Human Biology Review (ISSN 22774424) ***www.HumanBiologyJournal.com***
International Peer Reviewed Journal of Biological Anthropology
Volume 14, Number 1, January-March 2025 Issue

Original scientific paper

Birthweight of Babies in India and its Relationship with Socio-Economic Variables and Mother's Health Status: An Analysis with the Latest Nationwide Data, NFHS5

M. Pal and S. Biswas

Human Biology Review, Volume 14 (1), pp. 50-66

Revised and accepted on January 17, 2025

Citation: Pal M and Biswas S. 2025. Birthweight of Babies in India and its Relationship with Socio-Economic Variables and Mother's Health Status: An Analysis with the Latest Nationwide Data, NFHS5. Human Biology Review, 14 (1),50-66.

Authors and affiliations

Manoranjan Pal, Economic Research Unit, Indian Statistical Institute, Kolkata, India Email: Manoranjan.pal@gmail.com

Satabdi Biswas, Mrinalini Datta Mahavidyapith, Kolkata, India, Email: satabdibiswas2009@gmail.com

Birthweight of Babies in India and its Relationship with Socio-Economic Variables and Mother's Health Status: An Analysis with the Latest Nationwide Data, NFHS5

M. Pal and S. Biswas

Citation: Pal M and Biswas S. 2025. Birthweight of Babies in India and its Relationship with Socio-Economic Variables and Mother's Health Status: An Analysis with the Latest Nationwide Data, NFHS5. Human Biology Review, 14 (1), 50-66.

ABSTRACT

The paper finds the status of the birth-weight of new-born babies in India and investigates its association with socio-demographic risk factors and maternal factors using the latest national level NFHS-5 data. The regional analysis reveals that the middle belt States of India have very low birth weight on average compared to other States. The linear regression of birthweight and logistic regression of the status of birthweight on the relevant explanatory variables shows that weight, height, age-group, haemoglobin level, and pregnancy duration of mothers along with the sex of the child, wealth index of the household, intake of iron tablet during pregnancy, frequency of intake of meat, etc. have a significant effect on the birthweight of babies. Interaction effects of sex of babies and place of residence reveal that Pregnancy duration is the only variable that interacts with the Sex of the newborn baby as well as place of residence for both linear and Logistic regression models to increase the birthweight of babies significantly.

The health status and pregnancy duration of mothers are the key factors for reducing low birth weight (LBW) of babies. Instead of leading sedentary life, mothers should lead a moderately active life at least during early pregnancy.

Keywords

LBW, Maternal health, Socio-economic factors, Multiple linear regression, Binary logistic regression

1. INTRODUCTION

Low birth weight (LBW) of babies is an important global concern that has both short-term and long-term consequences for public health. The weight of a new born baby is considered to have low birth weight if its weight is less than 2500 gm when measured within the first hour after birth (WHO, 2012; Cutland et al., 2017; Sarika et al., 2020). It was estimated that 15% to 20% of global births are LBW, which comprises more than 20 million births annually. In the year 2012, the World Health Assembly, took a goal, in Global Target 3, to reduce LBW babies by 30% by the year 2025 (WHO, 2012). LBW has many consequences leading to a high risk of prenatal mortality, morbidity, and some non-communicable diseases like diabetes and cardiovascular problems in later life (WHO, 2012; UNICEF 2019).

Not only that severe LBW babies more likely to die during their first month of life but also otherwise have the possibility of facing lifelong consequences such as stunted growth and low IQ. It is a matter of concern that 28% of LBW babies are found in developing countries among low and middle-income groups of people, especially in South Asia (WHO 2012). From medical to socio-economic factors such as preterm neonates, chronic hypertension, history of miscarriage, the birth interval, intake of calcium, iron, ferrous sulphate, and folic acid tablets, chronic vascular diseases, renal diseases, height, weight gain during pregnancy, obstetric history, mother nutritional status, neonatal and post-natal clinical services, maternal age, occupation, education, social status, economic status, wealth index, haemoglobin, blood group, support from husband, smoking habit, smoking by family members, intake alcohol and drug, food frequency, ethnic group, religions, and place of residence, etc all were found to be responsible for low birth weight (Negi et at., 2006; Mahumud & Sarker 2017; Gupta et al., 2019; Khan et al., 2020; Anil, Basel, & Singh, 2020; Kumari et al., 2021). LBW babies were approximately 20 times more likely to die than normal babies (WHO, 2004). However, the data on low birth weight remain unreliable, in rural South-East Asia (WHO 2012). The status of LBW is a proxy indicator of India's multifaceted public health problem starting with malnutrition to poor pregnancy health care.

Many researchers concentrated their works on the poor health conditions of the mother, her physical or socio-economic conditions, and lifestyle as important determinants of LBW (Mohammed et al., 2019; Basel, & Singh, 2020; Sarika et al., 2020; Kumari et al., 2021). However, none of them addressed the combined effects of physical, medical, and socio-economic factors of a mother and the interaction effects of place of residence and sex of the newborn child with these factors on the birthweight of babies. The present paper attempts to address the same.

2. DATA AND METHODS

The relevant data for this paper has been taken from the fifth round National Family Health Survey (NFHS-5) collected during 2019-2021. This survey was conducted by the International Institute for Population Sciences (IIPS) in collaboration with the Ministry of Health and Family Welfare (IIPS). NFHS covered more than six hundred thousand households. However, in this present study, the weight of a new-born baby is the main concern. It is assumed that the birthweight has profound relation with the mother's health status. Hence, we have taken only the households where both the mother and at least one of her children of age less than five years is alive. Moreover, only the youngest child, in households with more than one child of age less than five years, is taken. Thus, the sample size has been reduced to 176843 households only in our analysis.

Several independent variables related to the maternal health condition such as weight, height, age, haemoglobin level, and pregnancy duration have been considered to understand the relationship between the birthweight of new-born babies with these variables.

Apart from the medical status of the mother, several other independent variables such as maternal food habits, amenities, socioeconomic status, and other related variables have been considered. To get an idea of the awareness status of the mother, we considered how regularly she watched TV. Besides the primary health status of mothers, we took the socio-economic data, place of residence, wealth index, etc. The list of variables along with the possible values is given in Table 1.

Table 1. Relation Between Status of LBW and the Socio-Demographic and Related Factors Responsible for LBW in India

Variables/Factors	Difference of Percentages
Child sex	Girl: 0, Boy: 1 (Transgender babies were not considered)
Places of residence	Rural: 0, Urban: 1
Weight of mother	Actual value in kg.
Height of mother	Actual value in cm.
Age of mother	Actual value from 15 to 49 years

Haemoglobin level of mother	Actual value in g/dl.
Drinking water	Not protected: 0, Protected: 1
Caste	Not ST: 0, ST: 1
Religion	Hindu or Muslim: 0, Others: 1
Wealth index	Poor (Poorest or Poorer): 0, Not Poor (Middle, Richer, Richest): 1
Mother's Education	Primary or less: 0, Higher than Primary: 1
Watching TV	Rare: 0, Nor rare: 1
Duration of pregnancy	Less than 9 months: 0, 9 months or more: 1
Antenatal care	No: 0, Yes: 1
Intake of iron tablet	No: 0, Yes: 1
Intake of milk/curd	Not daily or weekly: 0, Daily or weekly: 1
Intake of fruits	Not daily or weekly: 0, Daily or weekly: 1
Intake of eggs	Not daily or weekly: 0, Daily or weekly: 1
Intake of fish	Not daily or weekly: 0, Daily or weekly: 1
Intake of meat	Not daily or weekly: 0, Daily or weekly: 1
Intake of aerated drink	Not daily or weekly: 0, Daily or weekly: 1
Cooking Fuel	Harmful: 0, Harmless: 1
State Group	Middle belt States: 0*, Other States: 1
Birthweight	Actual birthweight in gram
Birthweight Group	Less than 2500 gm.: 0, 2500 gm. or more: 1

*: Middle belt States consist of Punjab, Uttarakhand, Haryana, Delhi, Rajasthan, Uttar Pradesh, West Bengal, Odisha, Chhattisgarh, Madhya Pradesh, Gujarat, and Maharashtra.

Source: The authors.

From Table 1, one can see that there are some continuous variables and some categorical factors considered for our analysis. Mother's Age is a continuous variable, which has a direct effect on the birth weight. Birthweight is known to increase with the age of mothers, but at higher ages, it didn't increase at the same rate as shown in Appendix 1. To account for it, we could have taken square of age, but it led to a multicollinearity problem. That is why we abandoned this idea. The weight for the Height index (WHZ) of the mother was also taken, but it was later discarded because of a multicollinearity problem. This is because both the weight and height of the mother were taken as explanatory variables in the regression. The status of the anaemia of the mother was also discarded for the same reason, as the Haemoglobin level of the mother was already taken.

Intake of iron tablets during pregnancy is an important part of antenatal care which directly affects the health status of the mother as well as the would-be child. Similarly, maternal food habits such as intake of milk or curd, intake of fruits, intake of eggs, intake of chicken, intake of fish and meat, and intake of aerated drinks all have been classified as 'frequent' and 'other'. Lastly, pregnancy duration is considered and is grouped into two categories i.e., 'below 9 months' and '9 months or more'. The Scheduled Tribe (ST) population is considered an important variable as most cases ST population's birth weight is found to be higher than others (Kumari et al., 2021).

Since we aim to see whether birthweight is different for different categorical groups of factors, such as rural vs. urban sectors and male vs. female babies, we have carried out an independent t-test to see whether the mean birthweight differs significantly from one group to the other. We have also prepared a bivariate contingency table and have carried out a chi-square test to see whether they are related. If both the explanatory and the explained variables are continuous, we have calculated the correlation coefficient between the two variables and have tested for their statistical significance.

In most of the cases, the bivariate tables have shown significant dependency between the birthweight and the explanatory variables. Only in a few cases, the variables are not significantly dependent on birthweight, thus, these are rejected for the analysis. Such variables are ‘household size’, ‘intake of leafy vegetables, etc.

Apart from performing a chi-square test of bivariate contingency tables and an independent t-test of mean birthweights between two groups of babies, we have also carried out multiple linear regression of birthweight and logistic regression of binary variable birthweight on the explanatory variables to see the joint effect of these variables on birthweight. Though there was evidence that girl babies have average birthweight less than that of boy babies, we have taken the same cut-off point of 2500gm for both girls and boys. A birthweight of less than 2500gm was defined as a low birthweight by the World Health Organization (UNICEF, 2019). We put the value 0 for LBW babies and 1 for normal babies. This is just for comparison of results with those of the usual regression.

While the linear regression model gave the effect of each explanatory variable on the average increase or decrease of birthweight due to one unit increase of the explanatory variable, the logistic regression gave the probability of not having LBW in terms of log-odds. The variables, that have a significant effect on the changes in birthweight or the LBW status, are included in the regression. For better comparison, we have included the same set of explanatory variables in each of the regressions that follow.

We also found the mean birthweight for each State and Union Territory. The result is given in Appendix 2. An interesting feature has emerged from these average birthweights of newborn babies by States and Union Territories. The middle belt consists of Maharashtra, Madhya Pradesh, Delhi, West Bengal, Odisha, etc., and has a birth weight of less than 2.8Kg., which is lower than other states. Most of the North-Eastern States have very high mean birth weight. North-Eastern States have a predominantly ST population. These results conform with the fact that Scheduled Tribes have high birthweight babies.

The equation of multiple linear regression is

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_K x_K + \varepsilon,$$

where, $x_1, x_2, \ldots, x_K$ are the explanatory variables by which y, the birth weight, is explained. The weight, height, haemoglobin level, pregnancy duration of mother, etc. are among the explanatory variables considered here, and ε is the error term. The coefficient β_i associated with x_i is the slope coefficient which is unknown and is to be estimated from the data for all i = 1. 2, …, K.

To see whether there is any difference in coefficients of this equation between the rural and urban sectors of a place of residence, we have employed a dummy variable technique. Suppose in the variable, named ‘R’, which stands for residence, say, the rural sector is represented by ‘0’ and the urban sector by ‘1’. We manipulate the above multiple linear regression equation by writing as follows,

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_K x_K + \beta_0' R + \beta_1' R x_1 + \beta_2' R x_2 + \cdots + \beta_K' R x_K + \varepsilon. \quad \ldots (1)$$

Clearly, for the rural sector, i.e., for R = 0, we have

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_K x_K + \varepsilon,$$

and for the urban sector, i.e., for R = 1, we have

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_K x_K + \beta'_0 + \beta'_1 x_1 + \beta'_2 x_2 + \cdots + \beta'_K x_K + \varepsilon.$$
$$= (\beta_0 + \beta'_0) + (\beta_1 + \beta'_1)x_1 + (\beta_2 + \beta'_2)x_2 + \cdots + (\beta_K + \beta'_K)x_K + \varepsilon.$$

The coefficients $\beta_0, \beta_1, \beta_2, \dots, \beta_K$ corresponding to the associated variables intercept and $x_1, x_2, \dots, x_K$ are for the rural sector, because these are found by putting R = 0 in the equation. The coefficients $\beta'_0, \beta'_1, \beta'_2, \dots \beta'_K$ corresponding to the associated variables R, $Rx_1, Rx_2, \dots, Rx_K$ are the differences between urban and rural sectors, because $(\beta_0 + \beta'_0), (\beta_1 + \beta'_1), (\beta_2 + \beta'_2), \dots, (\beta_K + \beta'_K)$ are the coefficients found by putting R = 1 in the equation. So, to test whether there is any significant change between the two sectors we just check whether the coefficients of R, $Rx_1, Rx_2, \dots, Rx_K$ are significant. Positive values signify an increase in the value and negative values signify a decrease.

Similarly, to see whether there is any difference in coefficients of this equation between girls and boys, we employ the dummy variable S, say, which signifies sex with S = 0 for girls and 1 for boys. In this case, the above multiple linear regression equation becomes,

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_K x_K + \beta^*_0 S + \beta^*_1 S x_1 + \beta^*_2 S x_2 + \cdots + \beta^*_K S x_K + \varepsilon, \quad \dots (2)$$

where the estimates of $\beta^*_0, \beta^*_1, \beta^*_2, \dots, \beta^*_K$ are interpreted as the differences between boys and girls in respect of the coefficients of the intercept and the respective variables $x_1, x_2, \dots, x_K$.

For the binary logistic regression, the explanatory variables remain the same as above. The dependent variable is expressed as log odds of the probability of occurrence.

3. RESULTS

As the status of LBW is one of the primary concerns, the bivariate contingency tables have been computed, taking LBW status on the one side and each of the several other variables, which are thought to influence birthweight, on the other side, and chi-square tests are performed to see the degree of the association. E.g., the relation between birthweight and wealth index is shown in Table 1A.

Table 1A. Contingency Table of Status of LBW against Wealth Index Along with Test of Significance

	Poorest	Poorer	Middle	Richer	Richest	Total
LBW	7299 (19.6%)	6419 (17.5%)	5204 (15.9%)	4633 (15.5%)	3698 (14.7%)	27253 (16.9%)
Not LBW	29938 (80.4%)	30238 (82.5%)	27462 (84.1%)	25226 (84.5%)	21479 (85.3%)	134343 (83.1%)
Total	37237 (100%)	36657 (100%)	32666 (100%)	29859 (100%)	25177 (100%)	161596 (100%)
	p-value < 0.001					

Source: The authors.

Table 1A shows that the percentage of LBW babies decreases as the level of wealth index increases, which is significant at a 1 percent level[1]. However, for a sharper comparison and to facilitate regression analysis, we have taken two groups as Poor (Poorest or Poorer) and Not

[1] Though it is significant at even 0.1 percent level, we shall take in this paper only 5% and 1% level of significance. Note also that the test of significance was carried out by using frequencies and not by using percentages.

Poor (Middle, Richer, Richest) taking binary values 0 and 1 respectively. The result of the contingency chi-square test is as follows.

Table 1B. Contingency Table of Status of LBW against Wealth Index Along with Test of Significance

	Poor	Non-Poor	Total
LBW	13718 (18.6%)	13535 (15.4%)	27253 (16.9%)
Not LBW	60176 (81.4%)	74167 (84.6%)	134343 (83.1%)
Total	73894 (100.0%)	87702 (100.0%)	161596 (100.0%)
	p-value < 0.001		

Source: The authors.

Table 1B not only gives a sharper comparison in terms of p values, but it also allows us to run the regression with a dummy variable for the wealth index without declaring it to be a categorical variable. For the same reason, all the categorical variables have two groups in this paper. We summarize all these findings in Table 2.

Table 2. Relation Between Status of LBW and the Socio-Demographic and Related Factors Responsible for LBW in India

	Percentages of LBW		**Difference of Percentages**
Child sex	Girls	Boys	
	18.2%	15.7%	2.5%
Places of residence	Rural	Urban	
	17.1%	16.0%	1.1%
Drinking water	Protected	Unprotected	
	17.1%	15.3%	1.8%
Caste	Non-ST	ST	
	17.4%	14.7%	2.9%
Religion	Hindu or Muslim	Others	
	17.5%	12.1%	5.4%
Wealth index	Poor	Non poor	
	18.6%	15.4%	3.2%
Mother's Education	Primary or less	Above Primary	
	19.4%	16.3%	3.1%
Watching TV	Not frequently	Frequently	
	18.0%	15.7%	2.3%
Duration of pregnancy	< 9 months	≥ 9 months	
	25.6%	15.7%	9.9%
Antenatal care	Not taken	Taken	
	20.3%	16.7%	3.6%
Intake of iron tablet	Not regular	Regular	
	19.5%	16.5%	3.0%
Intake of milk/curd	Not regular	Regular	
	17.3%	16.7%	0.6%

Intake of fruits	Not frequently	Frequently	
	17.7%	16.0%	1.7%
Intake of eggs	Not frequently	Frequently	
	17.6%	15.9%	1.7%
Intake of fish	Not frequently	Frequently	
	17.3%	16.1%	1.2%
Intake of meat	Not frequently	Frequently	
	17.6%	15.5%	2.1%
Intake of aerated drink	Not frequently	Frequently	
	17.0%	16.2%	0.8%
Cooking Fuel	Others	LPG or Electricity	
	18.1%	15.4%	2.7
State Group	Middle Belt	Others	
	19.2	13.9	5.3

Note: The results of each Chi-square test of frequencies and t-test of mean differences of birthweights (not shown here) are significant at a 1% level for all explanatory variables. The categorical variables, which are not significant, are not shown in the above table and have been excluded from our analysis.

Source: The authors.

Table 2 shows the relationship between maternal status, food habits, amenities, and related socio-economic factors that are responsible for LBW in India. The category with a lower percentage is put on the right side for ease of comparison and to get the difference to be positive. From the table, it is clear that 'religion', 'duration of pregnancy' and 'State groups' show the highest differences in the percentages of LBW babies with more than 5% in each case favoring "other" religion, i.e., neither Hindu nor Muslim, not less than 9-month duration of pregnancy and non-middle belt States. Needless to say, the favored categories have fewer LBW babies. The variables with a difference of 3% or more but less than 5% are as many as four, namely 'wealth index', 'mother's education', 'ante-natal care', and 'intake of iron tablet' favoring non-poor, higher educated, with ante-natal care and taking iron tablet categories.

All other variables included in the table are also significant. For example, the rural count of LBW babies is 17.1% as against 16.0% in urban areas. Thus, the rural sector has more LBW babies. This is significant at 0.01 level and so on. Though watching TV is known to bring awareness to mothers too much TV watching also creates health hazards. As a combined effect, it is found that the LBW percentage is higher when mothers who rarely watched TV – 18.0% as against 15.7% of mothers who watched it frequently. It is very interesting to see the status of LBW between ST and 'Other castes', the percentage of LBW is found to be 14.7% among the ST community as against 17.4% among 'other castes' which includes general caste and other religions. ST women are usually very active and hardworking which are pre-requisite for a healthy child. All other relations are as expected supporting the consumption of protected water, frequent intake of milk or curd, fruits, eggs, fish, and meat, etc. towards higher-weight babies. Thus, maternal food habits have a positive effect on birth weight.

Since weight, height, age and haemoglobin level are continuous, we find the correlation coefficient of birthweight with these variables. The computed values of correlation coefficients are found to be 0.142, 0.081, 0.061, and 0.048 respectively, all of which are found to be significant at a 1 percent level. Moreover, all these correlations are positive implying that birthweight increases with the increase of the values of these variables. We had another continuous variable, which is weight-for-height (WHZ). However, it was later found to create a multicollinearity problem and we had to delete it.

Multiple linear regression, as well as Binary Logistic regression, have been carried out to see the joint effect of four key explanatory continuous variables along with other binary variables on birthweight. Since there are too many variables, we have also tested for the multicollinearity problem as reflected by the VIF values in column 4 in Table 3. The results of multiple linear regression of birthweight and logistic regression of the status of lbw of babies on the socio-demographic variables of mothers and their families are given in Table 3.

Table 3. The Results of Multiple Linear Regression of Birthweight and Logistic Regression of Status of LBW of Babies on the Socio-demographic Variables of Mothers and Their Families: All India 2019-21

	Linear			**Logistic**		
	Coeff.	**Sig.**	**VIF**	**Coeff.**	**Sig.**	**Exp(B)**
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sex of Child	0.071	0.000	1.001	0.197	0.000	1.218
Residential Status	-0.009	0.036	1.258	-0.065	0.001	0.937
Weight_Mother	0.006	0.000	1.345	0.013	0.000	1.013
Height_Mother	0.004	0.000	1.194	0.018	0.000	1.018
Age_Mother	0.003	0.000	1.111	0.012	0.000	1.012
Haemoglobin_Mother	0.007	0.000	1.032	0.028	0.000	1.028
Drinking Water	0.007	0.075	1.045	-0.011	0.600	0.989
Caste	0.054	0.000	1.386	0.176	0.000	1.192
Religion	0.106	0.000	1.353	0.180	0.000	1.197
Wealth Index	0.023	0.000	1.857	0.112	0.000	1.119
Educational Level	0.036	0.000	1.209	0.089	0.000	1.093
TV Watching	0.007	0.030	1.239	0.032	0.045	1.033
Pregnancy Duration	0.149	0.000	1.005	0.594	0.000	1.811
Antenatal Care	-0.001	0.918	1.034	0.196	0.000	1.217
Iron Tab Pregnancy	0.026	0.000	1.038	0.172	0.000	1.188
Freq of Milk/Curd	-0.005	0.164	1.178	-0.001	0.962	0.999
Freq. of Fruits	0.000	0.924	1.227	-0.017	0.292	0.983
Freq. of Eggs	0.000	0.947	1.793	-0.005	0.816	0.995
Freq. of Fish	0.002	0.618	1.767	-0.049	0.021	0.952
Freq. of Meat	0.015	0.001	1.878	0.055	0.010	1.057
Freq, of Aerated Drinks	0.005	0.218	1.073	0.009	0.661	1.009
Cooking Fuel	0.011	0.004	1.647	0.018	0.348	1.018
State Group	0.106	0.000	1.247	0.351	0.000	1.421
Goodness of Fit	$R^2 = 0.056$			**Nagelkerke R^2 = 0.040**		

Note 1: For linear regression the dependent variable is Birthweight and for Logistic regression, the dependent variable is the Status of LBW (i.e., 0 if LBW and 1 otherwise). This is just to keep concordance with the linear regression.

Source: The authors.

Since all the VIF values are very small and are much smaller than the critical thumb rule value of 10, we can safely assume that there is no multicollinearity among the explanatory variables.

In Logistic regression, we have taken the value 0 when the baby has LBW and 1 otherwise. Thus, the coefficients of Logistic regression are expected to have the same signs as that of linear regression. But**,** drinking water, antenatal care, and frequency of intake of most of the food items except meat/chicken behave in opposite directions. However, the coefficients are not significant except in the case of antenatal care for Logistic regression. Almost all the food items intake of aeriated drink are not significant in any of the regressions. The only exception is the intake of meat/chicken items. All other variables are significant at least in one of the two regressions.

The variables that have a significant effect on birthweight as well as on the status of LBW are the Weight of mother, Height of mother, Age of the mother, Haemoglobin level of the mother, Sex of the child, Residential status, Wealth index of the household, Religion, Level of education of mother, TV watching of mother, Pregnancy duration, Iron tab during pregnancy, and Frequency of intake of meat. The implication is clear. These variables directly affect the birth weight and status of the health of new-born babies.

As already stated earlier we have taken a dummy variable representing two groups of States. The coefficient is found to be significant. The coefficient is positive because the base group is taken as the States with low mean birthweight, which happens to be the middle-belt States, which means that the middle-belt States have substantially fewer birthweight babies compared to the rest of the States.

The sex of the baby and residential status is expected to have a differential impact on the birthweight as well as on the category of birthweight for many of the explanatory variables. Because wealth index, educational levels are higher in urban areas than in rural areas on average. Urban women watch TV for more time. The percentage of the ST population is less in urban areas. All these may affect the mean birthweight differently. On the other hand, since the sex of the child is not predetermined, there may be much less differential effect of the explanatory variables on the birthweight. It cannot be denied the fact that the average birthweight of female babies is much less than that of male babies. If we do not get any interaction effect of the sex of the child, then it may be assumed to be a natural phenomenon. The following two tables of regression results may shed some light on these phenomena.

Table 4A. The Results of Linear Regression of Birthweight of Babies on the Socio-demographic Variables of Mothers and Their Families Along with Interactions with Sex of the Children and Residential Status: All India 2019-21

	Main Variables			**Interactions with Sex**			**Interactions with Residence**		
	Coeff.	**Sig.**	**VIF**	**Coeff.**	**Sig.**	**VIF**	**Coeff.**	**Sig.**	**VIF**
Weight_Mother	.006	.000	1.347	*	*	*	*	*	*
Height_Mother	.004	.000	1.195	*	*	*	*	*	*
Age_Mother	.003	.000	1.114	*	*	*	*	*	*
Haemoglobin_Mother	.007	.000	1.033	*	*	*	*	*	*
Drinking Water	.008	.195	2.225	.001	.895	5.660	-.012	.169	5.325
Caste	.045	.000	3.098	.004	.645	3.118	.058	**.000**	1.793
Religion	.108	.000	3.180	-.011	.318	2.944	.008	.536	1.862
Wealth Index	.021	.000	1.872	*	*	*	*	*	*
Educational Level	.027	.000	2.576	.022	**.005**	6.708	-.033	**.005**	9.549
TV Watching	.006	.217	2.949	.005	.428	3.674	-.009	.270	3.592
Pregnancy Duration	.114	.000	2.161	.034	**.000**	7.248	.072	**.000**	6.880
Antenatal Care	-.001	.879	1.035	*	*	*	*	*	*
Iron Tab Pregnancy	.024	.001	2.146	.012	.166	8.234	-.022	.052	8.948
Freq of Milk/Curd	-.009	.084	2.688	.010	.142	4.796	-.004	.635	4.854
Freq. of Fruits	-.002	.749	2.968	.004	.521	3.787	.001	.931	3.610
Freq. of Eggs	-.006	.323	4.394	.007	.420	5.233	.011	.257	4.135

Freq. of Fish	.005	.427	4.347	.006	.479	4.626	-.024	**.013**	3.254
Freq. of Meat/Chicken	.012	.063	4.581	.001	.932	5.015	.003	.759	3.818
Freq. of Aerated Drinks	.012	.074	2.699	-.009	.286	2.508	-.008	.393	1.670
Cooking Fuel	.017	.002	3.265	-.012	.075	3.738	-.002	.877	7.238
State Group	.107	.000	2.997	.003	.703	3.480	-.014	.099	2.583
Goodness of Fit	$R^2 = 0.057$								

Dependent Variable = Birthweight, *: Deleted since it leads to high VIF.
Source: The authors.

Table 4B. The Results of Logistic Regression of Status of Birthweight of Babies on the Socio-demographic Variables of Mothers and Their Families Along with Interactions with Sex of the Children and Residential Status: All India 2019-21

	Main Variables			**Interactions with Sex**			**Interactions with Residence**		
	Coeff.	**Sig.**	**EXP($\hat{\beta}$)**	**Coeff.**	**Sig.**	**EXP($\hat{\beta}$)**	**Coeff.**	**Sig.**	**EXP($\hat{\beta}$)**
Weight_Mother	.013	.000	1.013	*	*	*	*	*	*
Height_Mother	.018	.000	1.018	*	*	*	*	*	*
Age_Mother	.012	.000	1.012	*	*	*	*	*	*
Haemoglobin_Mother	.028	.000	1.029	*	*	*	*	*	*
Drinking Water	-.013	.653	.987	-.002	.957	.998	-.010	.823	.990
Caste	.163	.000	1.177	.012	.778	1.012	.089	.189	1.093
Religion	.176	.000	1.192	-.035	.532	.965	.094	.213	1.098
Wealth Index	.110	.000	1.116	*	*	*	*	*	*
Educational Level	.073	.009	1.075	.044	.226	1.045	-.055	.317	.947
TV Watching	.055	.024	1.056	-.025	.419	.975	-.040	.306	.961
Pregnancy Duration	.474	.000	1.606	.119	**.001**	1.126	.254	**.000**	1.289
Antenatal Care	.194	.000	1.214	*	*	*	*	*	*
Iron Tab Pregnancy	.204	.000	1.226	.003	.937	1.003	-.175	**.001**	.840
Freq of Milk/Curd	-.033	.184	.967	.081	**.013**	1.084	-.045	.295	.956
Freq. of Fruits	-.031	.200	.969	.013	.693	1.013	.042	.287	1.043
Freq. of Eggs	-.037	.216	.963	.048	.229	1.049	.044	.355	1.045
Freq. of Fish	-.086	.007	.918	.094	**.027**	1.098	-.037	.462	.964
Freq. of Meat/Chicken	.092	.004	1.097	-.058	.175	.943	-.045	.383	.956
Freq. of Aerated Drinks	.035	.277	1.036	-.036	.394	.965	-.035	.466	.965
Cooking Fuel	.034	.188	1.034	-.035	.275	.966	-.005	.914	.995
State Group	.362	.000	1.437	.001	.983	1.001	-.057	.166	.945
Goodness of Fit	**Nagelkerke R^2 = 0.041**								

Dependent Variable: Status of Birthweight (i.e., 0 if LBW and 1 otherwise), *: Deleted since it leads to high VIF.

Source: The authors.

The effect of the main variables in Tables 4A and 4B are similar to that of the all-India case. The result of the multiple linear regression shows that almost all variables have a significant effect on birthweight and there is no multicollinearity problem though many explanatory variables are taken. Most of the effects are in the expected direction if significant. The coefficients of the continuous variables - weight, height, haemoglobin, and pregnancy duration - are all significant at a 1% level. The interpretations are straightforward, e.g., (i) a one-kilogram increase in the weight of the mother leads to an increase in the birth weight on average by 6 grams, (ii) one unit increase in the haemoglobin level leads to an increase in the birthweight on the average by 7 grams and (iii) one month increase in the pregnancy duration leads to increase in the birthweight of babies on the average by 114 grams. In the last case, one may interpret a one-day increase in the pregnancy duration would lead to an increase in the birthweight of babies on average by about 4 grams. The corresponding interpretations for logistic regression are as follows (i) the odds of having an LBW baby will decrease by about 1 percent if the weight of the mother increases by one kilogram, (ii) the odds of having an LBW baby will decrease by about 3 percent if the haemoglobin level of mother increases by one unit, and (iii) the odds of having LBW baby will increase by about 61 percent if the pregnancy duration is increased by one month. One can imagine now how important the pregnancy duration is. We are emphasizing these three variables because the values of these variables can be manipulated by appropriate medical or other scientific methods. Other variables can be controlled, e.g., the Educational level of the mother, Intake of food items, etc. Some of these have significant effects on birth weight so due attention should be given.

Let us now discuss the interaction effects. It was not possible to incorporate all the variables as interactions because of the multicollinearity problem. In the linear regression model, there are only two variables namely, Level of education and Pregnancy duration of the mother, which significantly interacted with the sex of the newborn babies to enhance the birthweight. The variables that significantly interact with Place of residence are Caste, Educational level of mother, Pregnancy duration of mother, and Intake of fish of mother. Caste, Educational level of the mother, and Pregnancy duration of the mother have positive effects meaning that ST, higher education, or higher pregnancy duration have further influence towards increased birthweight if the place of residence is urban. Interestingly, the Intake of fish shows a significant effect in the negative direction. Thus, the interaction of Intake of fish with sex has a significantly positive effect on birthweight in favour of male babies, though there is no meaningful explanation for it.

In the Logistic regression model, there are only two variables each having significant interaction effects. Sex of the newborn has significantly positive interactions with Pregnancy duration, Intake of milk/curd, and Intake of fish towards an increase of birthweight in favour of male babies, whereas Place of residence has a significantly positive interaction with Pregnancy duration and significantly negative interaction with Intake of an iron tablet. Again, there is a higher chance of non-LBW babies in urban areas if pregnancy duration is high and a lower chance of non-LBW babies in urban areas if the mother takes iron tablets during pregnancy.

4. DISCUSSIONS

Half of the infants in developing countries were not weighed at all or properly, thus it was a major challenge (WHO, 2004). As many rural deliveries occur at homes under the supervision of an untrained person or sometimes it occurs at small health centres and are not documented, thus, it is underestimated (WHO 2012).

In the present data, many of the babies were not weighed at birth and hence could not be taken in our analysis.

While LBW is an important indicator of child survival as well as long-term consequences of the onset of non-communicable disease in the life course, mortality and morbidity can be prevented by addressing the factors related to low birth weight (Basel & Singh, 2020). Better education and health care have played a crucial role in the social development of a society

(Mukherjee & Banerjee, 2009). Mothers who have not received good quality antenatal care are found to be more at risk of having low birth weight babies.

LBW babies face stunting, have lower IQ, and in extreme cases even death. Other researchers Sarika et al., (2020) and Balasubramaniam et al. (2020) suggested focusing on public health strategies related to better maternal nutrition and educational attainment has a strong relation to the health of the babies in the long run. In adulthood, LBW babies may face adult overweight or obesity, heart disease, diabetes, or other non-communicable diseases (UNICEF, 2019). Khan et al. (2020) found that LBW might be the result of adverse maternal circumstances like intimate partner violence. UNICEF (2019) found that the birth weight of a newborn depended on the duration of pregnancy, the poor nutritional diet of a mother from birth to pregnancy, the mother's height, age, and most importantly underpinned by poverty. Early-born babies are highly susceptible to low birth weight (WHO, 2012).

Work demanding physical hard labour during pregnancy also contributed to poor foetal growth (WHO 2012). Kumari et al., (2021) also found that LBW is dominant among the tribal infants of India. But in our paper, we found LBW to be less among ST mothers i.e., 14.7% against 17.4% among other castes. ST mothers are known to do many non-domestic works for their living besides doing domestic work. However, it seems ST mothers were very aware of dos and don’ts during pregnancy, especially during a later stage of pregnancy. The mean birthweight among ST families (2.89 kg.) is found to be more than that of non-ST families (2.80 kg.).

Generally, girls' birth weight is found to be less than that of boys (WHO 2004), the same was found by us – mean birthweight being 2.79 kg. for female babies as against 2.85 kg. for male babies. Also, LBW babies were more among female babies (18.20%) as against (15.71%).

Jayachandran & Pande, (2017) made an interesting observation that the family size was large for some families because of son preference. Human capital investments are disproportionately allocated among girl and boy children favouring boy children. As a result, chronic malnutrition was more common among girl children which further led to LBW babies among future mothers. Another reason was that in the rural sector expecting mothers did not understand the importance of taking iron and folic acid tablets as they received these tablets for free. Sometimes they were not the decision-makers (Prakash 2008).

Metgud and Mallapur (2012) found a reciprocal relationship between the chances of having LBW and the increase in maternal age. In our case, we observed the mean birthweight to increase with the age of the mother up to a certain age (Appendix 1).

Contrary to our study, Mohammed et al., (2019) found that the LBW babies were significantly high (OR 1.77, 95%CI 1.14-2.76) among urban households. However, urban mothers have higher education levels than rural mothers. One should not forget that urban mothers live a sedentary lifestyle.

Though we have not included the morbidity status of mothers like high blood pressure, diabetes, and infection, the health status of these three issues plays important roles in determining the birth weight of babies (UNESCO 2019). However, maternal malnutrition issues like Haemoglobin level and underweight are also responsible for LBW babies (UNESCO 2019). Whereas, Borooah (2022) made an interesting observation that there is a sharp imbalance in the allocation of health facilities between rural and urban areas. In rural areas, very few health workers take the responsibilities and they are not efficient. Further mentioned that Indian health policies are rhetoric and based on poor governance thus need to address these issues.

But in our observation, the continuous variables like weight, height, age, and haemoglobin levels of mothers have a positive effect on the birth weight of babies. It is not the social characteristics like religion and frequency of intakes of different food items, but simply the health status of the mother, pregnancy duration, and wealth index, which have a significant effect on the birth weight of babies. All these variables have a positive influence on the birth weight of babies. The health status of the mother includes Weight, Height, and Hemoglobin level of mothers.

Further, most of the several binary variables have significant relations with birth weight. Surprisingly, drinking water, birth order, intake of milk or curd, intake of fruits, intake of egg, and intake of aerated drinks were not significant.

The result of the chi-square test reveals that proportion of LBW babies is less among mothers who watch TV frequently compared to the mothers who watch it less. Does it mean that the entertainment/recreation of the mother is necessary for the good health of the mother as well as for her child? Or does it mean that it is the confounding effect of the high wealth index because mothers of non-poor families have more leisure time?

Pregnancy duration is the only significant variable that interacted with the Sex of the newborn baby as well as place of residence for both linear and Logistic regression models to increase the birthweight of babies significantly. One of the other variables, which have a significant effect on the birthweight of babies due to interactions is the Level of education of the mother in the linear regression model. Does it mean that a higher-educated mother is prone to give birth to male babies? The present data shows that among the newborn female babies, the percentage of non-LBW babies is 82.4%, whereas it is 84.9% among the male babies. It would not be meaningful to seek a similar explanation for the significance of the interaction of Pregnancy duration. There is a greater number of variables that significantly interact with Place of residence. One should not forget that urban mothers have other advantages compared to rural mothers of the same category.

The result of Logistic regression suggests that there are added chances of getting non-LBW male babies of mothers with higher pregnancy duration, and intake of milk/card or fish. However, it is difficult to know why. Differential impact of interaction with place of residence was also found for the Intake of iron tablets. It should be remembered that giving iron tablets to a mother during pregnancy is not mandatory, it is given only when the doctor thinks it to be necessary. Moreover, in rural areas, pregnant mothers get iron tablets free of cost.

5. Conclusions

Pregnancy duration is one of the important variables which determine birthweight. This is why immature birth is not advised. Babies in the womb should grow to the full extent before being born. The caesarean operation should be done only when it is necessary.

The findings of the paper help us to pinpoint the issues that need prior attention and design sustainable planning by the Government towards better health of mothers and children. To ensure safe motherhood and high quality of life, the Government should arrange for social protection for women by (i) establishing equal rights and eradicating negligence of girl child through awareness, (ii) ensuring each girl has proper education so that they become empowered to take their own decision, (iii) arranging health care visits to schools to address anaemia and undernutrition problems of adolescents, and (iv) spreading the knowledge of the good effect of indigenous foods to improve iron and calcium deficiency. However, late childbearing, shorter inter-pregnancy intervals, weight gain during pregnancy, and late antenatal registration are other vital things that need to be addressed. To conclude, mothers' health status should be given maximum priority to avoid health hazards and improve the birth weight and health status of new-born babies.

The Government of India is also making efforts to provide antenatal, and post-natal services along with nutritional intake, financial incentives to mothers, and transport facilities for mothers and newborns. There were many different policies and programs including Integrated Child Development Services, Pradhan Mantri Matritva Vandana Yojana, Pradhan Mantri Surakshit Matritva Abhiyan, Janani Suraksha Yojana, Janani Shishu Suraksha Karyakaram, etc. However, despite the implementation of multiple policies and programs to improve the outcome of delivery, India is still lagging far behind in achieving the target (Mahanta et al., 2013).

Indeed, it is not possible to reduce the number of LBW babies completely overnight. It needs prolonged good Governance which takes care of mothers as well as children's physical and mental health.

Acknowledgements

We acknowledge the National Family Health Survey (NFHS-5) collected during 2019-2021, which helped a lot to write the article.

Declaration of Conflict of Interest and Consent of publication

The authors declare that there is no conflicts of interest between the authors with respect to the research, authorship and/or publication of this article.

Ethical approval

This study was conducted using DHS data. The DHS Program maintains strict standards for protecting the privacy of respondents and household members in all DHS surveys. Procedures and questionnaires for standard DHS surveys have been reviewed and approved by ICF Institutional Review Board (IRB). Additionally, country-specific DHS survey protocols are reviewed by the ICF IRB and typically by an IRB in the host country. ICF IRB ensures that the survey complies with the U.S. Department of Health and Human Services regulations for the protection of human subjects (45 CFR 46), while the host country IRB ensures that the survey complies with laws and norms of the nation.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article

Authors' contribution

M Pal conceptualized the theme, carried out statistical regressions and made final corrections. S Biswas made analysis of data wrote the manuscript and then revised it taking comments from others.

REFERENCES

Basel, A. K. C., P. L., & Singh, S. (2020). Low birth weight and its associated risk factors: Health facility-based case-control study. *PLoS ONE*, *15*(6 June). https://doi.org/10.1371/journal.pone.0234907

Balasubramaniam, D., Chatterjee, S., & Mustard, D. B. (2020). Public Versus Private

Investment in Determining Child Health Outcomes: Evidence from India. In *Arthaniti: Journal of Economic Theory and Practice* (Vol. 19, Issue 1). https://doi.org/10.1177/0976747919854257

Borooah, V. K. (2022). Issues in the Provision of Health Care in India: An Overview1. *Arthaniti: Journal of Economic Theory and Practice*, *21*(1), 43–64. https://doi.org/10.1177/0976747920945186

Cutland, C. L., Lackritz, E. M., Mallett-Moore, T., Bardají, A., Chandrasekaran, R., Lahariya, C., Nisar, M. I., Tapia, M. D., Pathirana, J., Kochhar, S., & Muñoz, F. M. (2017). Low Birth Weight: Case Definition & Guidelines for Data Collection, Analysis, and Presentation of Maternal Immunization Safety Data. *Vaccine*, *35*(48), 6492–6500. https://doi.org/10.1016/j.vaccine.2017.01.049

Gupta, R. Das, Swasey, K., Burrowes, V., Hashan, M. R., & Al Kibria, G. M. (2019). Factors Associated with Low Birth Weight in Afghanistan: A Cross-sectional Analysis of the Demographic and Health Survey 2015. *BMJ Open*, *9*(5). https://doi.org/10.1136/bmjopen-2018-025715

Jayachandran, S., & Pande, R. (2017). Why are Indian children so short? the role of birth order and son preference. *American Economic Review*, *107*(9), 2600–2629. https://doi.org/10.1257/aer.20151282

Khan, M. M. A., Mustagir, M. G., Islam, M. R., Kaikobad, M. S., & Khan, H. T. A. (2020). Exploring the Association between Adverse Maternal Circumstances and Low Birth Weight in Neonates: A Nationwide Population-based Study in Bangladesh. *BMJ Open*, *10*(10). https://doi.org/10.1136/bmjopen-2019-036162

Kumari, N., Algur, K., Chokhandre, P. K., & Salve, P. S. (2021a). Low birth weight among tribal in India: Evidence from National Family Health Survey-4. *Clinical Epidemiology and Global Health*, *9*(September 2020), 360–366. https://doi.org/10.1016/j.cegh.2020.10.010

Mahanta, T. G., Joshi, R., Mahanta, B. N., & Xavier, D. (2013). Journal of Epidemiology and Global Health Prevalence of modifiable cardiovascular risk factors among tea garden and general population in Dibrugarh, Assam, India) Prevalence of modifiable cardiovascular risk factors among tea garden and general population. *Journal of Epidemiology and Global Health*, *3*, 147–156. https://doi.org/10.1016/j.jegh.2013.04.001

Mahumud, R. A., Sultana, M., & Sarker, A. R. (2017). Distribution and Determinants of Low Birth Weight in Developing Countries. *Journal of Preventive Medicine and Public Health*, *50*(1), 18–28. https://doi.org/10.3961/jpmph.16.087

Metgud, C. S., Naik, V. A., & Mallapur, M. D. (2012). Factors affecting birth weight of a newborn - a community based study in rural Karnataka, India. *PLoS ONE*, *7*(7). https://doi.org/10.1371/journal.pone.0040040

Mohammed, S., Bonsing, I., Yakubu, I., & Wondong, W. P. (2019). Maternal obstetric and socio-demographic determinants of low birth weight: A retrospective cross-sectional study in Ghana. *Reproductive Health*, *16*(1). https://doi.org/10.1186/s12978-019-0742-5

Mukherjee, J., & Banerjee, S. (2009). Education and Health: Strategic Sequencing in Social Development. *Arthaniti-Journal of Economic Theory and Practice*, *8*(1–2), 25–49. https://doi.org/10.1177/0976747920090103

Negi, K.S., Kandpal, S.D., Kukreti, M. K. (2006). Epidemiological Factors Affecting Low Birth Weight. *JK Science*, *8*(1), 31–33.

Prakash, N. (2008). Training camp on safe motherhood in rural India: A research note. *Marriage and Family Review*, *44*(2–3), 389–395. https://doi.org/10.1080/01494920802271957

Sarika, M., Vishwakarma, R., & Rao, R. (2020). Study of low birth weight babies and their association with maternal risk factors. *Pediatric Review: International Journal of Pediatric Research*, *7*(7), 379–387. https://doi.org/10.17511/ijpr.2020.i07.10

UNICEF, (2019). Low Birthweight Estimates Levels and Trends 2000-2015. In *UNICEF* (Vol. 7, Issue 7). Elsevier Ltd. https://doi.org/10.1016/S2214-109X(18)30565-5

WHO. (2012). *Global Nutrition Targets 2025*.

WHO (2004). *Low Birthweight : Country, Regional and Global Estimates*. WHO.