0.91 (0.63-1.31)	0.624	1.08 (0.71-1.64)	0.715	0.89 (0.61-1.28)	0.521
Height (in cm)										
<145	4	153	1.00		1.00		1.00		1.00	
145-149.9	26	270	0.81 (0.23-2.80)	0.740	0.84 (0.63-1.12)	0.240	0.81 (0.23-2.87)	0.744	0.85 (0.63-1.14)	0.277
150-154.9	63	271	0.58 (0.18-1.90)	0.370	0.64 (0.49-0.84)	0.001	0.60 (0.18-1.99)	0.403	0.64 (0.48-0.85)	0.002
155-159.9	184	144	0.74 (0.23-2.35)	0.609	0.58 (0.41-0.81)	0.002	0.79 (0.24-2.57)	0.695	0.59 (0.42-0.84)	0.003
≥160	610	49	0.66 (0.21-2.06)	0.475	0.61 (0.36-1.04)	0.069	0.74 (0.23-2.36)	0.607	0.63 (0.37-1.08)	0.092
BMI										
<17.00	54	86	1.00		1.00		1.00		1.00	
17.00–18.49	126	130	0.93 (0.60-1.44)	0.744	1.08 (0.74-1.58)	0.677	0.94 (0.60-1.45)	0.770	1.12 (0.77-1.62)	0.566
18.50–23.49	500	483	0.82 (0.55-1.23)	0.338	1.08 (0.79-1.49)	0.617	0.84 (0.56-1.26)	0.400	1.12 (0.82-1.55)	0.477
23.50–24.99	84	80	0.69 (0.42-1.13)	0.142	1.30 (0.80-2.13)	0.289	0.73 (0.44-1.20)	0.211	1.39 (0.85-2.27)	0.193

25.00–29.99	103	82	0.65 (0.41-1.04)	0.075	1.03 (0.65-1.63)	0.909	0.66 (0.41-1.07)	0.094	1.09 (0.68-1.73)	0.719
≥30.00	20	26	1.01 (0.44-2.29)	0.989	1.20 (0.67-2.14)	0.534	1.04 (0.45-2.38)	0.935	1.28 (0.71-2.30)	0.414
Tobacco use										
Non-user	319	768	1.00		1.00		1.00		1.00	
User	568	119	1.02 (0.81-1.29)	0.844	1.39 (1.02-1.88)	0.034	1.00 (0.80-1.26)	0.998	1.38 (1.02-1.88)	0.039
Alcohol use										
Non-user	558	856	1.00		1.00		1.00		1.00	
User	329	31	0.81 (0.66-1.00)	0.046	1.08 (0.64-1.83)	0.770	0.79 (0.64-0.97)	0.026	1.17 (0.67-2.03)	0.586
Diabetes status										
Non-diabetic	822	854	1.00		1.00		1.00		1.00	
Diabetic	65	33	1.30 (0.89-1.89)	0.175	0.82 (0.52-1.30)	0.407	1.32 (0.91-1.94)	0.147	0.80 (0.50-1.28)	0.356
Hypertension status										
Non-hypertensive	847	874	1.00		1.00		1.00		1.00	
Hypertensive	40	13	1.01 (0.67-1.51)	0.970	0.87 (0.43-1.75)	0.689	1.02 (0.68-1.52)	0.938	0.85 (0.43-1.70)	0.647

All *n* are un-weighted

BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio

$^{\alpha}$ Adjusted for father's characteristics and maternal age at birth, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{\beta}$ Adjusted for mother's characteristics and maternal age at birth, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

$^{¥}$ Adjusted for parental (father and mother) characteristics and maternal age at birth, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

Table S4.11. Association between parental characteristics and post-neonatal mortality (aged 0-59 months).

Parental characteristics	Number of post-neonatal mortality, n		Model 1 [α]		Model 1I [β]		Model III [¥]			
			Father		Mother		Father		Mother	
	Father	Mother	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age (in years)										
15-29	105	200	1.00		1.00		1.00		1.00	
30–39	162	105	0.88 (0.59-1.31)	0.524	0.80 (0.55-1.18)	0.268	0.85 (0.57-1.29)	0.446	0.83 (0.55-1.26)	0.377
≥40	52	14	0.96 (0.53-1.71)	0.881	0.80 (0.34-1.87)	0.601	1.02 (0.56-1.87)	0.952	0.68 (0.27-1.70)	0.412
Age at marriage (years)										
<18	32	128	1.00		1.00		1.00		1.00	
18-20	82	108	1.29 (0.77-2.17)	0.338	0.92 (0.60-1.43)	0.714	1.38 (0.83-2.32)	0.217	0.91 (0.59-1.40)	0.660
21-25	140	72	1.27 (0.80-2.04)	0.311	1.47 (0.83-2.61)	0.191	1.36 (0.84-2.20)	0.217	1.61 (0.90-2.89)	0.108
≥26	65	11	0.90 (0.49-1.65)	0.726	0.50 (0.16-1.55)	0.230	0.94 (0.51-1.76)	0.858	0.59 (0.19-1.84)	0.366
Education										
No or incomplete primary	106	154	1.00		1.00		1.00		1.00	
Primary or incomplete secondary	171	137	0.80 (0.57-1.13)	0.202	0.67 (0.44-1.03)	0.067	0.87 (0.61-1.24)	0.436	0.70 (0.46-1.07)	0.100
Secondary or higher	42	28	0.54 (0.31-0.95)	0.032	0.35 (0.17-0.72)	0.004	0.70 (0.38-1.28)	0.242	0.40 (0.18-0.87)	0.022
Employment										
Unemployed	21	224	1.00		1.00		1.00		1.00	
Non-manual	55	21	0.62 (0.31-1.26)	0.187	1.44 (0.69-3.00)	0.326	0.67 (0.33-1.33)	0.249	1.37 (0.69-2.71)	0.367
Agricultural	129	55	0.42 (0.23-0.79)	0.006	0.89 (0.55-1.45)	0.642	0.44 (0.24-0.82)	0.009	0.90 (0.55-1.47)	0.675
Manual/others	114	19	0.48 (0.25-0.91)	0.025	0.92 (0.51-1.66)	0.790	0.49 (0.26-0.93)	0.030	0.88 (0.48-1.61)	0.684
Height (in cm)										
<145	2	49	1.00		1.00		1.00		1.00	
145-149.9	3	101	0.50 (0.07-3.42)	0.481	1.05 (0.65-1.71)	0.840	0.58 (0.08-4.07)	0.585	1.07 (0.66-1.73)	0.788
150-154.9	25	94	0.63 (0.12-3.36)	0.591	0.75 (0.45-1.26)	0.277	0.75 (0.14-4.20)	0.748	0.77 (0.47-1.26)	0.297
155-159.9	69	60	0.68 (0.14-3.32)	0.631	0.81 (0.45-1.45)	0.473	0.86 (0.17-4.40)	0.851	0.83 (0.47-1.47)	0.528
≥160	220	15	0.72 (0.15-3.46)	0.679	0.57 (0.26-1.24)	0.158	0.95 (0.19-4.82)	0.954	0.60 (0.28-1.29)	0.195
BMI										
<17.00	18	35	1.00		1.00		1.00		1.00	
17.00–18.49	35	51	1.24 (0.57-2.67)	0.590	0.89 (0.55-1.47)	0.660	1.25 (0.58-2.71)	0.571	0.92 (0.55-1.51)	0.732
18.50–23.49	190	161	1.15 (0.63-2.09)	0.655	0.75 (0.48-1.17)	0.199	1.20 (0.66-2.17)	0.552	0.77 (0.48-1.22)	0.264
23.50–24.99	30	33	0.52 (0.25-1.07)	0.075	1.81 (0.97-3.39)	0.064	0.55 (0.27-1.12)	0.100	1.90 (1.00-3.60)	0.049

25.00–29.99	39	30	1.02 (0.49-2.10)	0.958	0.71 (0.37-1.36)	0.304	1.03 (0.51-2.09)	0.939	0.75 (0.38-1.45)	0.390
≥30.00	7	9	0.89 (0.30-2.59)	0.828	1.26 (0.50-3.19)	0.625	0.89 (0.30-2.64)	0.831	1.32 (0.50-3.50)	0.579
Tobacco use										
Non-user	100	264	1.00		1.00		1.00		1.00	
User	219	55	1.21 (0.84-1.74)	0.296	1.48 (0.95-2.33)	0.086	1.17 (0.82-1.66)	0.395	1.45 (0.92-2.27)	0.106
Alcohol use										
Non-user	181	305	1.00		1.00		1.00		1.00	
User	138	14	1.06 (0.77-1.46)	0.722	1.54 (0.62-3.79)	0.352	1.05 (0.77-1.44)	0.768	1.60 (0.64-4.02)	0.316
Diabetes status										
Non-diabetic	290	306	1.00		1.00		1.00		1.00	
Diabetic	29	13	0.99 (0.54-1.81)	0.982	0.94 (0.48-1.84)	0.854	1.00 (0.57-1.75)	0.988	0.97 (0.50-1.92)	0.940
Hypertension status										
Non-hypertensive	302	313	1.00		1.00		1.00		1.00	
Hypertensive	17	6	1.21 (0.62-2.35)	0.569	1.27 (0.43-3.76)	0.669	1.18 (0.61-2.30)	0.626	1.28 (0.43-3.78)	0.656

All *n* are un-weighted
BMI: Body Mass Index (kg/m^2); CI: Confidence interval; OR: Odds ratio
$^{\alpha}$ Adjusted for father's characteristics and maternal age at birth, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.
$^{\beta}$ Adjusted for mother's characteristics and maternal age at birth, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.
$^{¥}$ Adjusted for parental (father and mother) characteristics and maternal age at birth, sex, birth order, area of residence, religion, social group, wealth index, and states of residence.

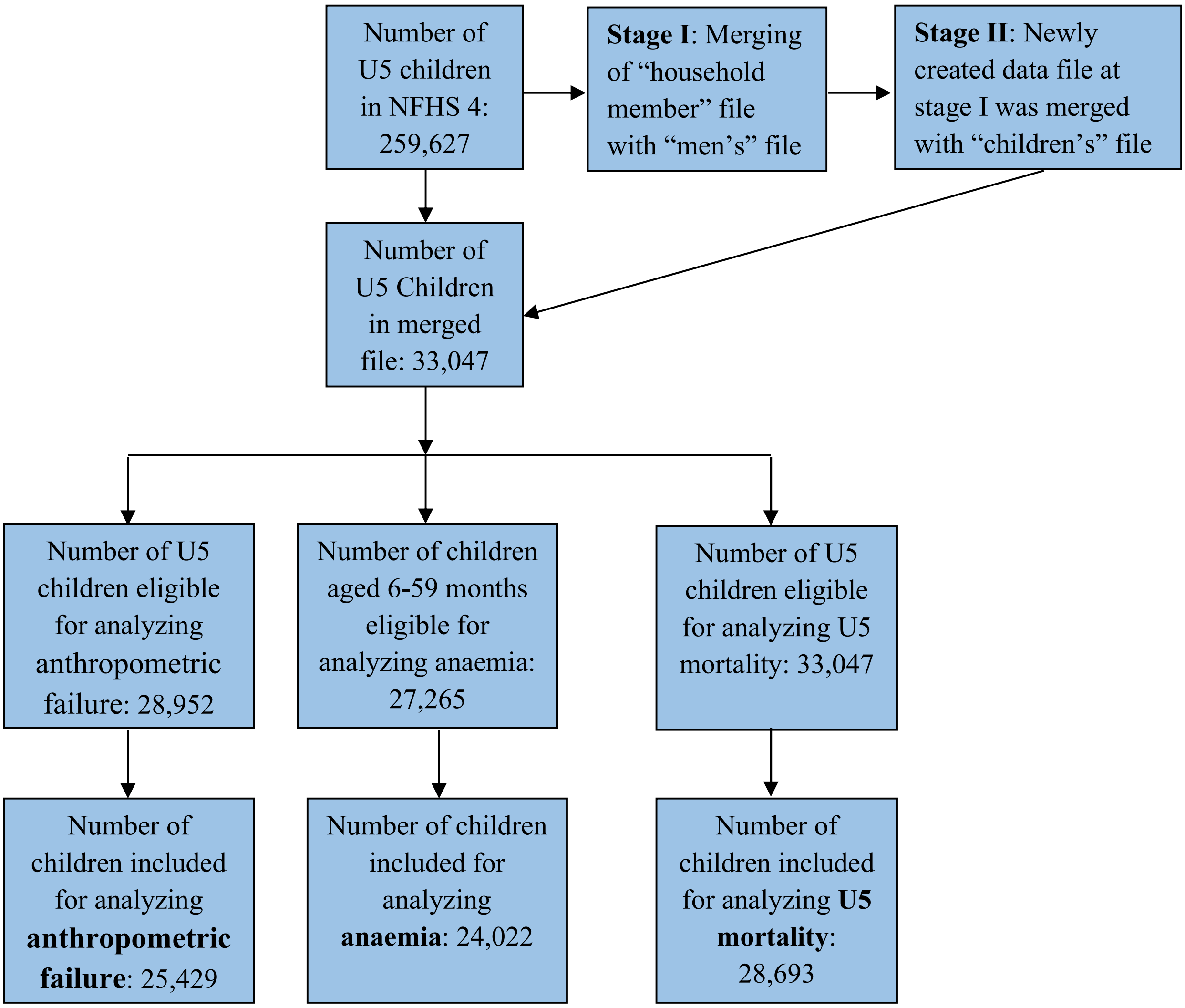

Figure S4.1. Derivation of sample size (unweighted) for analyzing anthropometric failure, anaemia, and under-five (U5) mortality.
NFHS: National Family Health Survey

5. Maternal iron-and-folic-acid supplementation and its association with low-birth weight and neonatal mortality in India§

RAJESH KUMAR RAI, JAN-WALTER DE NEVE, PASCAL GELDSETZER, and SEBASTIAN VOLLMER

This study assessed intake of iron-and-folic-acid (IFA) tablet/syrup (grouped into none, <100 days of IFA consumption or <100 IFA, and ≥100 days of IFA consumption or ≥100 IFA) among prospective mothers and its association with various stages of low-birthweight (ELBW: extremely low-birthweight, VLBW: very low-birthweight, and LBW: low-birthweight) and neonatal mortality (death during day 0-1, 2-6, 7-27, and 0-27) in India. The cross-sectional, nationally representative, 2015-2016 National Family Health Survey (NFHS-4) data were used. Weighted descriptive analysis, and multiple binary logistic regression modelling were used. A total of 120,374 and 143,675 index children aged 0-59 months were included to analyse LBW and neonatal mortality, respectively. Overall, 30.7% mothers consumed ≥100 IFA in 2015-2016, and this estimate ranged from 0.0% in Zunheboto district of Nagaland state to 89.5% in Mahe district of Puducherry of India. Multiple regression analysis revealed that children of mothers who consumed ≥100 IFA had lower odds of ELBW, VLBW, LBW, and neonatal mortality during day 0-1, as compared to mothers who did not buy/receive any IFA. Consumption of IFA (<100 IFA and ≥100 IFA) had protective association with neonatal death during day 7-27, and 0-27. Consumption of IFA was not associated with neonatal death during day 2-6. While ≥100 IFA consumption during pregnancy was found to be associated with preventing select types of LBW and neonatal mortality, a large variation in coverage of ≥100 IFA consumption across 640 districts is concerning.

Keywords: anaemia, iron-deficiency anaemia, iron-and-folic-acid, micronutrients, India

§ Rai RK, De Neve JW, Geldsetzer P, Vollmer S. Maternal iron-and-folic-acid supplementation and its association with low-birth weight and neonatal mortality in India. *Public Health Nutrition*. 2022; 25(3): 623-633. DOI: https://doi.org/10.1017/S1368980021004572.

5.1 Introduction

India has the largest anaemic population in the world (Ministry of Health and Family Welfare, 2013). Anaemia is defined as concentration of haemoglobin (Hb) in the blood below an established threshold (Balarajan et al., 2011). Iron-deficiency anaemia (IDA) is the most common cause of anaemia, but other nutritional deficiencies (including folate, vitamin B12 and vitamin A), acute and chronic inflammation, parasitic infections, and hereditary or acquired disorders that affect Hb synthesis, red blood cell production or red blood cell survival can also cause anaemia (Ministry of Health and Family Welfare, 2013; Balarajan et al., 2011; Cappellini et al., 2020). According to the 2017 Global Burden of Disease (GBD) study (Indian Council of Medical Research et al., 2017), IDA was the leading cause of years lived with disability in India, resulting in an unprecedented loss to the country's productivity (Chaparro and Suchdev, 2019; Horton and Ross, 2003). IDA disproportionately affects women, especially pregnant women (Jung et al., 2019; Young et al., 2019). In 2018, an estimated 181.3 million women were found to be anaemic (95% confidence interval: 171.4–190.2) in India, of which an estimated 103.4 million (95% confidence interval: 94.2–112.7) were moderately or severely anaemic (Kinyoki et al., 2021). As compared to a non-anaemic pregnant woman, an anaemic pregnant woman has higher likelihood of pregnancy complications, experiencing adverse pregnancy and poor birth outcomes such as preterm birth (PTB), intrauterine growth restriction (IUGR), stillbirth, low-birthweight (LBW) and neonatal deaths (Ministry of Health and Family Welfare, 2013; Jung et al., 2019; Young et al., 2019; Kinyoki et al., 2021; Finkelstein et al., 2020; Rahman et al., 2016).

To combat the IDA burden among its most vulnerable populations - children, adolescents, pregnant and lactating mothers and women - the Indian government has undertaken various initiatives, starting from the National Nutritional Anaemia Prophylaxis Programme launched in 1970, followed by the 1991 National Nutritional Anaemia Control Programme, the 2012 Weekly Iron-and-Folic-Acid Supplementation Programme, and the National Iron Plus Initiative (NIPI) launched in 2013. Despite these multiple initiatives, over 50% of all women (including pregnant and non-pregnant women) aged 15-49 years were found to be anaemic in 2015-2016 (International Institute for Population Sciences and ICF, 2017). Learning from the failure of anaemia reduction initiatives (Rai et al., 2018; Rai et al., 2021; Rai, 2022; Singh et al., 2020; Sudfeld et al., 2020), a programme called the Prime Minister's Overarching Scheme for Holistic Nourishment (POSHAN) *Abhiyaan* (or National Nutrition Mission), was set up in 2018 to address nutrition issues under the oversight of the Ministry of Women & Child Development, Government of India. The POSHAN *Abhiyaan* pledged for an Anaemia *Mukt Bharat* (Anaemia Free India) and targeted reduction in anaemia among adolescent girls and women aged 15-49 years at the rate of three percent per annum (NITI Aayog, 2020).

Antenatal iron-and-folic-acid (IFA) supplementation is a cost-effective public health intervention to avert poor pregnancy outcomes which may occur due to anaemia during pregnancy (Perumal et al., 2021; Christian, 2021). The NIPI guideline recommends that pregnant women should consume a dose of 100 mg of elemental iron and 500 mcg of folic acid daily for at least 100 days (≥100 IFA), starting after the first trimester, at 14–16 weeks of gestation (Ministry of Health and Family Welfare, 2013). The supplementation of elemental iron is expected to correct iron-deficiency and IDA among pregnant women, which would in turn help reduce the chances of adverse birth outcomes and strengthen the health of new-borns (Ministry of Health and Family Welfare, 2013, World Health Organization, 2012). While execution and effectiveness of existing public programmes have been heavily criticized, the uptake of IFA among pregnant women has been sub-optimal (Rai et al., 2018).

The empirical evidence on the effect of IFA supplementation to pregnant mothers on LBW and survival status of their children in India is at a premature stage. Existing studies on this issue are either outdated (Balarajan et al., 2013; Malhotra et al., 2014; Singh et al., 2014) or focus on specific administrative regions of India (Finkelstein et al., 2020) and small sample studies are prone to low external validity. Against this knowledge gap, using cross-sectional, nationally representative data from India, we assessed whether maternal consumption of IFA (categorized into three groups: none, <100 IFA, and ≥100 IFA) during their last pregnancy were associated with selected child health indicators – extremely low-birthweight (ELBW), very low-birthweight (VLBW), low-birthweight (LBW) and neonatal mortality (death during day 0-27) including death during day 0-1, 2-6, day 7-27. To date, no study has assessed the association between IFA and various stages of LBW and neonatal mortality in India. Findings of this study could be helpful in exploring the need for targeted IFA intervention in mitigating overall LBW and neonatal deaths in India. As an add-on analysis, we also estimated the change (between 2005-2006 and 2015-2016) in prevalence of ≥100 IFA consumption across states in India, whereas coverage of ≥100 IFA uptake was analysed for 2015-2016 in 640 districts.

5.2 Methods

5.2.1 *Dataset*

The 2015-2016 National Family Health Survey (NFHS-4) data were used to attain the study objectives (International Institute for Population Sciences and ICF, 2017). NFHS-4 is a cross-sectional and nationally representative survey, conducted under the stewardship of the Ministry of Health and Family Welfare, Government of India. NFHS-4 covered 640 districts spread across 37 states and union territories of India. The 2011 Census of India sampling frame was used to draw the sample for both rural and urban areas using two-stage stratified random sampling. Villages in rural areas and census enumeration blocks (CEBs) in urban areas served as the primary sampling unit (PSU) or clusters. With household response rates above 97%, a total of 601,509 households were selected, consisting of 699,686 women and 112,122 men in NFHS-4. Details of the NFHS-4 sampling procedures are available in its published report (International Institute for Population Sciences and ICF, 2017). NFHS-4 data are available in the public domain with all participant identifiers removed. Prior to conducting the NFHS-4, ethical approval was obtained by the nodal agency – International Institute for Population Sciences, Mumbai – from the independent ethics review committee constituted by the Ministry of Health and Family Welfare, Government of India.

In NFHS-4, a total of 190,797 mothers were asked about their IFA consumption for their index pregnancy. To analyse LBW, a total of 120,374 children were found eligible, whereas the denominator for analysing neonatal mortality was 143,675 children. As the exclusion of survey participants may lead to sample selection bias, sample included in the analysis was compared with the sample excluded from the analysis for age and sex of children. NFHS-4 records information on birthweight for children born in the five years preceding the survey date, whereas age at death was recorded for children ever born. However, this study included record of birthweight and/or child mortality only for index children which helped minimize recall errors. The prevalence of ≥100 IFA in 2015-2016 was compared with ≥100 IFA in 2005-2006 across 29 states and union territories of India to understand the change in coverage of ≥100 IFA over the last decade. The 2005-2006 National Family Health Survey (NFHS-3) data (International Institute for Population Sciences and ICF, 2007) were compared with NFHS-4, and by virtue of their sampling design, estimates from both rounds of NFHSs are comparable (Corsi et al., 2012). In addition, the coverage of ≥100 IFA intake in NFHS-4 was analysed for 640 districts spread across 37 states and union territories of India.

5.2.2 *Outcome events*

Two outcome events were analysed – LBW and neonatal mortality, and their sub-categories. According to WHO, LBW is defined as weight at birth of less than 2.5 kilograms (kg) or 5.5 pounds (United Nations Children's Fund and World Health Organization, 2004). For this study, children's birthweight was categorized into three groups: low-birthweight (LBW) with weight of <2.5 kg, very low-birthweight (VLBW) with weight of < 1.5 kg, and extremely-low-birthweight (ELBW) with weight of < 1.0 kg (United Nations Children's Fund and World Health Organization, 2004). In NFHS-4, women were asked if the children born to them were weighed at birth, and if the response was affirmative, the weight at birth was recorded in kg. It was advised to record the birthweight from their government issued health card (i.e. a written record of the birth weight on a government issued document, such as the vaccination card, the antenatal card, or the birth certificate), if available, otherwise reporting of birthweight was based on the mother's recall from memory. Of 120,374 children included for analysing LBW, birthweight of 55,227 (unweighted) children (42.8%) were based on mother's recall (calculated by authors, from NFHS-4 data).

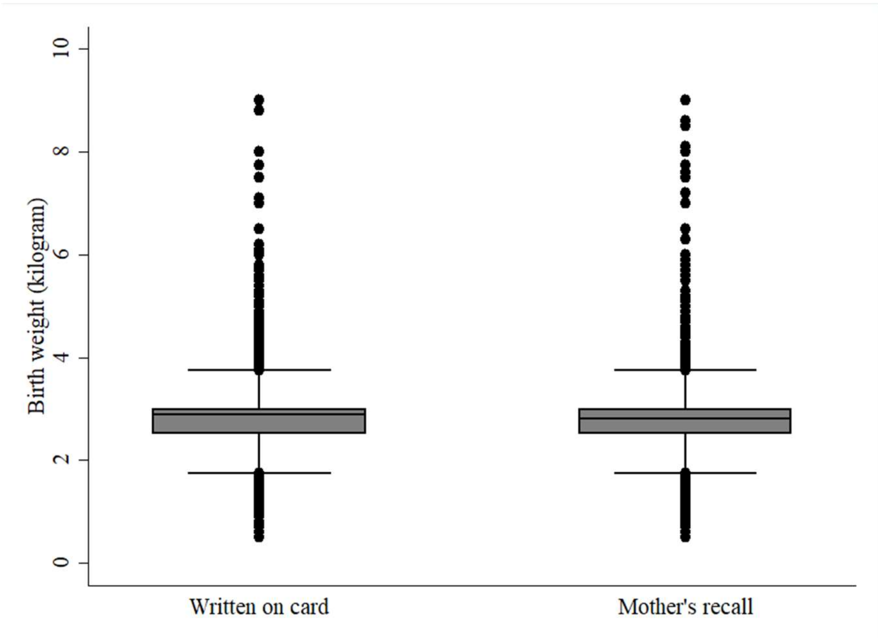

Figure 5. 1. Box plot showing the distribution of birthweight datapoints, recorded from health card and mother's recall.

The distribution of birthweight datapoints from health card and mother's recall is presented in **Figure 5.1**. The mean birthweight collected from health cards was 2.82 kg (95% confidence interval: 2.81-2.83) whereas the mean birthweight from mother's recall was estimated to be 2.80 kg (95% confidence interval: 2.79-2.81), and an independent group t-test indicated that the mean of birthweight between two groups (from health card and mother's recall) was different with a two-tailed p-value of <0.001. In the women's questionnaire, the birth and death history of children ever born to them was recorded. If the child was reported to be dead, a further question was posed on age at which the child died. Age at death was recorded in days if the child died within the first month of life, in months if the child died between one month and the second birthday, or otherwise in years. In this study, death of children during the first 28 days of life (0-27 days) is defined as neonatal mortality. Neonatal mortality was further investigated by age at death: day 0-1, day 2-6, and day 7-27. This categorization of age of death is critical as neonatal death varies greatly with days (Sankar et al., 2016) and analysing the role of IFA on various categories of neonatal deaths would help understand if IFA consumption is associated with neonatal death of a particular age-group.

5.2.3 *Primary independent variable and covariates*

While IFA consumption was used as a primary variable, a range of covariables were considered as potential confounders. In NFHS-4, women aged 15-49 years were asked – whether they were given or if they had bought any iron-and-folic-acid (IFA) tablets or equivalent syrup during their last pregnancy in the five years preceding the survey date. If the response was affirmative, they were asked about the number of days they took the tablet or syrup, and if the answer was non-numeric, they were probed about approximate number of days (for example, by asking how many months pregnant she was when she began taking the tablets and whether she took the tablets every day after that). Although asking approximate number of days of IFA consumption may lead to recall errors, this information is deemed useful for understanding overall coverage of IFA consumption and for informing public health policy in India (Rai et al., 2018; Singh et al., 2014; Deb, 2015). The NFHS-4 does not collect information about the proportion of women who required probing to obtain information on number of days of IFA consumption during their pregnancy. Interviewers were asked to show sample IFA tablets or syrup to the respondents while asking the questions on IFA to minimize recall errors. Inclusion of information on IFA consumption for index birth refers to a birth in 2011 or later for NFHS-4. Using the information on IFA consumption, the primary variable of interest was computed into three categories: none, <100 days of IFA consumption (<100 IFA), and ≥ 100 days of IFA consumption (≥ 100 IFA). The category "none" represents the group of women who did not receive or buy any IFA during their last pregnancy. Consumption of <100 IFA include women who received or bought IFA but did not consume any of it, and their proportion is negligible (<0.5%). A maximum of 300 days of IFA tablets or equivalent syrup consumption was recorded in NFHS-4. On average, the gestation for term pregnancy lasts 40 weeks (280 days), therefore women with term pregnancy are expected to consume a maximum of 280 IFA. However, reporting of consumption of >280 IFA (nearly 3.1 % of all mothers) is indicative of mothers who had post-term pregnancies (ACOG Committee Opinion No 579, 2013).

The conceptualization of association between IFA consumption (exposure variable) and child health indicators of LBW and neonatal mortality (outcome variables), was guided by a Directed Acyclic Graph (DAG) (Tennant et al., 2021; Williams et al., 2018), available in the online supplement (**Figure S5.1**). Although this study does not establish the causal link between IFA intake and selected child health indicators, a DAG may help establish the pathways between exposure and outcome variables of interest by identifying potential confounders (confounding is the bias of the estimated effect of an exposure on an outcome due to the presence of a common cause of the exposure and the outcome), mediator (a variable that lies "between" the exposure and the outcome), and collider (a variable directly affected by two or more other variables in the causal diagram), guided by existing literature on the issue. Based on a DAG and depending on the available information in NFHS-4 dataset, a range of covariables were identified as potential confounders. Potential confounders included current age group of mother (15-19, 20-29, 30-39, and ≥40), mother's age at marriage (<18, and ≥18), education of mother (none or incomplete primary, primary or incomplete secondary, and secondary or higher), sex of child (male, and female), child birth order (1, 2, 3, 4, and ≥5), place of residence (urban and rural), social group (Others, Scheduled Castes, Scheduled Tribes, and Other Backward Classes), religion (Hinduism, Islam, Christianity, and others), economic group (poorest, poorer, middle, richer, and richest), state of residence ("non-high focus" and "high focus" defined below), antenatal care (ANC) and delivery care are clubbed under number of ANC visits (<4, and ≥4), received supplementary food from *Anganwadi* centre (yes and no), mother's blood sample taken during ANC visit (yes and no), and institutional delivery (yes and no), where maternal nutrition was based on measurement of body mass index or BMI (underweight, optimum, and overweight including obesity). In addition, variables on sources of birthweight data (e.g. written health card and mother's recall) were also identified as a potential confounder for the birthweight analysis.

Primary education refers to grades 1 to 8, while secondary education refers to grades 9 to 10. Of social group, as per the Constitution of India (Government of India, 1950), Scheduled Tribes, Scheduled Castes, and (so called) Other Backward Classes are historically socially, and economically disadvantaged populations compared to the rest of the population (labelled as Others). NFHS-4 includes a wealth index variable, calculated using assets and durables owned by the household, which included ownership of consumable items and dwelling characteristics. Individuals were ranked based on their household scores and divided into different quintiles, each representing 20 percent of the score, between 1 (poorest) and 5 (richest) (Rutstein and Johnson, 2004). Because of their high fertility and high mortality indicators the following nine states are regarded as high focus states: Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, Rajasthan, Uttarakhand, Uttar Pradesh, and Assam (Kumar et al., 2012). Under the 2013 National Food Security Act, pregnant women are entitled to receive cooked or take-home ration during their pregnancy from the *Anganwadi* centre (meaning, "courtyard shelter") (Kumar and Rai, 2015). According to the WHO, a BMI of <18.5 kg/m^2 is considered a measure of underweight, 18.5- 22.99 kg/m^2 as optimum weight, and ≥ 23 kg/m^2 is labelled as the measure of overweight including obesity for Asian populations (WHO Expert Consultation, 2004).

The objective of IFA supplementation during pregnancy is to correct iron deficiency and IDA which depends on bioavailability, gut integrity, iron stores, and infection (Gosdin et al., 2021). Anaemia level during pregnancy can act as a potential mediator in establishing the linkages between IFA consumption and child health indicators. But NFHS-4 does not collect information on Hb level during pregnancy retrospectively, instead NFHS-4 measures anaemia level among women at the time of survey which cannot be used and the proxy measure of anaemia during their last pregnancy.

5.2.4 *Statistical analysis*

A combination of descriptive statistics and multiple regression analyses was used. In addition, an analysis of changes in the coverage of ≥ 100 IFA intake (between 2005-2006 and 2015-2016), and prevalence of ≥ 100 IFA consumption across 640 districts of India were undertaken. Bivariate analysis was run to understand the proportional difference of outcome events – ELBW, VLBW, LBW, and neonatal death (day 0-27) stratified by days of death (day 0-1, day 2-6, and day 7-27) by IFA consumption and other potential confounders. Prior to running bivariate analysis, a chi-squared (χ^2) test was run to understand if the distribution of children's age and sex differ between the sample included in and the sample excluded from the analysis. Multiple logistic regression analyses were conducted for all outcome variables coded in binary terms (1 and 0), where occurrence of the outcome event was coded as "1" and its absence was coded as "0". For each outcome, the model included the primary variable of interest – IFA intake (categorized into three groups - none, <100 IFA, and ≥100 IFA), variables representing socio-economic characteristics, variables representing ANC and delivery care, and maternal BMI. For all the outcomes on birthweight, one additional variable representing source of birthweight was adjusted as birthweight reporting could differ between the health card and maternal recall [(22)]. Also, while running the regression models for LBW, sex of the child is not a confounder in any of the models.

Recording of birthweight through mother's recall is likely to have digit preference, often in multiples of 500 grams (Balarajan et al., 2013) which leads to heaping (Channon et al., 2011). To check the sensitivity of it, an alternate analysis with alternate definition of ELBW of ≤1.0 kg, VLBW ≤1.5 kg, and LBW of ≤2.5 kg was done. Appropriate sample weighting provided with the NFHS dataset was used for running descriptive analysis and "svy" suite available to adjust sample weighting with the statistical software Stata, version 14 (StataCorp., 2015) was used. While weighted descriptive analysis was run, unweighted multiple binary logistic regression models (Solon et al., 2015) were developed to understand the association between the primary variable and various stages of LBW and neonatal mortality.

5.3 Results

The sample included in the analysis was checked for sample selection bias, and the distribution of child age and sex were not different between the sample included in and the sample excluded from the analysis (data not shown separately). An analysis of changing coverage of ≥100 IFA intake by states (**Table S5.1, and Figure 5.2**) between 2005-2006 and 2015-2016 was conducted, followed by extent of coverage of ≥100 IFA intake across 640 districts in India (**Table S5.2**). Overall, the coverage of ≥100 IFA intake doubled between 2005-2006 (15.6%) and 2015-2016 (30.7%). During same time, the state of Mizoram gained 36.2 percentage points in ≥100 IFA intake, whereas the state of Kerala, with 74.8% coverage in 2015-2016, saw a 6.9 percentage point reduction of ≥100 IFA intake. District-wise coverage of ≥100 IFA in 2015-2016 ranged from 0.0% in Zunheboto districts of Nagaland to 89.5% in Mahe district of Puducherry. Among 640 districts in India, the state of Nagaland has five districts (Zunheboto, Longleng, Mon, Phek, and Kiphire) with the lowest coverage of ≥100 IFA intake, followed by three districts in Arunachal Pradesh (West Siang, Upper Subansiri, and East Kameng).

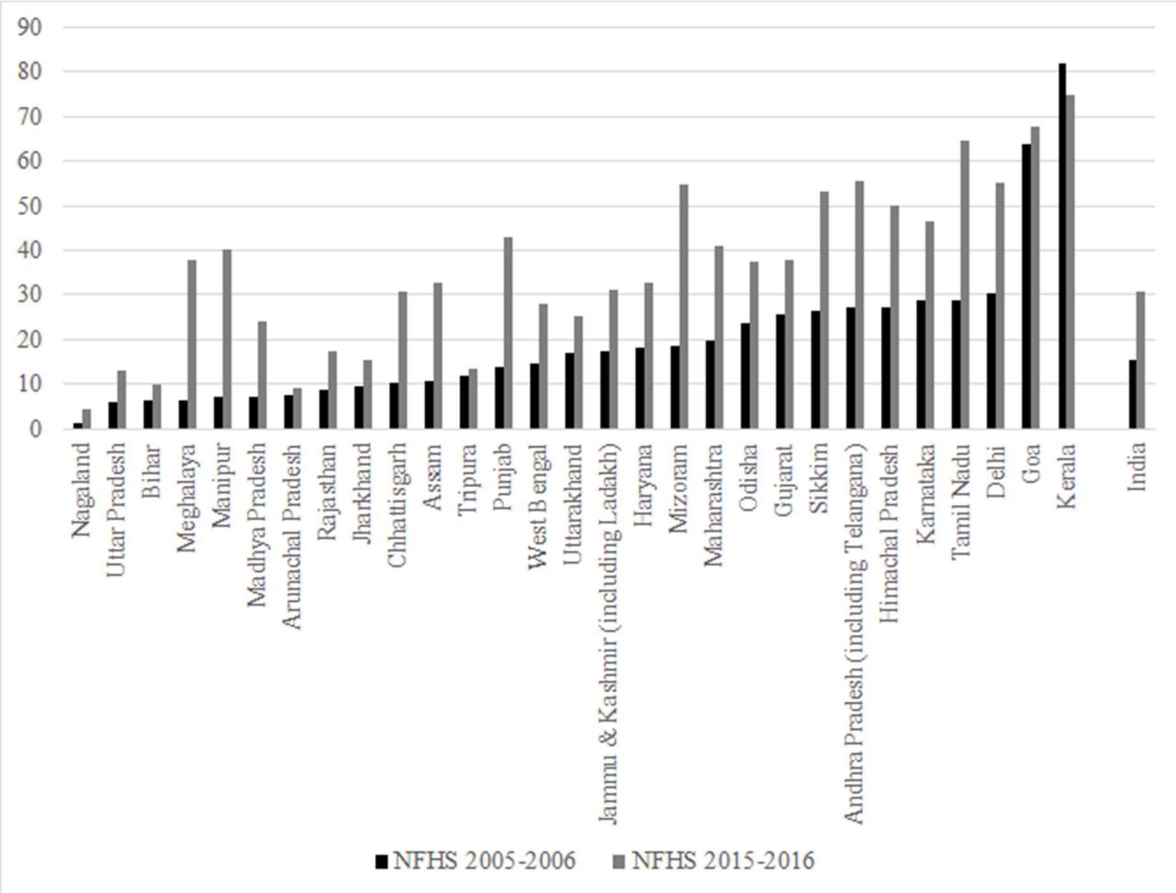

Figure 5.2. Change in prevalence (%) of ≥100 iron-and-folic-acid receipt between 2005-2006 and 2015-2016, in 29 states / union territories of India.
During survey period of the 2005–2006 National Family Health Survey, Ladakh was part of Jammu & Kashmir; and during survey period of the 2005–2006 National Family Health Survey, Telangana was part of Andhra Pradesh.
NFHS: National Family Health Survey

Prevalence with 95% confidence interval (CI) of ELBW, VLBW, and LBW, and prevalence of timing of neonatal mortality (day 0-1, day 2-6, and day 7-27) and neonatal mortality (day 0-27) by select background characteristics are presented in **Table 5.1**. Overall, 0.11% (CI: 0.09-0.14), 1.14% (CI: 1.06-1.23), and 17.0% (CI: 16.7-17.3) children had ELBW, VLBW, and LBW, respectively. Prevalence of neonatal mortality is 1.69% (CI: 1.61-1.78), with 0.96% (CI: 0.90-1.02) reporting a death during day 0-1.

Table 5.1. Prevalence of extremely low-birthweight, very low-birthweight, and low-birthweight, and prevalence of timing of neonatal mortality (day 0-1, day 2-6, and day 7-27) and neonatal mortality (day 0-27) by primary variable and covariables.

	n	Extremely low-birthweight, % (95% CI)	Very low-birthweight, % (95% CI)	Low-birthweight, % (95% CI)	n	Neonatal mortality (day 0-1), % (95% CI)	Neonatal mortality (day 2-6) % (95% CI)	Neonatal mortality (day 7-27), % (95% CI)	Neonatal mortality, (day 0-27) % (95% CI)
IFA consumption									
No IFA	16,751	0.17 (0.11-0.26)	1.58 (1.36-1.85)	19.1 (18.3-19.9)	24,432	1.37 (1.20-1.56)	0.61 (0.51-0.74)	0.49 (0.39-0.61)	2.47 (2.24-2.72)
<100 IFA	60,141	0.11 (0.08-0.15)	1.21 (1.10-1.33)	17.9 (17.5-18.4)	72,651	1.01 (0.92-1.10)	0.50 (0.44-0.57)	0.29 (0.24-0.35)	1.80 (1.68-1.92)
≥100 IFA	43,482	0.09 (0.05-0.15)	0.90 (0.78-1.05)	15.1 (14.6-15.6)	46,592	0.69 (0.60-0.80)	0.33 (0.27-0.41)	0.14 (0.11-0.18)	1.17 (1.05-1.31)
Current age-group of mother									
15-19	3,764	0.11 (0.04-0.33)	1.73 (1.28-2.34)	20.8 (19.0-22.6)	4,364	1.40 (1.06-1.83)	1.18 (0.81-1.73)	0.65 (0.43-0.98)	3.23 (2.64-3.94)
20-29	83,556	0.10 (0.07-0.13)	1.12 (1.03-1.22)	16.9 (16.6-17.3)	98,155	0.92 (0.85-1.00)	0.43 (0.38-0.49)	0.24 (0.20-0.28)	1.60 (1.50-1.70)
30-39	30,650	0.14 (0.09-0.23)	1.11 (0.96-1.30)	16.7 (16.1-17.3)	37,755	0.95 (0.83-1.09)	0.43 (0.36-0.52)	0.30 (0.24-0.37)	1.68 (1.52-1.85)
≥40	2,404	0.14 (0.02-1.00)	1.40 (0.89-2.20)	17.1 (15.0-19.5)	3,401	1.56 (1.12-2.17)	0.56 (0.33-0.95)	0.51 (0.25-1.04)	2.64 (2.03-3.42)
Mother's age at first birth									
<18	12,259	0.13 (0.07-0.26)	1.19 (0.96-1.47)	18.8 (17.8-19.8)	15,728	1.03 (0.85-1.26)	0.51 (0.38-0.68)	0.26 (0.19-0.36)	1.80 (1.55-2.09)
≥18	108,115	0.11 (0.08-0.14)	1.14 (1.06-1.23)	16.8 (16.5-17.1)	127,947	0.95 (0.88-1.01)	0.45 (0.41-0.50)	0.27 (0.24-0.31)	1.67 (1.59-1.77)
Education of mother									
No or incomplete primary	30,580	0.13 (0.09-0.20)	1.48 (1.31-1.67)	19.4 (18.8-20.0)	43,064	1.40 (1.27-1.55)	0.62 (0.54-0.72)	0.39 (0.32-0.47)	2.41 (2.24-2.60)
Primary or incomplete secondary	59,973	0.11 (0.08-0.15)	1.15 (1.04-1.27)	17.5 (17.1-18.0)	68,896	0.89 (0.80-0.98)	0.44 (0.38-0.51)	0.27 (0.22-0.32)	1.59 (1.48-1.72)
Secondary or higher	29,821	0.09 (0.04-0.17)	0.83 (0.69-0.99)	13.8 (13.3-14.4)	31,715	0.57 (0.48-0.67)	0.30 (0.23-0.40)	0.15 (0.11-0.20)	1.02 (0.89-1.16)
Sex of child									
Male	na	na	na	na	78,140	1.01 (0.92-1.10)	0.48 (0.42-0.54)	0.27 (0.22-0.32)	1.75 (1.64-1.87)
Female	na	na	na	na	65,535	0.90 (0.81-0.99)	0.44 (0.38-0.51)	0.28 (0.23-0.34)	1.62 (1.50-1.74)
Birth order									
1	45,200	0.08 (0.06-0.12)	1.21 (1.08-1.37)	17.7 (17.2-18.2)	49,993	0.96 (0.86-1.06)	0.53 (0.45-0.62)	0.24 (0.19-0.29)	1.72 (1.59-1.87)
2	42,394	0.11 (0.07-0.18)	0.94 (0.83-1.07)	15.9 (15.4-16.4)	48,925	0.69 (0.61-0.79)	0.34 (0.28-0.40)	0.23 (0.17-0.30)	1.25 (1.13-1.38)
3	18,856	0.13 (0.08-0.23)	1.15 (0.96-1.38)	16.9 (16.2-17.7)	23,997	1.10 (0.93-1.30)	0.38 (0.30-0.48)	0.31 (0.23-0.42)	1.79 (1.58-2.03)
4	7,917	0.16 (0.08-0.32)	1.72 (1.38-2.13)	18.4 (17.3-19.6)	11,126	1.45 (1.19-1.77)	0.71 (0.54-0.94)	0.34 (0.23-0.50)	2.50 (2.16-2.90)
≥5	6,007	0.15 (0.06-0.37)	1.52 (1.18-1.95)	19.0 (17.7-20.3)	9,634	1.66 (1.38-2.01)	0.72 (0.54-0.97)	0.61 (0.44-0.85)	3.00 (2.60-3.46)

Place of residence									
Urban	35,312	0.10 (0.06-0.16)	1.10 (0.96-1.27)	16.0 (15.4-16.6)	39,157	0.72 (0.62-0.84)	0.31 (0.24-0.40)	0.21 (0.15-0.29)	1.25 (1.10-1.41)
Rural	85,062	0.11 (0.09-0.15)	1.16 (1.07-1.26)	17.5 (17.2-17.9)	104,518	1.06 (0.99-1.14)	0.53 (0.48-0.58)	0.30 (0.26-0.34)	1.89 (1.79-2.00)
Social group									
Others	25,466	0.12 (0.09-0.18)	1.00 (0.86-1.17)	15.6 (15.0-16.3)	29,344	0.75 (0.64-0.88)	0.37 (0.28-0.49)	0.25 (0.18-0.35)	1.37 (1.20-1.56)
Scheduled castes	22,978	0.11 (0.06-0.20)	1.33 (1.15-1.55)	18.1 (17.5-18.8)	27,657	1.16 (1.02-1.32)	0.53 (0.44-0.63)	0.32 (0.25-0.41)	2.00 (1.82-2.20)
Scheduled tribes	22,384	0.10 (0.05-0.22)	1.11 (0.88-1.40)	19.1 (18.2-20.1)	27,741	0.87 (0.72-1.05)	0.56 (0.44-0.73)	0.29 (0.21-0.41)	1.72 (1.50-1.98)
Other Backward Classes	49,546	0.10 (0.07-0.15)	1.13 (1.02-1.26)	16.7 (16.3-17.1)	58,933	0.98 (0.89-1.08)	0.45 (0.39-0.51)	0.26 (0.21-0.31)	1.69 (1.57-1.81)
Religion									
Hinduism	92,966	0.11 (0.08-0.14)	1.12 (1.03-1.21)	17.2 (16.9-17.6)	108,753	0.94 (0.87-1.01)	0.47 (0.42-0.52)	0.28 (0.24-0.32)	1.68 (1.59-1.78)
Islam	13,121	0.13 (0.08-0.22)	1.32 (1.09-1.60)	16.2 (15.3-17.1)	17,856	1.19 (1.00-1.42)	0.45 (0.35-0.59)	0.29 (0.22-0.39)	1.93 (1.70-2.20)
Christianity	8,554	0.04 (0.01-0.17)	1.14 (0.58-2.23)	15.4 (13.4-17.5)	10,634	0.59 (0.35-0.98)	0.18 (0.09-0.34)	0.13 (0.05-0.34)	0.89 (0.61-1.32)
Others	5,733	0.05 (0.01-0.20)	1.13 (0.71-1.80)	15.9 (14.4-17.5)	6,432	0.74 (0.52-1.05)	0.46 (0.26-0.80)	0.20 (0.11-0.38)	1.40 (1.06-1.84)
Economic group									
Poorest	20,303	0.17 (0.09-0.30)	1.43 (1.22-1.67)	19.5 (18.8-20.2)	28,847	1.41 (1.25-1.60)	0.67 (0.56-0.80)	0.45 (0.36-0.55)	2.53 (2.32-2.77)
Poorer	25,054	0.11 (0.07-0.16)	1.36 (1.18-1.55)	18.1 (17.4-18.8)	31,813	1.18 (1.05-1.34)	0.59 (0.50-0.70)	0.26 (0.20-0.34)	2.04 (1.86-2.24)
Middle	26,217	0.12 (0.08-0.18)	1.07 (0.92-1.25)	17.1 (16.5-17.8)	30,458	0.95 (0.82-1.09)	0.48 (0.38-0.60)	0.31 (0.23-0.42)	1.73 (1.54-1.94)
Richer	25,116	0.07 (0.04-0.11)	1.04 (0.88-1.22)	17.3 (16.6-18.0)	27,643	0.73 (0.61-0.87)	0.27 (0.21-0.36)	0.17 (0.12-0.26)	1.18 (1.03-1.35)
Richest	23,684	0.10 (0.05-0.20)	0.92 (0.76-1.13)	13.7 (13.1-14.4)	24,914	0.52 (0.41-0.64)	0.29 (0.21-0.39)	0.17 (0.13-0.24)	0.98 (0.83-1.14)
State of residence									
Non-high focus	54,451	0.09 (0.06-0.14)	0.99 (0.88-1.12)	16.5 (16.0-16.9)	60,010	0.63 (0.55-0.72)	0.32 (0.26-0.39)	0.16 (0.12-0.22)	1.11 (1.00-1.23)
High Focus	65,923	0.13 (0.10-0.17)	1.33 (1.23-1.44)	17.7 (17.4-18.1)	83,665	1.29 (1.20-1.38)	0.61 (0.55-0.67)	0.38 (0.33-0.44)	2.27 (2.16-2.40)
Number of ANC visit									
≥4	74,404	0.09 (0.07-0.13)	1.03 (0.93-1.14)	16.4 (16.0-16.8)	81,457	0.78 (0.71-0.87)	0.37 (0.32-0.43)	0.22 (0.18-0.26)	1.37 (1.27-1.48)
<4	45,970	0.14 (0.10-0.21)	1.36 (1.23-1.51)	18.3 (17.8-18.8)	62,218	1.23 (1.13-1.34)	0.60 (0.53-0.68)	0.36 (0.30-0.42)	2.19 (2.05-2.33)
Received supplementary food from *Anganwadi* centre									
Yes	74,804	0.09 (0.07-0.13)	0.99 (0.90-1.09)	17.0 (16.6-17.4)	86,414	0.87 (0.80-0.95)	0.44 (0.39-0.50)	0.24 (0.20-0.29)	1.55 (1.45-1.66)
No	45,570	0.13 (0.09-0.18)	1.38 (1.23-1.53)	17.0 (16.5-17.6)	57,261	1.08 (0.98-1.19)	0.49 (0.42-0.57)	0.32 (0.27-0.39)	1.89 (1.76-2.04)
Blood sample taken during ANC visit									
Yes	108,561	0.11 (0.08-0.14)	1.12 (1.04-1.21)	16.9 (16.6-17.2)	122,716	0.90 (0.83-0.96)	0.43 (0.39-0.48)	0.25 (0.21-0.29)	1.58 (1.49-1.67)
No	11,813	0.13 (0.07-0.23)	1.37 (1.15-1.63)	18.4 (17.6-19.3)	20,959	1.37 (1.19-1.56)	0.64 (0.52-0.78)	0.43 (0.34-0.56)	2.44 (2.21-2.70)

Institutional delivery									
Yes	111,987	0.09 (0.07-0.12)	1.11 (1.03-1.20)	16.9 (16.6-17.2)	119,711	0.89 (0.83-0.96)	0.44 (0.40-0.49)	0.24 (0.21-0.27)	1.57 (1.49-1.66)
No	8,387	0.32 (0.15-0.65)	1.65 (1.28-2.12)	19.3 (18.1-20.6)	23,964	1.36 (1.17-1.57)	0.57 (0.46-0.70)	0.47 (0.34-0.65)	2.40 (2.14-2.69)
BMI of mother									
Optimum	57,779	0.09 (0.06-0.12)	1.10 (0.99-1.22)	16.6 (16.1-17.0)	70,140	0.99 (0.90-1.09)	0.52 (0.46-0.59)	0.25 (0.21-0.30)	1.76 (1.64-1.89)
Underweight	26,835	0.16 (0.10-0.24)	1.36 (1.20-1.54)	20.8 (20.2-21.5)	33,036	0.89 (0.78-1.02)	0.49 (0.40-0.60)	0.29 (0.22-0.37)	1.67 (1.51-1.85)
Overweight and obesity	35,760	0.11 (0.06-0.18)	1.06 (0.91-1.22)	14.9 (14.3-15.4)	40,499	0.95 (0.84-1.08)	0.34 (0.27-0.42)	0.30 (0.23-0.39)	1.59 (1.44-1.75)
Sources of birthweight data									
From written card	65,147	0.06 (0.04-0.10)	0.88 (0.78-0.98)	16.1 (15.7-16.5)	na	na	na	na	na
From mother's recall	55,227	0.17 (0.13-0.23)	1.50 (1.37-1.65)	18.2 (17.8-18.7)	na	na	na	na	na
Overall	120,374	0.11 (0.09-0.14)	1.14 (1.06-1.23)	17.0 (16.7-17.3)	143,675	0.96 (0.90-1.02)	0.46 (0.42-0.51)	0.27 (0.24-0.31)	1.69 (1.61-1.78)

All n are unweighted
ANC: Antenatal Care, BMI: Body Mass Index, CI: Confidence Interval, p: level of significance

Table 5.2. Association between maternal iron-and-folic-acid (IFA) consumption and extremely low birthweight, very low birthweight, and low birthweight.

	Extremely low-birthweight*		**Very low-birthweight***		**Low-birthweight***	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
No IFA	1.00 (referent)		1.00 (referent)		1.00 (referent)	
<100 IFA	0.84 (0.53-1.34)	0.473	0.94 (0.81-1.09)	0.430	0.97 (0.93-1.02)	0.194
≥100 IFA	0.54 (0.31-0.95)	0.032	0.71 (0.59-0.84)	<0.001	0.84 (0.80-0.89)	<0.001

*Model is adjusted for IFA consumption, current age group of mother, mother's age at first birth, education of mother, birth order, place of residence, social group, religion, economic group, state of residence, number of ANC visit, received supplementary food from *Anganwadi* centre, blood sample taken during ANC visit, institutional delivery, BMI of mother, and sources of birthweight data.

ANC: Antenatal Care, BMI: Body Mass Index, CI: Confidence Interval, OR: Odds Ratio, p: level of significance

Table 5.3. Association between iron-and-folic-acid (IFA) consumption and timing of neonatal mortality (day 0-1, day 2-6, and day 7-27) and neonatal mortality (day 0-27).

	Neonatal mortality (day 0-1) *		**Neonatal mortality (day 2-6)** *		**Neonatal mortality (day 7-27)** *		**Neonatal mortality (day 0-27)** *	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
No IFA	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
<100 IFA	0.89 (0.78-1.01)	0.079	0.92 (0.76-1.12)	0.431	0.74 (0.59-0.94)	0.015	0.87 (0.79-0.96)	0.006
≥100 IFA	0.74 (0.63-0.88)	<0.001	0.85 (0.67-1.07)	0.171	0.62 (0.46-0.84)	0.002	0.75 (0.66-0.84)	<0.001

*Model is adjusted for IFA consumption, current age group of mother, mother's age at first birth, education of mother, sex of child, birth order, place of residence, social group, religion, economic group, state of residence, number of ANC visit, received supplementary food from *Anganwadi* centre, blood sample taken during ANC visit, institutional delivery, and BMI of mother.

ANC: Antenatal Care, BMI: Body Mass Index, CI: Confidence Interval, OR: Odds Ratio, p: level of significance

Table 5.2 represents the association between maternal anaemia, IFA intake and ELBW, VLBW, and LBW, with odds ratio (OR) and 95% confidence interval (CI) estimated from the logistic regression model. Results showed a protective association for ELBW if a mother had consumed ≥100 IFA (OR: 0.54, CI: 0.31-0.95, $p = 0.032$), as compared to a mother who did not buy/receive any IFA. A similar observation was noted in the case of VLBW (OR: 0.71, CI: 0.59-0.84, $p < 0.001$), and LBW (OR: 0.84, CI: 0.80-0.89, $p < 0.001$). Detailed results on various stages of LBW and its sub-categories with primary variables adjusted for confounders are available in the online supplement (**Table S5.3**).

Association between IFA consumption and neonatal mortality with timing of neonatal death is presented in **Table 5.3**. For neonatal mortality during day 0-1, the association with consumption of ≥100 IFA was protective (OR: 0.74, CI: 0.63-0.88, $p <0.001$), as compared to women who did not buy/receive any IFA. In case of neonatal death during day 2-6, no association with IFA consumption ($p>0.05$) was observed. In the case of neonatal death during day 7-27 and death during day 0-27, multiple regression models showed a protective association for both groups of women –women who consumed <100 IFA intake and women who consumed ≥100 IFA. Detailed analysis on association between neonatal mortality and IFA consumption with adjusted confounders is presented in the online supplement (**Table S5.4**).

5.4 Discussion

This study aimed to understand the coverage of IFA consumption among prospective mothers and to assess the association between IFA consumption and various stages of low-birthweight and neonatal mortality in India. Aside from the protective association between ≥100 IFA consumption and LBW and neonatal mortality, the suboptimal increase in coverage (between 2005-2006 and 2015-2016) and a large variation in coverage of ≥100 IFA intake across 640 districts in India remain challenges to India's public health system. Findings revealed that ≥100 IFA consumption by pregnant mothers was associated with reduced odds of ELBW, VLBW, LBW, and neonatal death during day 0-1, day 7-27, and day 0-27. In addition, a protective association from neonatal death during day 7-27, and day 0-27 was observed for women who consumed <100 IFA. No association between IFA consumption and neonatal death during day 2-6 was observed.

In the case of birthweight, multiple regression adjusted for potential confounders indicates that prevention of ELBW, VLBW, and LBW were associated with IFA consumption by prospective mothers who consumed ≥100 IFA, but no association was observed for women who consumed <100 IFA. The primary causes of ELBW and VLBW are PTB and IUGR, and the prevention of PTB and IUGR is multi-factorial since biological pathways and preventive measures for these two conditions are different (Cutland et al., 2017). As to the role of IFA as a preventive measure against LBW, this finding is consistent with previous studies on India (Balarajan et al., 2013; Malhotra et al., 2014) conducted using NFHS data, although these studies did not analyse various stages of LBW. Multiple regression analysis adjusted for potential confounders also indicates that women with no history of buying or receiving IFA had a higher likelihood of neonatal mortality and death at age day 0-1, day 7-27, and day 0-27 (neonatal mortality), as compared to women who consumed ≥100 IFA during their pregnancy. Existing population-based studies (Singh et al., 2014; Upadhyay et al., 2020; Kumar et al., 2014) have concluded that lack of IFA consumption leads to neonatal mortality. A child's death on day 0-1 among anaemic women indicates the importance of IFA as most neonatal deaths occur during the first three days of life (Sankar et al., 2016).

This study acknowledges certain limitations which should be considered while interpreting the findings. First, data on all possible determinants (and unobservable determinants) of birthweight and neonatal mortality are not available with NFHS-4, thus they could not be included in the analysis. For example, availability of information on PTB and IUGR would have been helpful in better correlating IFA consumption with LBW and neonatal mortality. Second, most information is self-reported, which might be affected by recall errors and social desirability bias. Third, IFA consists of iron as well as folic acid, but as it is given as a combined fixed dose, the association may not be attributed to iron alone (Balarajan et al., 2013). Also, no details on the method of IFA consumption (for example: timing of IFA intake) was captured in NFHS as this information would have been helpful in interpreting the association. Fourth, information on birthweight is based on data from health cards and mother's recall, which reduced the sample size. However, the prevalence on LBW in this study is comparable to the general population which offers confidence about the generalizability of the study findings. Fifth, supported by the sensitivity analysis, the multiple regression models adjusted for recording of birthweight data indicate that mothers' recall had higher likelihood to record ELBW, VLBW, and LBW (online supplement **Table S5.3**). Sixth, a major limitation of this study is the absence of data on anaemia status during pregnancy as this would enable an investigation into whether there is a modifying effect of anaemia on IFA-child health relationship, that is if the association stronger in anaemic women. Seventh, and probably the most important limitation is that pregnant women have approximately twice the iron demands of a growing foetus during pregnancies than non-pregnant women (Ministry of Health and Family Welfare, 2013). However without screening the need for iron, if IFA is given to non-anaemic pregnant women, an overdose may lead to adverse pregnancy outcomes (Kapil et al., 2019). Also, according to the World Health Organization (WHO), around 50% of women aged 15-49 years are amenable to iron supplementation to mitigate IDA (World Health Organization, 2015), and the other half of women might have anaemia from other causes (such as malaria, hemoglobinopathies, fluorosis and others) which cannot be treated with IFA supplementation. Finally, this study used cross-sectional data and analysed the association between IFA and birthweight and neonatal mortality, thus the reader should refrain from drawing any causal inference from the study. Despite these limitations, this study is the first of its kind to demonstrate the association between IFA consumption and various types of LBW and neonatal mortality using a nationally representative dataset in India. Future study on this issue should investigate the effect of IFA supplementation separately on various types of LBW and neonatal mortality, where a comprehensive set of additional information on various socioeconomic and clinical parameters of pregnant mothers (e.g., Hb during pregnancy) are desired for discerning the effect of iron and folic acid on LBW and neonatal deaths.

Based on the findings of this study, it is encouraging to note the potential role of ≥100 IFA intake by prospective mothers in controlling various stages of LBW and neonatal mortality in India. However, the poor coverage of ≥100 IFA intake poses a threat to the success of the National Nutrition Mission. The government of India should reinforce the guidelines for distribution and consumption of IFA outlined for achieving the goals of the National Nutrition Mission.

Table S5.1. Change in prevalence (%) of ≥100 iron-and-folic-acid receipt, between 2005-2006 and 2015-2016, in 29 states / union territories of India.

	NFHS 2005-2006	NFHS 2015-2016	Absolute change*	Relative change**
Nagaland	1.2	4.5	3.3	3.8
Uttar Pradesh	6.1	13.0	6.9	2.1
Bihar	6.4	9.8	3.4	1.5
Meghalaya	6.4	38.0	31.6	5.9
Manipur	7.0	40.1	33.1	5.7
Madhya Pradesh	7.2	23.9	16.7	3.3
Arunachal Pradesh	7.6	9.0	1.4	1.2
Rajasthan	8.8	17.4	8.6	2.0
Jharkhand	9.7	15.5	5.8	1.6
Chhattisgarh	10.5	30.6	20.1	2.9
Assam	10.8	32.8	22.0	3.0
Tripura	12.0	13.6	1.6	1.1
Punjab	13.8	42.9	29.1	3.1
West Bengal	14.8	28.2	13.4	1.9
Uttarakhand	16.9	25.2	8.3	1.5
Jammu & Kashmir (including Ladakh)[1]	17.4	31.0	13.6	1.8
Haryana	18.2	32.7	14.5	1.8
Mizoram	18.6	54.8	36.2	2.9
Maharashtra	19.6	40.9	21.3	2.1
Odisha	23.5	37.4	13.9	1.6
Gujarat	25.6	37.7	12.1	1.5
Sikkim	26.6	53.1	26.5	2.0
Andhra Pradesh (including Telangana)[2]	27.1	55.7	28.6	2.1
Himachal Pradesh	27.2	50.2	23.0	1.8
Karnataka	28.9	46.4	17.5	1.6
Tamil Nadu	28.9	64.7	35.8	2.2
Delhi	30.5	55.1	24.6	1.8
Goa	63.7	67.8	4.1	1.1
Kerala	81.7	74.8	-6.9	0.9
India	15.6	30.7	15.1	2.0

* Absolute change is the difference (NFHS 2015-2016 *minus* NFHS 2005-2006) of prevalence.
** Relative change is the ratio (NFHS 2015-2016 / NFHS 2005-2006) of prevalence.
[1]During survey period of the 2005–2006 National Family Health Survey, Ladakh was part of Jammu & Kashmir.
[2]During survey period of the 2005–2006 National Family Health Survey, Telangana was part of Andhra Pradesh.
NFHS: National Family Health Survey.

Table S5.2. Prevalence (%) of ≥100 iron-and-folic-acid receipt in 640 districts of 37 states / union territories of India, NFHS 2015-2016.

Andaman & Nicobar Islands	
Nicobars	20.3
North & Middle Andaman	45.7
South Andaman	68.0
Andhra Pradesh	
Guntur	39.2
West Godavari	44.8
Prakasam	49.0
Kurnool	54.6
Vizianagaram	55.9
Visakhapatnam	57.1
Kadapa	57.8
Anantapur	59.6
East Godavari	61.1
Chittoor	64.1
Srikakulam	65.7
Nellore	69.1
Krishna	71.3
Arunachal Pradesh	
West Siang	1.6
Upper Subansiri	1.8
East Kameng	2.0
Kurung Kumey	2.9
Anjaw	4.8
East Siang	7.0
West Kameng	8.0
Tawang	9.3
Tirap	9.7
Upper Siang	9.9
Changlang	11.2
Lower Subansiri	11.4
Lower Dibang Valley	11.8
Papumpare	12.5
Lohit	14.4
Dibang Valley	25.8
Assam	
Dhubri	13.8
Karimganj	18.3
Cachar	19.2

Barpeta	19.3
Kamrup	24.2
Hailakandi	24.3
Darrang	25.1
Karbi Anglong	27.0
Kokrajhar	27.6
Udalguri	30.5
Goalpara	31.9
Nagaon	32.1
Nalbari	33.9
Chirang	34.6
Dima Hasao	34.8
Dhemaji	35.3
Bongaigaon	36.1
Morigaon	38.2
Baksa	40.1
Tinsukia	40.3
Sonitpur	40.7
Sivasagar	42.9
Golaghat	45.2
Lakhimpur	46.3
Kamrup Metropolitan	47.2
Dibrugarh	57.4
Jorhat	66.3
Bihar	
Sheohar	2.6
Madhepura	2.6
Kaimur (Bhabua)	3.4
Purba Champaran	3.9
Lakhisarai	4.5
Sitamarhi	4.7
Muzaffarpur	4.8
Gaya	5.7
Begusarai	5.9
Khagaria	6.0
Arwal	6.0
Katihar	6.7
Darbhanga	6.8
Rohtas	7.2
Nalanda	7.3
Saran	7.5
Aurangabad	7.8
Araria	8.0

Supaul	8.2
Nawada	8.8
Buxar	9.3
Purnia	9.6
Samastipur	9.8
Munger	10.2
Bhojpur	10.4
Sheikhpura	10.5
Saharsa	12.5
Jamui	12.7
Jehanabad	13.4
Madhubani	13.5
Gopalganj	14.2
Pashchim Champaran	14.4
Vaishali	14.7
Kishanganj	15.4
Banka	17.1
Bhagalpur	17.6
Siwan	20.0
Patna	21.2
Chandigarh	44.9
Chhattisgarh	
Surguja	18.5
Janjgir - Champa	18.6
Kabirdham	19.0
Raigarh	21.3
Bijapur	21.3
Narayanpur	23.7
Mahasamund	23.8
Korba	24.3
Jashpur	26.1
Dantewada	26.2
Bastar	29.3
Raipur	31.7
Durg	37.6
Kanker	38.5
Bilaspur	39.4
Koriya	39.6
Rajnandgaon	40.0
Dhamtari	42.9

Dadra & Nagar Haveli	44.3
Daman & Diu	
Daman	44.0
Diu	50.3
Delhi	
North East	42.0
North	42.4
East	43.3
West	52.1
South	52.3
North West	53.9
New Delhi	58.6
Central	70.2
South West	72.4
Goa	
North Goa	88.6
South Goa	35.8
Gujarat	
Dahod	14.2
Panchmahal	20.8
Banaskantha	23.5
Patan	24.4
Surendranagar	28.0
Sabarkantha	28.1
Junagadh	28.3
Amreli	32.1
Bhavnagar	32.4
Kheda	32.9
Mahesana	34.5
Surat	37.7
Vadodara	38.1
Kachchh	38.4
Dang	39.7
Anand	40.3
Valsad	41.1
Rajkot	42.2
Tapi	43.5
Porbandar	43.9
Jamnagar	44.8
Narmada	45.6

Gandhinagar	45.8
Bharuch	52.0
Ahmadabad	57.3
Navsari	59.3
Haryana	
Mewat	6.4
Palwal	8.2
Faridabad	19.2
Gurgaon	19.4
Rewari	24.5
Rohtak	28.0
Sonipat	29.9
Jhajjar	30.5
Panipat	31.8
Bhiwani	32.0
Hisar	32.9
Jind	33.2
Mahendragarh	35.6
Kurukshetra	39.6
Sirsa	41.2
Ambala	48.2
Fatehabad	49.3
Panchkula	51.9
Kaithal	54.9
Karnal	57.8
Yamunanagar	61.5
Himachal Pradesh	
Mandi	34.5
Chamba	39.3
Lahul and Spiti	46.0
Sirmaur	47.7
Solan	49.0
Kinnaur	50.4
Una	53.6
Hamirpur	53.8
Shimla	55.3
Bilaspur	57.0
Kullu	57.2
Kangra	59.6
Jammu & Kashmir	
Doda	9.2

Anantnag	11.9
Ganderbal	13.1
Bandipore	16.2
Kishtwar	17.3
Ramban	18.1
Kupwara	20.2
Badgam	20.2
Kulgam	20.6
Rajouri	21.4
Shupiyan	21.8
Srinagar	27.6
Pulwama	30.4
Baramula	31.9
Reasi	37.0
Punch	41.1
Samba	49.5
Udhampur	50.7
Kathua	57.1
Jammu	57.5

Jharkhand

Garhwa	3.4
Chatra	6.9
Simdega	7.3
Sahibganj	7.5
Latehar	8.5
Godda	8.8
Pakur	9.2
Palamu	9.3
Giridih	9.7
Pashchimi Singhbhum	10.9
Kodarma	11.1
Hazaribagh	13.5
Dumka	14.3
Jamtara	14.4
Purbi Singhbhum	15.9
Ramgarh	19.5
Gumla	20.0
Dhanbad	20.7
Deoghar	20.8
Lohardaga	23.2
Bokaro	24.2
Saraikela Kharsawan	24.8
Khunti	24.9

Ranchi	35.1
Karnataka	
Mandya	19.9
Chikmagalur	23.2
Koppal	26.1
Yadgir	26.5
Haveri	28.3
Gulbarga	34.3
Ramanagara	36.2
Uttara kannada	38.1
Kodagu	38.4
Bijapur	39.1
Hassan	39.7
Shimoga	40.4
Udupi	40.8
Dakshina Kannada	41.9
Gadag	44.1
Bellary	45.3
Chitradurga	45.8
Dharwad	46.4
Bagalkot	46.6
Bangalore Rural	46.7
Chikkaballapura	48.0
Bidar	49.4
Bangalore	50.9
Mysore	51.9
Chamarajanagar	53.7
Raichur	54.6
Tumkur	55.1
Kolar	61.5
Belgaum	62.0
Davanagere	66.6
Kerala	
Kottayam	61.0
Thiruvananthapuram	61.0
Alappuzha	65.8
Kollam	66.2
Malappuram	71.3
Idukki	72.2
Ernakulam	72.9
Pathanamthitta	74.0
Wayanad	77.2

Thrissur	80.6
Kannur	85.8
Kasaragod	86.8
Kozhikode	86.9
Palakkad	88.4
Lakshadweep	85.5
Ladakh	
Kargil	29.3
Leh	31.7
Madhya Pradesh	
Sidhi	10.4
Alirajpur	12.7
Tikamgarh	14.2
Rewa	14.2
Dhar	14.2
Mandsaur	15.0
Vidisha	15.6
Panna	16.3
Datia	16.6
Shivpuri	16.6
Umaria	16.6
Chhatarpur	16.9
Rajgarh	17.3
Satna	17.5
Sagar	18.0
Morena	18.2
Ashoknagar	18.2
Singrauli	19.1
Ujjain	19.3
Dindori	19.3
Jhabua	19.7
Barwani	20.1
Sehore	20.5
Shahdol	21.1
Guna	21.3
Damoh	21.6
Sheopur	21.7
Harda	21.7
Bhind	23.3
Raisen	23.3
Neemuch	23.6

Ratlam	23.6
Khargone (West Nimar)	24.1
Dewas	25.7
Hoshangabad	26.8
Betul	27.8
Mandla	27.9
Burhanpur	28.9
Shajapur	29.3
Katni	29.8
Anuppur	30.9
Gwalior	33.6
Balaghat	33.7
Narsimhapur	34.1
Khandwa (East Nimar)	34.6
Indore	35.4
Seoni	37.4
Chhindwara	38.2
Bhopal	39.0
Jabalpur	44.0
Maharashtra	
Dhule	15.8
Aurangabad	19.8
Buldana	21.6
Ahmadnagar	23.5
Bid	23.6
Sindhudurg	29.4
Parbhani	31.1
Satara	33.7
Akola	33.8
Yavatmal	35.7
Mumbai Suburban	37.1
Osmanabad	37.6
Washim	37.7
Nanded	39.3
Sangli	39.6
Nandurbar	39.7
Jalgaon	39.7
Bhandara	40.7
Latur	40.7
Nashik	41.2
Hingoli	42.8
Thane	44.5
Wardha	45.2

Jalna	46.0
Kolhapur	46.7
Chandrapur	47.0
Raigarh	47.3
Gadchiroli	48.9
Amravati	50.2
Solapur	50.9
Nagpur	52.7
Mumbai	52.7
Ratnagiri	53.5
Pune	55.9
Gondiya	71.7
Manipur	
Senapati	14.2
Ukhrul	14.8
Tamenglong	15.7
Churachandpur	22.0
Chandel	26.4
Bishnupur	45.6
Imphal east	46.3
Thoubal	49.0
Imphal west	54.9
Meghalaya	
West Garo Hills	14.4
East Garo Hills	20.8
West Khasi Hills	33.0
Ribhoi	35.7
Jaintia Hills	44.5
South Garo Hills	49.0
East Khasi Hills	60.5
Mizoram	
Lunglei	40.8
Lawngtlai	42.9
Mamit	52.0
Champhai	53.7
Saiha	54.8
Kolasib	59.3
Aizawl	62.0
Serchhip	62.9

Nagaland	
Zunheboto	0.0
Longleng	0.4
Mon	0.8
Phek	0.9
Kiphire	1.4
Tuensang	2.4
Mokokchung	7.6
Peren	7.6
Dimapur	8.1
Kohima	8.7
Wokha	10.0
Odisha	
Baleshwar	18.4
Gajapati	22.7
Ganjam	23.8
Kendrapara	24.6
Bhadrak	29.1
Cuttack	31.4
Koraput	32.3
Kalahandi	33.5
Khordha	34.5
Debagarh	35.2
Mayurbhanj	36.2
Nabarangapur	36.3
Dhenkanal	36.9
Anugul	38.4
Nayagarh	39.0
Malkangiri	39.9
Baudh	42.6
Sundargarh	42.8
Bargarh	43.5
Nuapada	43.7
Sambalpur	43.9
Jajapur	45.0
Kandhamal	45.8
Kendujhar	46.5
Jagatsinghapur	47.0
Puri	49.0
Jharsuguda	50.1
Balangir	50.1
Subarnapur	50.2
Rayagada	52.5

Puducherry	
Karaikal	65.0
Puducherry	65.6
Yanam	78.1
Mahe	89.5
Punjab	
Firozpur	26.0
Mansa	32.3
Shahid Bhagat Singh Nagar	33.9
Hoshiarpur	35.8
Patiala	37.4
Bathinda	37.8
Barnala	39.9
Kapurthala	40.1
Fatehgarh Sahib	40.3
Faridkot	40.7
Moga	41.0
Ludhiana	42.4
Amritsar	43.9
Rupnagar	47.3
Muktsar	48.4
Sangrur	48.5
Gurdaspur	52.4
Jalandhar	53.6
Tarn Taran	57.6
Sahibzada Ajit Singh Nagar	61.5
Rajasthan	
Bharatpur	5.3
Sawai Madhopur	8.2
Rajsamand	8.6
Baran	8.6
Dungarpur	8.9
Ajmer	9.1
Bikaner	10.5
Jaisalmer	10.5
Barmer	10.7
Bundi	10.8
Nagaur	11.8
Karauli	12.2
Dhaulpur	12.9
Alwar	13.0

Banswara	13.9
Jodhpur	14.8
Hanumangarh	15.6
Pali	16.2
Chittaurgarh	16.2
Sikar	16.6
Churu	17.9
Dausa	18.1
Sirohi	18.7
Jhalawar	19.6
Tonk	19.9
Udaipur	19.9
Jalor	21.6
Pratapgarh	30.8
Jhunjhunun	30.9
Jaipur	31.4
Kota	31.6
Bhilwara	31.7
Ganganagar	31.8
Sikkim	
East District	42.7
South District	63.3
West District	66.8
North District	70.4
Tamil Nadu	
Virudhunagar	37.9
Tirunelveli	45.3
Dharmapuri	51.1
Ariyalur	52.3
Thoothukkudi	53.1
Nagapattinam	54.6
Ramanathapuram	54.9
Theni	56.6
Nilgiris	57.3
Perambalur	57.3
Tiruvannamalai	58.9
Tiruchirappalli	60.4
Kancheepuram	60.8
Viluppuram	62.2
Pudukkottai	63.1
Thanjavur	64.6
Salem	65.0

Cuddalore	65.5
Namakkal	66.8
Madurai	66.9
Dindigul	67.5
Tiruppur	68.1
Erode	68.3
Vellore	69.6
Chennai	70.2
Sivaganga	70.6
Thiruvallur	71.4
Kanniyakumari	71.9
Thiruvarur	72.5
Karur	73.4
Coimbatore	75.6
Krishnagiri	81.6
Tripura	
North Tripura	12.6
Dhalai	13.2
West Tripura	13.9
South Tripura	14.2
Uttar Pradesh	
Kanshiram Nagar	2.0
Shrawasti	2.6
Auraiya	3.1
Rampur	4.9
Unnao	5.1
Sitapur	5.2
Bahraich	5.7
Gonda	5.9
Fatehpur	6.2
Moradabad	6.4
Balrampur	6.4
Jhansi	6.5
Basti	6.5
Sant Kabir Nagar	6.5
Mathura	6.6
Mau	6.6
Banda	6.8
Kanpur Dehat	6.9
Mainpuri	7.2
Firozabad	7.7
Etawah	7.8

Faizabad	7.8
Mahoba	7.9
Jyotiba Phule Nagar	8.6
Bulandshahr	9.2
Farrukhabad	9.2
Bareilly	9.5
Kaushambi	9.7
Ghazipur	9.7
Sultanpur	9.9
Ballia	10.1
Bara banki	10.2
Azamgarh	10.6
Kannauj	10.7
Etah	10.7
Jalaun	10.9
Siddharth nagar	10.9
Aligarh	11.6
Lalitpur	11.8
Shahjahanpur	12.1
Budaun	12.4
Hardoi	13.2
Mahamaya Nagar	13.3
Agra	13.7
Hamirpur	14.0
Bijnor	14.2
Kheri	14.3
Saharanpur	14.7
Ambedkar Nagar	15.2
Sant Ravidas Nagar	15.5
Pratapgarh	16.4
Deoria	16.6
Meerut	16.8
Muzaffarnagar	17.0
Jaunpur	17.1
Pilibhit	17.3
Chitrakoot	17.4
Ghaziabad	17.6
Gorakhpur	17.8
Lucknow	19.7
Varanasi	20.3
Gautam Buddha Nagar	20.7
Chandauli	21.2
Rae Bareli	21.4
Sonbhadra	21.7

Mahrajganj	22.0
Mirzapur	22.5
Kushinagar	24.2
Allahabad	24.7
Baghpat	26.0
Kanpur Nagar	26.3
Uttarakhand	
Udham Singh Nagar	16.8
Chamoli	19.0
Hardwar	19.3
Bageshwar	23.9
Rudraprayag	24.5
Tehri Garhwal	25.0
Garhwal	26.4
Champawat	27.7
Uttarkashi	28.1
Pithoragarh	28.7
Dehradun	29.6
Almora	35.7
Nainital	41.4
West Bengal	
Uttar Dinajpur	6.1
Maldah	19.3
Kochbihar	20.5
North Twenty-Four Parganas	21.5
Murshidabad	22.7
Birbhum	22.7
South Twenty-Four Parganas	23.8
Jalpaiguri	24.2
Paschim Medinipur	26.2
Purba Medinipur	29.6
Hugli	33.4
Puruliya	34.9
Nadia	36.4
Barddhaman	36.8
Haora	38.6
Dakshin Dinajpur	39.6
Kolkata	42.1
Darjiling	42.6
Bankura	46.7

Telangana	
Nalgonda	36.5
Medak	37.3
Adilabad	41.9
Mahbubnagar	49.1
Karimnagar	49.4
Nizamabad	49.6
Rangareddy	54.0
Khammam	57.0
Warangal	70.4
Hyderabad	72.3

NFHS: National Family Health Survey.

Table S5.3. Association between iron-and-folic-acid (IFA) consumption and extremely low-birthweight, very low-birthweight, and low-birthweight.

	Extremely low-birthweight		**Very low-birthweight**		**Low-birthweight**	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
IFA consumption						
No IFA	**1.00 (referent)**		**1.00 (referent)**		**1.00 (referent)**	
<100 IFA	**0.84 (0.53-1.34)**	**0.473**	**0.94 (0.81-1.09)**	**0.430**	**0.97 (0.93-1.02)**	**0.194**
≥100 IFA	**0.54 (0.31-0.95)**	**0.032**	**0.71 (0.59-0.84)**	**<0.001**	**0.84 (0.80-0.89)**	**<0.001**
Current age-group of mother						
15-19	1.00 (referent)		1.00 (referent)		1.00 (referent)	
20-29	1.18 (0.41-3.41)	0.766	0.67 (0.51-0.88)	0.004	0.87 (0.80-0.95)	0.001
30-39	1.20 (0.37-3.90)	0.760	0.57 (0.41-0.78)	<0.001	0.85 (0.78-0.94)	0.001
≥40	0.52 (0.05-5.17)	0.575	0.68 (0.42-1.10)	0.119	0.83 (0.72-0.97)	0.017
Mother's age at first birth						
<18	1.00 (referent)		1.00 (referent)		1.00 (referent)	
≥18	0.97 (0.53-1.79)	0.934	1.13 (0.93-1.36)	0.222	0.96 (0.91-1.02)	0.169
Education of mother						
No or incomplete primary	1.00 (referent)		1.00 (referent)		1.00 (referent)	
Primary or incomplete secondary	0.99 (0.63-1.56)	0.974	0.86 (0.75-0.98)	0.027	0.91 (0.88-0.95)	<0.001
Secondary or higher	0.66 (0.34-1.28)	0.224	0.66 (0.54-0.80)	<0.001	0.74 (0.70-0.79)	<0.001
Birth order						
1	1.00 (referent)		1.00 (referent)		1.00 (referent)	
2	0.85 (0.55-1.32)	0.469	0.85 (0.74-0.97)	0.017	0.86 (0.83-0.90)	<0.001
3	0.84 (0.47-1.50)	0.560	0.87 (0.73-1.04)	0.123	0.86 (0.82-0.90)	<0.001
4	0.95 (0.44-2.04)	0.886	1.20 (0.95-1.51)	0.126	0.89 (0.83-0.95)	0.001
≥5	0.73 (0.27-1.97)	0.534	0.93 (0.70-1.25)	0.646	0.88 (0.81-0.96)	0.003
Place of residence						
Urban	1.00 (referent)		1.00 (referent)		1.00 (referent)	
Rural	0.86 (0.55-1.35)	0.523	0.87 (0.76-1.00)	0.058	0.93 (0.89-0.96)	<0.001
Social group						
Others	1.00 (referent)		1.00 (referent)		1.00 (referent)	
Scheduled castes	0.71 (0.40-1.23)	0.219	1.21 (1.02-1.44)	0.031	1.11 (1.05-1.16)	<0.001
Scheduled tribes	0.46 (0.22-0.96)	0.037	0.76 (0.61-0.94)	0.012	0.94 (0.88-0.99)	0.023
Other Backward Classes	0.68 (0.44-1.05)	0.084	1.00 (0.86-1.16)	0.969	0.99 (0.95-1.03)	0.572
Religion						
Hinduism	1.00 (referent)		1.00 (referent)		1.00 (referent)	
Islam	1.32 (0.80-2.17)	0.272	1.07 (0.91-1.27)	0.410	0.95 (0.90-1.00)	0.035
Christianity	0.31 (0.07-1.41)	0.130	0.36 (0.24-0.55)	<0.001	0.49 (0.45-0.54)	<0.001
Others	0.36 (0.09-1.50)	0.162	1.08 (0.82-1.42)	0.578	0.86 (0.79-0.93)	<0.001

Economic group						
Poorest	1.00 (referent)		1.00 (referent)		1.00 (referent)	
Poorer	0.92 (0.51-1.64)	0.771	1.08 (0.91-1.28)	0.375	0.96 (0.92-1.01)	0.163
Middle	1.08 (0.60-1.97)	0.791	0.93 (0.77-1.12)	0.438	0.96 (0.91-1.02)	0.188
Richer	0.74 (0.37-1.49)	0.398	0.96 (0.78-1.18)	0.674	1.03 (0.97-1.09)	0.340
Richest	0.91 (0.42-1.98)	0.812	0.87 (0.68-1.10)	0.244	0.92 (0.85-0.98)	0.011
State of residence						
Non-high focus	1.00 (referent)		1.00 (referent)		1.00 (referent)	
High Focus	0.87 (0.58-1.32)	0.524	1.05 (0.93-1.20)	0.424	1.00 (0.97-1.04)	0.928
Number of ANC visit						
≥4	1.00 (referent)		1.00 (referent)		1.00 (referent)	
<4	1.08 (0.72-1.60)	0.719	1.02 (0.90-1.15)	0.807	1.03 (1.00-1.07)	0.070
Received supplementary food from *Anganwadi* centre						
Yes	1.00 (referent)		1.00 (referent)		1.00 (referent)	
No	1.27 (0.86-1.86)	0.225	1.36 (1.21-1.53)	<0.001	1.03 (1.00-1.07)	0.052
Blood sample taken during ANC visit						
Yes	1.00 (referent)		1.00 (referent)		1.00 (referent)	
No	0.85 (0.47-1.55)	0.598	0.93 (0.78-1.12)	0.452	0.97 (0.92-1.02)	0.223
Institutional delivery						
Yes	1.00 (referent)		1.00 (referent)		1.00 (referent)	
No	1.74 (0.98-3.10)	0.058	1.19 (0.97-1.46)	0.093	1.11 (1.04-1.17)	0.001
BMI of mother						
Optimum	1.00 (referent)		1.00 (referent)		1.00 (referent)	
Underweight	1.71 (1.13-2.60)	0.012	1.28 (1.12-1.46)	<0.001	1.29 (1.24-1.34)	<0.001
Overweight and obesity	1.09 (0.68-1.73)	0.728	1.06 (0.92-1.21)	0.434	0.92 (0.89-0.96)	<0.001
Sources of birthweight data						
From written card	1.00 (referent)		1.00 (referent)		1.00 (referent)	
From mother's recall	2.41 (1.63-3.55)	<0.001	1.56 (1.39-1.74)	<0.001	1.12 (1.09-1.16)	<0.001

ANC: Antenatal Care, BMI: Body Mass Index, CI: Confidence Interval, OR: Odds Ratio, p: level of significance

Table S5.4. Association between iron-and-folic-acid (IFA) consumption and timing of neonatal mortality (day 0-1, day 2-6, and day 7-27) and neonatal mortality (day 0-27).

	Neonatal mortality (day 0-1)		**Neonatal mortality (day 2-6)**		**Neonatal mortality (day 7-27)**		**Neonatal mortality (day 0-27)**	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Anaemia status and IFA intake								
No IFA	**1.00 (referent)**		**1.00 (referent)**		**1.00 (referent)**		**1.00 (referent)**	
<100 IFA	**0.89 (0.78-1.01)**	**0.079**	**0.92 (0.76-1.12)**	**0.431**	**0.74 (0.59-0.94)**	**0.015**	**0.87 (0.79-0.96)**	**0.006**
≥100 IFA	**0.74 (0.63-0.88)**	**<0.001**	**0.85 (0.67-1.07)**	**0.171**	**0.62 (0.46-0.84)**	**0.002**	**0.75 (0.66-0.84)**	**<0.001**
Current age-group of mother								
15-19	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
20-29	0.61 (0.47-0.79)	<0.001	0.51 (0.36-0.71)	<0.001	0.30 (0.20-0.45)	<0.001	0.51 (0.42-0.61)	<0.001
30-39	0.55 (0.41-0.74)	<0.001	0.48 (0.32-0.72)	<0.001	0.25 (0.15-0.41)	<0.001	0.46 (0.37-0.56)	<0.001
≥40	0.72 (0.48-1.08)	0.112	0.59 (0.33-1.07)	0.081	0.21 (0.10-0.45)	<0.001	0.55 (0.40-0.75)	<0.001
Mother's age at first birth								
<18	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
≥18	1.08 (0.91-1.28)	0.372	1.36 (1.04-1.77)	0.023	1.45 (1.04-2.00)	0.026	1.21 (1.06-1.37)	0.005
Education of mother								
No or incomplete primary	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
Primary or incomplete secondary	0.89 (0.79-1.01)	0.076	0.85 (0.70-1.01)	0.071	1.00 (0.79-1.28)	0.971	0.89 (0.81-0.98)	0.023
Secondary or higher	0.74 (0.61-0.91)	0.003	0.66 (0.50-0.87)	0.004	0.71 (0.49-1.03)	0.073	0.71 (0.61-0.82)	<0.001
Sex of child								
Male	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
Female	0.90 (0.81-0.99)	0.039	0.95 (0.82-1.10)	0.487	0.99 (0.81-1.20)	0.899	0.92 (0.85-1.00)	0.048
Birth order								
1	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
2	0.73 (0.63-0.84)	<0.001	0.68 (0.56-0.82)	<0.001	0.96 (0.74-1.25)	0.773	0.74 (0.67-0.82)	<0.001
3	0.87 (0.74-1.03)	0.108	0.67 (0.52-0.86)	0.002	1.21 (0.88-1.66)	0.244	0.85 (0.75-0.97)	0.015
4	1.03 (0.84-1.28)	0.754	1.00 (0.74-1.35)	0.992	1.43 (0.96-2.15)	0.081	1.08 (0.92-1.26)	0.361
≥5	1.12 (0.89-1.42)	0.337	0.96 (0.68-1.37)	0.834	2.18 (1.42-3.34)	<0.001	1.21 (1.01-1.44)	0.040
Place of residence								
Urban	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
Rural	0.99 (0.86-1.14)	0.873	1.10 (0.89-1.36)	0.362	1.18 (0.90-1.55)	0.235	1.05 (0.94-1.17)	0.399
Social group								
Others	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
Scheduled castes	1.35 (1.14-1.60)	0.001	1.44 (1.12-1.85)	0.005	1.21 (0.88-1.66)	0.242	1.35 (1.19-1.54)	<0.001
Scheduled tribes	0.89 (0.73-1.09)	0.270	1.09 (0.81-1.45)	0.579	1.07 (0.75-1.54)	0.695	0.97 (0.83-1.13)	0.692

Other Backward Classes	1.00 (0.86-1.16)	0.978	1.19 (0.95-1.49)	0.131	0.92 (0.70-1.21)	0.547	1.03 (0.92-1.16)	0.591
Religion								
Hinduism	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
Islam	1.20 (1.03-1.40)	0.023	1.00 (0.79-1.27)	0.969	1.11 (0.83-1.49)	0.466	1.13 (1.01-1.28)	0.040
Christianity	0.92 (0.70-1.22)	0.576	0.48 (0.30-0.79)	0.004	0.40 (0.21-0.77)	0.006	0.70 (0.56-0.88)	0.002
Others	1.07 (0.80-1.44)	0.651	0.89 (0.57-1.38)	0.598	0.83 (0.47-1.47)	0.523	0.98 (0.78-1.22)	0.827
Economic group								
Poorest	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
Poorer	1.01 (0.87-1.17)	0.913	1.11 (0.90-1.37)	0.309	0.68 (0.51-0.91)	0.008	0.98 (0.87-1.09)	0.672
Middle	0.87 (0.74-1.03)	0.113	0.92 (0.72-1.17)	0.483	0.80 (0.59-1.08)	0.146	0.87 (0.77-0.99)	0.030
Richer	0.69 (0.57-0.85)	<0.001	0.73 (0.54-0.98)	0.036	0.61 (0.42-0.89)	0.011	0.69 (0.59-0.80)	<0.001
Richest	0.53 (0.41-0.68)	<0.001	0.75 (0.53-1.06)	0.104	0.77 (0.50-1.18)	0.232	0.62 (0.51-0.74)	<0.001
State of residence								
Non-high focus	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
High Focus	1.52 (1.32-1.74)	<0.001	1.51 (1.24-1.83)	<0.001	1.47 (1.14-1.89)	0.003	1.51 (1.37-1.68)	<0.001
Number of ANC visit								
≥4	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
<4	1.11 (0.98-1.24)	0.090	1.05 (0.89-1.24)	0.588	0.98 (0.79-1.21)	0.834	1.07 (0.98-1.17)	0.139
Received supplementary food from *Anganwadi* center								
Yes	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
No	1.29 (1.15-1.44)	<0.001	1.17 (1.00-1.38)	0.052	1.44 (1.17-1.77)	0.001	1.28 (1.18-1.39)	<0.001
Blood sample taken during ANC visit								
Yes	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
No	0.87 (0.75-1.00)	0.054	0.83 (0.67-1.03)	0.093	0.87 (0.66-1.14)	0.302	0.85 (0.76-0.96)	0.006
Institutional delivery								
Yes	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
No	1.11 (0.97-1.27)	0.128	0.99 (0.81-1.22)	0.953	1.10 (0.85-1.41)	0.474	1.08 (0.97-1.20)	0.155
BMI of mother								
Optimum	1.00 (referent)		1.00 (referent)		1.00 (referent)		1.00 (referent)	
Underweight	0.80 (0.70-0.91)	0.001	0.80 (0.67-0.96)	0.019	0.90 (0.71-1.16)	0.421	0.81 (0.73-0.90)	<0.001
Overweight and obesity	1.26 (1.11-1.44)	<0.001	0.92 (0.76-1.12)	0.405	1.37 (1.08-1.74)	0.010	1.18 (1.07-1.30)	0.001

ANC: Antenatal Care, BMI: Body Mass Index, CI: Confidence Interval, OR: Odds Ratio, p: level of significance

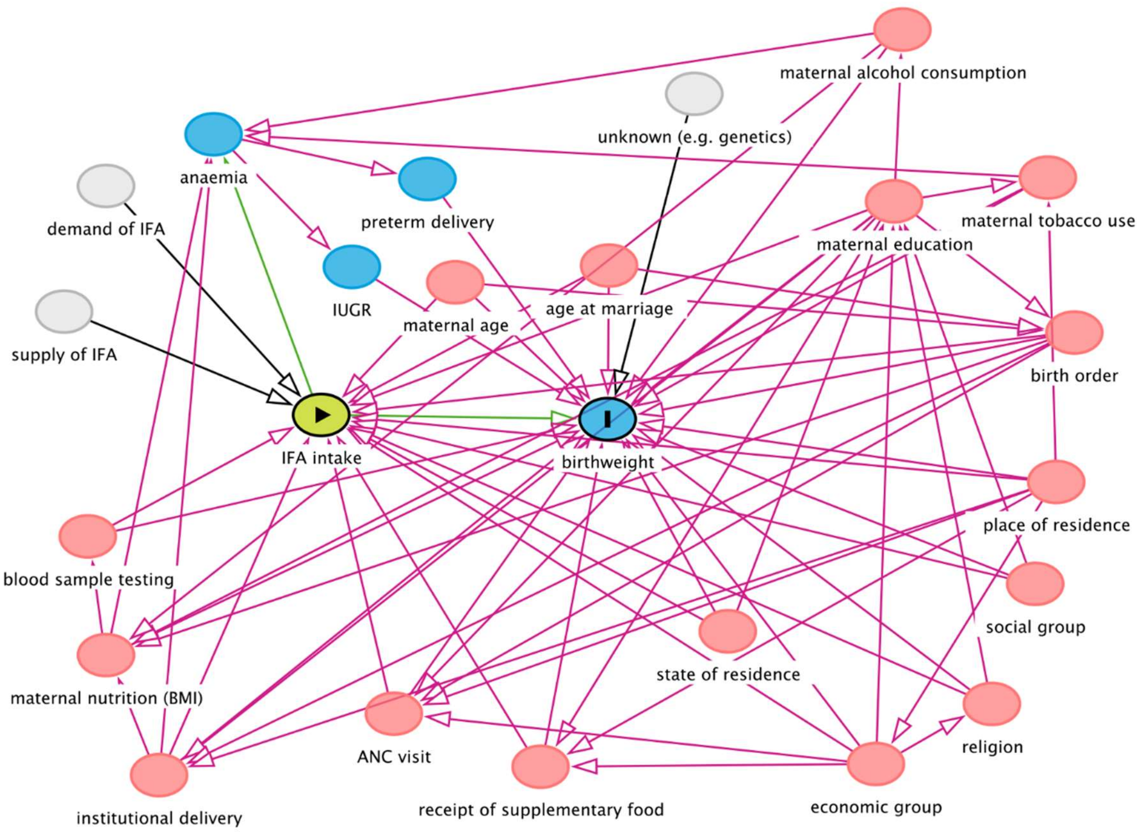

Figure S5.1. Directed Acyclic Graph (DAG) showing the causal pathways between exposure (IFA or iron-and-folic-acid tablet/ syrup intake during pregnancy) and outcome (birthweight) variable.
Sources of birthweight data, a potential confounder for the causal relationship between IFA intake and birthweight, is not shown separately.

ANC: antenatal care, BMI: Body Mass Index, IUGR: intrauterine growth restriction.

Legend

exposure, outcome, ancestor of outcome, ancestor of exposure *and* outcome,

unobserved (latent), causal path, biasing path

Figure was developed using online browser - http://www.dagitty.net/

Note: A separate DAG on the causal pathways between IFA intake (exposure) and neonatal mortality (outcome) is not shown separately, as it is similar to Figure S5.1, except that sex of the child was identified as an additional confounder for the causal relationship between IFA intake and neonatal mortality.

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