RESEARCH ARTICLE

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Determinants of very low birth weight in India: The National Family Health Survey – 4 [version 2; peer review: 2 approved]

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Abstract

Background

Low birth weight (LBW) is susceptible to neonatal complications, chronic medical conditions, and neurodevelopmental disabilities. We aim to describe the determinants of very low birth weight (VLBW) in India and compare it with the determinants of LBW based on the National Family Health Survey – 4 (NHFS-4)

Methods

Data from the NFHS-4 on birthweight and other socio-demographic characteristics for the youngest child born in the family during the five years preceding the survey were used. Data of 147,762 infant–mother pairs were included. Multiple logistic regression models were employed to delineate the independent predictors of VLBW (birth weight<1500 g) or LBW (birth weight: 1500-2499 g).

Results

Of the 147,762 children included in the study, VLBW and LBW were observed in 1.2% and 15.8% of children, respectively. The odds of VLBW were higher in female children (aOR: 1.36, 95% CI: 1.15–1.60), among mothers aged 13–19 years (aOR: 1.58, 95% CI: 1.22–2.07), mothers with severe or moderate anaemia (aOR: 1.61, 95% CI: 1.34–1.94), mothers without recommended antenatal care (aOR: 1.47, 95% CI: 1.31–1.90), maternal height less than 150 cm (aOR: 1.54, 95% CI: 1.29–1.85) and among mothers with multiple pregnancy (aOR: 21.34, 95% CI: 14.70–30.96) in comparison to their corresponding counterparts. In addition to the variables associated with VLBW, educational status of mothers (no education; aOR: 1.08, 95% CI: 1.02–1.15 and primary education; aOR: 1.16, 95% CI: 1.08–1.25), caste of the children (scheduled tribe; aOR: 1.13, 95% CI: 1.03–1.24), and wealthiness of the family (poorest wealth quintiles; aOR: 1.11, 95% CI: 1.03–1.19) were associated with LBW.

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Conclusions
Interventions targeting improvements in antenatal care access, maternal health, and nutritional status may reduce the number of VLBW infants. Social determinants of LBW require further detailed study to understand the high propensity of low birth-weight phenotypes in the disadvantaged communities in India.

Keywords
Low birth weight, very low birth weight, determinants, National Family Health Survey, India

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REVISED **Amendments from Version 1**

We have added a Poisson Regression model as suggested by the reviewer (Supplementary table 3: 10.6084/m9.figshare.19556476). The results of the Poisson regression model yielded similar results as that of the corresponding logistic regression model. The determinants of VLBW compared to the reference category of LBW was also assessed (Supplementary Table 4: 10.6084/m9.figshare.19556461 and Supplementary Table 5: 10.6084/m9.figshare.19556470).

Any further responses from the reviewers can be found at the end of the article

Introduction

Low birth weight (LBW), defined as birth weight less than 2500 g, is a significant public health problem globally, and remains as a major health issue in India[1,2]. Very low birth weight (VLBW), a sub-group with birth weight <1500 g, is a high-risk group with considerable mortality and morbidity[3–5]. Advances in medical care, treatment facilities, and progress in availability of these services over the last several decades including the establishment of level three nurseries for neonates across India, improved the survival of both LBW and VLBW babies[6–8]. However, the survived babies with LBW are susceptible to neonatal complications, recurrent hospitalisations, chronic medical conditions and neurodevelopmental disabilities like intellectual disabilities, and learning disabilities[9,10]. It also increases the future risk of chronic diseases and other co-morbidities. For example, adult diseases such as hypertension, dyslipidaemia and insulin resistance are closely related to a LBW, leading to markedly increased rates of cardiovascular, metabolic and renal diseases in later life[11]. Understanding the determinants of VLBW among infants is critical for planning further interventions in reducing the associated morbidity and mortality. We describe the socio economic and maternal determinants of VLBW infants and compare it with the determinants of Low Birth Weight (LBW) in India based on the National Family Health Survey – 4 (NHFS-4) data.

Methods

Ethical statement

Our study is based on a secondary analysis of existing data from NFHS-4, which is an anonymous and publicly available dataset. The dataset has no identifiers of the survey participants. At the beginning of the survey, the interviewer took informed consent from each participant after explaining the purpose of the study. The informed consent explained that the participation was voluntary, and participants had the right to refuse or stop the interview at any point. The NFHS-4 obtained ethical clearance from the Ethical Review Board of the International Institute for Population Science (IIPS), which performed these surveys. We registered at the DHS site as data users and submitted a research proposal to study the determinants of VLBW. The Demographic Health Survey (DHS) program gave access to the data after reviewing the submitted proposal (10.6084/m9.figshare.16606787). We downloaded the required data from https://www.dhsprogram.com/data/available-datasets.cfm. We accepted all terms and conditions attached with the data sharing policy of DHS.

Data source

We used data from the NFHS-4 which was conducted during the year 2015–2016. The first NHFS survey began during early 1990s. The NFHS presents nationally representative data on population, health, and nutrition for India including its states as well as union territories. The survey also intended to offer state and national-level estimates of fertility, mortality, family planning, adolescent reproductive health, high-risk sexual behavior, HIV-related knowledge and use of healthcare services in the country.

Using a multi-stage sample design, NFHS-4 covered sample households all over India. A stratified two-stage sampling design was adopted for the NFHS-4 survey. For all districts surveyed, a uniform sampling design was used considering rural and urban areas as strata. To select primary sampling units (PSUs), the Census of India 2011 served as the sampling frame. The PSUs in rural areas were villages whereas it was census enumeration blocks (CEBs) in urban areas. The villages and CEBs were selected from the sampling frame with probability proportional to size (PPS) sampling. A household mapping and listing operation was performed at every selected PSU before the main survey. In the second stage, a random selection of 22 households from each PSU was done. The details on study design, sampling, and data collection schedule of the NFHS have been published elsewhere (http://rchiips.org/Nfhs/NFHS-3%20Data/VOL-1/India_volume_I_corrected_17oct08.pdf, https://dhsprogram.com/pubs/pdf/FR339/FR339.pdf). The fourth round (NFHS-4) collected data from 30 states and six union territories from India. The NFHS-4 survey gathered information from 699,686 women, and 112,122 men.

Study participants

We used the data on birthweight and other socio-demographic characteristics for the youngest child born in the family during the past five years preceding the survey (n=190,898 children). Data of 37,306 children were reported as not weighed. Additionally, data from 5729 children were reported as special answers or do not know (Figure 1). Children with a birth weight of less than 1500 g and birth weight between 1500–2499 g were considered as VLBW and LBW, respectively. We included 147,762 infant-mother pairs meeting the inclusion criteria in the study (Figure 1).

Study variables

We grouped the study variables into three blocks representing distal, intermediate and proximal determinants, using a conceptual hierarchy-based approach[12] *i.e.*, socioeconomic characteristics, use of the healthcare services or the programmatic factors including antenatal care (ANC), and maternal and new-born characteristics, respectively (Figure 2).

The key study variables were individual and household socio-demographic characteristics including age and education of

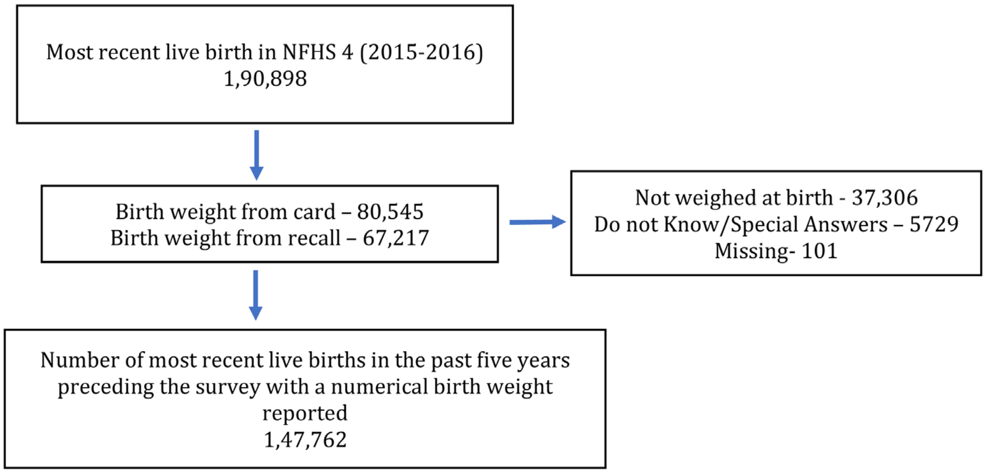

Figure 1. Flow chart description detailing study inclusion.

the mother, wealth index, marital status, religious background, and place of residence (Table 1). Reproductive characteristics of the mother included age at birth of the index child, birth order, birth interval, the type of complications during pregnancy and general health behaviours including smoking and alcohol status. The antenatal check-up (ANC) status included the timing of the first ANC visit, number of ANC visits, tetanus injection during pregnancy, place of delivery, and service accessibility. Anthropometric measures included height and body mass index of the mother. We also included the anaemia status of the mother as a study variable.

Data analysis

We used STATA Version 16.1 STATA Corp (RRID:SCR_012763) for the data analysis. We explored the bivariate associations between socio-demographic and maternal variables and low birth-weight phenotypes (VLBW and LBW). The statistically significant predictors ($P<0.10$) from the bivariate model were further analysed using multiple logistic regression models to establish the independent association between these variables and LBW phenotypes. A correlation matrix was employed to check multicollinearity. In the final multivariable regression model, we excluded BMI, type of delivery, place of delivery, pregnancy duration, first ANC visit and religion to avoid multicollinearity. We generated adjusted odds ratio (aOR) with their 95% confidence intervals (CI). A Poisson regression model was also generated to explore associations of socio-demographic and maternal variables and VLBW.

Results

General characteristics

Of the 147,762 children included in the study, 1722 (1.2%) were with VLBW. In total 23,308 (15.8%) children had LBW. More than half (54.5%) of the children were boys (Table 2). Nearly two-thirds (64%) of the mothers reported height greater than 150 cm. The body mass index was more than 18.5 kg/m^2 in four-fifths (80.0%) of the mothers. 87% of the mothers belonged to the 20–34 years at the time of childbirth. About 19% each belonged to scheduled caste and scheduled tribes. Nearly two-thirds of the mothers (64.8%) reported secondary or higher education. 40% belonged to poorer or poorest wealth quintiles. One-third of the mothers reported severe or moderate anaemia. More than two-thirds (72.4%) of the mothers reported their first antenatal care (ANC) visits during the first trimester itself.

Factors associated with very low birth weight

In the bivariate analysis, the child's gender, height, BMI, birth order, age of the mother, anaemia level, tobacco and alcohol use, thyroid disease, antenatal visits, place of delivery, multiple pregnancy, caste, religion, educational status, wealth quintile, geographic region, and pregnancy duration, were associated with VLBW (Supplementary Table 1: 10.6084/m9.figshare.18393749). In the multivariable logistic regression model, odds of VLBW were higher in female children when compared with male children (aOR: 1.36, 95% CI: 1.15–1.60) (Table 3). Mothers aged 13–19 years had higher odds for VLBW when compared with mothers aged 20–34 years (aOR: 1.58, 95% CI: 1.22–2.07). Children from Eastern states had lower odds for VLBW (aOR: 0.47, 95% CI: 0.33–0.67) as compared with children from Western states. The odds of VLBW were 1.61-times higher in mothers with severe or moderate anaemia *versus* non-anaemic mothers (aOR: 1.61, 95% CI: 1.34–1.94). Mothers who did not follow recommended ANC had 47% higher odds of VLBW compared to the reference group of mothers who adhered to ANC recommendations (aOR: 1.47, 95% CI: 1.31–1.90). The odds of having VLBW was 21-times higher (aOR: 21.34, 95% CI: 14.70–30.96) among children of mothers with the multiple pregnancy *versus* singleton pregnancy. Mothers whose height was less than 150 cm had 54% higher odds of VLBW compared to mothers with height greater than 150 cm (aOR: 1.54, 95% CI: 1.29–1.85). The results of the Poisson regression model were consistent with the logistic regression model (Supplementary Table 3: 10.6084/m9.figshare.19556476). The determinants of VLBW compared to the reference of LBW was also assessed (Supplementary Table 4: 10.6084/m9.figshare.19556461 and Supplementary Table 5: 10.6084/m9.figshare.19556470) and they were consistent with the main analysis.

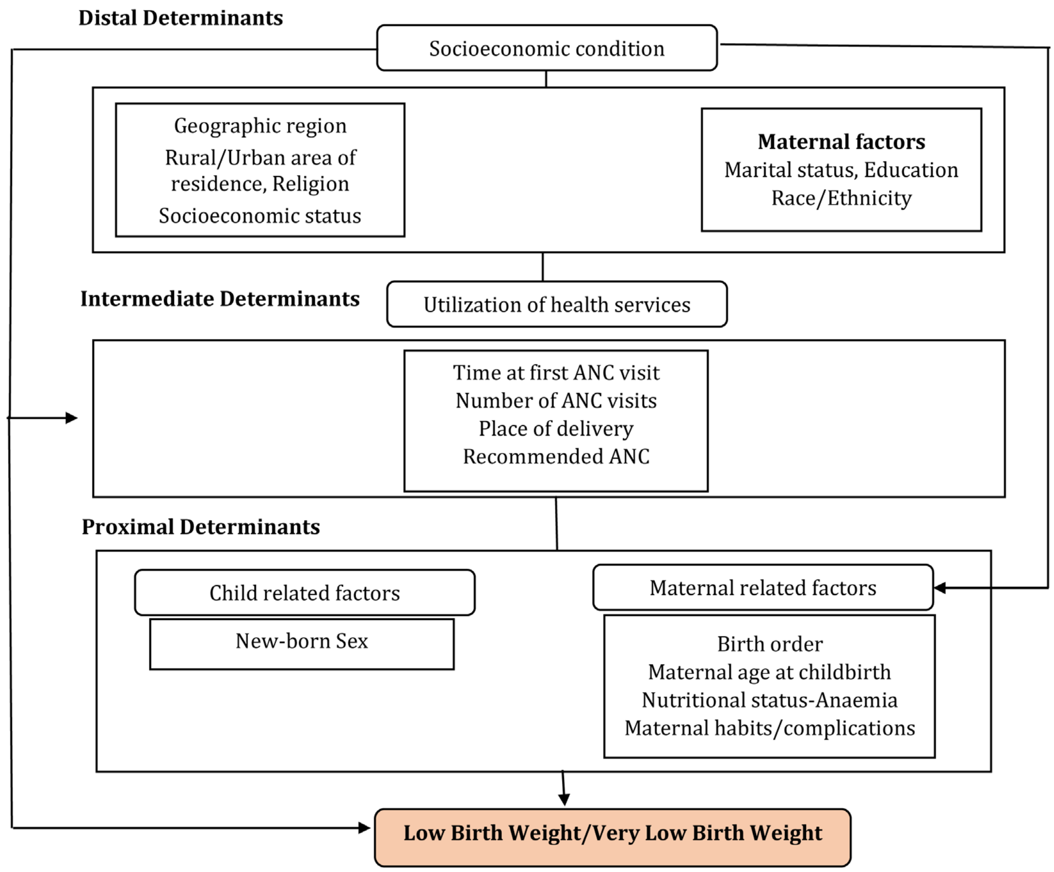

Figure 2. Conceptual hierarchy-based model ANC=Antenatal Care used to analyze factors associated with low birth weight. (Adapted from Falcão *et al.* BMC Pregnancy and Childbirth 2020).

Factors associated with low birth weight

In the bi-variate analysis, the child's gender, height, BMI, birth order, age of the mother, anaemia level, tobacco and alcohol use, antenatal visits, place of delivery, multiple pregnancy, place of residence, caste, religion, educational status, wealth quintile, geographic region, timing of first ANC visits and appropriate ANC use were associated with LBW (Supplementary Table 2: 10.6084/m9.figshare.18393758). In the multivariable logistic regression model (Table 4), odds of LBW were higher in girl children when compared to boys (aOR: 1.21, 95% CI: 1.15–1.26). Children with birth order greater than four were having lower odds for LBW than children with birth order one to three (aOR: 0.86, 95% CI: 0.80–0.92). Mothers aged 13-19 years had higher odds for VLBW when compared to mothers aged 20–24 years (aOR: 1.17, 95% CI: 1.06–1.26). Mothers with no education (aOR: 1.08, 95% CI: 1.02–1.15) and those with primary education (aOR: 1.16, 95% CI: 1.08–1.25) had higher odds of LBW as compared to those in the secondary education category. Children who belonged to scheduled tribe had 1.13-times higher odds for LBW *versus* children from other forward caste (aOR: 1.13, 95% CI: 1.03–1.24). Children from poorest/poorer wealth quintiles had higher odds of LBW *versus* those from rich or richest wealth quintiles (aOR: 1.11, 95% CI: 1.03–1.19). When compared with children from Western states, those from Eastern states (aOR: 0.75, 95% CI: 0.68–0.82), North-Eastern states (aOR: 0.61, 95% CI: 0.55–0.69) and Southern states (aOR: 0.90, 95% CI: 0.82–0.99) had lower odds for LBW. The odds of LBW were 1.20-times higher in mothers with severe or moderate anaemia *versus* non-anaemic mothers (95% CI: 1.13–1.26). Mothers who followed recommended ANC had lower odds of LBW compared with the reference group of mothers who did not follow ANC recommendations (aOR: 0.78, 95% CI: 0.73–0.83). The odds of having LBW were eight-times higher (aOR: 8.68, 95% CI: 7.05–10.68) among children of mothers with the multiple pregnancy *versus* singleton pregnancy. Mothers whose height was less than 150 cm had 36% higher odds of LBW compared to mothers with height greater than 150 cm (aOR: 1.36, 95% CI 1.29–1.43).

Discussion

The programmatic factors included in the conceptual model as intermediate factors and the proximal factors were significant predictors of VLBW in India. Although the distal determinants such as the social and economic predictors were not independently associated with VLBW, they may directly influence the intermediate determinants and therefore influence

Table 1. **List of explanatory variables and their categories used in this study.**

Maternal or child related factors	
Sex of the child	Male, female
Birth order of the child	1–3, 4 or more
Mother's age at birth in years	<19, 20–34, 35–49
Anaemia	Moderate/severe anaemia, Mild Anaemia, Not anaemic Mild anaemia (10.0–10.9 grams/decilitre for pregnant women), moderate anaemia (7.0–9.9 g/dl), and severe anaemia (less than 7.0 g/dl)
Thyroid Disease	Yes, No (self-reported)
Smoking	Yes, no (current smoking status)
Alcohol consumption	Yes, No (current alcohol consumption)
Type of delivery	Normal Delivery, Caesarean
Pregnancy type	Singleton, Multiple
Duration of pregnancy	<9 months, > 9 months
Mother 's Height	Height <150 cm, Height >150 cm
BMI of the mother	>18.5, <18.5 (calculated using height and weight of mother)
Programmatic factors	
Time at first ANC visit	1st trimester, after 1st trimester
Number of ANC visits	<4 ANC visits, >4 visits
Place of delivery	Institutional, Home
ANC – recommended	ANC in first trimester, at least four antenatal visits, at least one tetanus toxoid (TT) injection and iron folic acid tablets or syrup taken for 100 or more days
Socio-economic factors	
Area of residence	Urban, rural
Social group of mothers	Scheduled caste, Scheduled tribe, OBC, Others
Mother's schooling	No education, Primary, Secondary or Higher
Wealth index of the household	Poorest/poorer, middle, richer/richest (Based on scores on ownership of consumer goods and household characteristics: https://dhsprogram.com/pubs/pdf/FR339/FR339.pdf)
Religion	Hindu, Christian, Muslim, Others
Marital Status	Currently married, Not married currently
Geographic region	
Northern states	Chandigarh, Delhi, Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Rajasthan, Uttarakhand
Central states	Chhattisgarh, Madhya Pradesh, Uttar Pradesh
Eastern states	Bihar, Jharkhand, Odisha, West Bengal
North Eastern states	Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura
Western states	Dadra & Nagar Haveli, Daman & Diu, Goa, Gujarat, Maharashtra
Southern States	Andaman & Nicobar Islands, Andhra Pradesh, Karnataka, Kerala, Lakshadweep, Puducherry, Tamil Nadu, Telangana

OBC- Other Backward Class, ANC- Antenatal Care, BMI- Body Mass Index.

Table 2. Sample distribution by selected background characteristics – NFHS-4.

	LBW, n (%)	VLBW, n (%)	Normal Weight, n (%)	Total n (%)
Gender				
Male	11870(14.74)	872(1.08)	67764(84.17)	80506(100)
Female	11438(17.01)	850(1.26)	54968(81.73)	67256(100)
Birth Order				
1 to 3	20236(15.70)	1472(1.14)	107220(83.16)	128928(100)
>4	3072(16.31)	250(1.33)	15512(82.36)	18834(100)
Age of mother				
13–19 years	2058(10.16)	9101(44.92)	9101(44.92)	20260(100)
20–34 years	19306(15.34)	1250(0.99)	105301(83.67)	125857(100)
>35 years	1045(14.26)	80(1.09)	6201(84.64)	7326(100)
Marital Status				
Currently married	389(10.00)	1478(37.99)	2023(52.01)	3890(100)
Currently not married	22919(15.95)	20(0.01)	120709(84.03)	143648(100)
Place of residence				
Urban	6376(15.21)	500(1.19)	35033(83.59)	41909(100)
Rural	16932(16.00)	1222(1.15)	87699(82.85)	105853(100)
Social Group				
SC	4788(17.69)	381(1.41)	21902(80.91)	27071(100)
ST	3717(13.96)	193(0.72)	22716(85.32)	26626(100)
OBC	9382(16.09)	718(1.23)	48209(82.68)	58309(100)
Others	4371(15.14)	344(1.19)	24164(83.67)	28879(100)
Educational status				
No education	5835(17.91)	489(1.50)	26257(80.59)	32581(100)
Primary	3438(17.64)	254(1.30)	15793(81.05)	19485(100)
Secondary/Higher	14035(14.67)	979(1.02)	80682(84.31)	95696(100)
Wealth Quintiles				
Poorest/Poorer	10163(17.1)	788(1.33)	48472(81.57)	59423(100)
Middle	4961(15.69)	336(1.06)	26322(83.25)	31619(100)
Richer/Richest	8184(14.43)	598(1.05)	47938(84.52)	56720(100)
Religion				
Hindu	18474(16.64)	1336(1.20)	91184(82.15)	110994(100)
Muslim	3088(15.46)	282(1.41)	16609(83.13)	19979(100)
Christian	876(8.57)	37(0.36)	9304(91.06)	10217(100)
Others	870(13.24)	67(1.02)	5635(85.74)	6572(100)
Geographic region				
Northern states	5151(17.67)	411(1.41)	23587(80.92)	29149(100)
Central states	6550(18.03)	588(1.62)	29198(80.36)	36336(100)
Eastern states	4406(14.92)	255(0.86)	24868(84.22)	29529(100)

	LBW, n (%)	VLBW, n (%)	Normal Weight, n (%)	Total n (%)
North Eastern states	1994(9.78)	117(0.57)	18287(89.65)	20398(100)
Western states	2274(17.48)	170(1.31)	10567(81.22)	13011(100)
Southern States	2933(15.17)	181(0.94)	16225(83.90)	19339(100)
Anaemia				
Severe/Moderate	6634(18.11)	512(1.4)	29483(80.49)	36629(100)
Mild	4705(14.64)	316(0.98)	27117(84.38)	32138(100)
Not Anaemic	6806(13.81)	408(0.83)	42074(85.36)	49288(100)
Tobacco use				
User	1876(13.92)	118(0.88)	11485(85.21)	13479(100)
Non-user	21432(15.96)	1604(1.19)	111247(82.85)	134283(100)
Alcohol				
No	22973(15.82)	1705(1.17)	120566(83.01)	145244(100)
Yes	335(13.3)	17(0.68)	2166(86.02)	2518(100)
Thyroid Disease				
No	22797(15.75)	1674(1.16)	120294(83.1)	144765(100)
Yes	355(15.67)	35(1.55)	1875(82.78)	2265(100)
First ANC visit				
During 1st Trimester	14370(15.15)	1049(1.11)	79445(83.75)	94864(100)
After 1st Trimester	5855(16.17)	404(1.12)	29941(82.71)	36200(100)
Recommended ANC care				
Appropriate	18711(16.56)	1435(1.27)	92829(82.17)	112975(100)
Inappropriate	4597(13.21)	287(0.83)	29903(85.96)	34787(100)
Place of delivery				
Home delivery	1964(17.58)	160(1.43)	9049(80.99)	11173(100)
Institutional	21344(15.63)	1562(1.14)	113683(83.23)	136589(100)
Pregnancy type				
Singleton	22584(15.43)	1556(1.06)	122208(83.51)	146348(100)
Multiple pregnancy	724(51.2)	166(11.74)	524(37.06)	1414(100)
Pregnancy duration				
Preterm	2459(25.97)	538(5.68)	6472(68.35)	9469(100)
Full term	20849(15.08)	1184(0.86)	116260(84.07)	138293(100)
Height				
<150 cm	9384(18.03)	718(1.38)	41958(80.60)	52060(100)
> 150 cm	13610(14.51)	977(1.04)	79242(84.45)	93829(100)
BMI				
Underweight	6278(19.53)	466(1.45)	25404(79.02)	32148(100)
Normal Weight	13544(15.14)	972(1.09)	74926(83.77)	89442(100)
Overweight	3168(13.05)	256(1.05)	20850(85.89)	24274(100)

SC- Scheduled Caste, ST- Scheduled Tribe, OBC- Other Backward Class,

ANC- Antenatal Care, BMI- Body Mass Index

Table 3. Logistic regression of the selected characteristics with birth weight <1500gms as outcome compared with normal birth weight - Model 1.

	VLBW-Normal Birth Weight, (n= 94,705)	
	Unadjusted Odds Ratio (95% Conf. Interval)	**Adjusted Odds Ratio (95% Conf. Interval)**
Gender		
Male	Ref	Ref
Female	1.22 (1.06-1.39) ***	1.36(1.15 to 1.60) ***
Birth order		
One to three	Ref	Ref
>4	1.27 (1.08-1.49) **	0.8(0.63 to 1.01)
Age of the mother		
13–19 years	1.57 (1.25-1.96) ***	1.58 (1.22 to 2.07) **
20–34 years	Ref	Ref
>35 years	1.27 (9.97-1.70)	1.3 (0.92 to 1.86)
Education		
No education	1.45 (1.25-1.68) ***	1.24(0.99 to 1.55)
Primary	1.25 (1.30-1.52) *	0.95(0.75 to 1.20)
Secondary	Ref	Ref
Social Group		
SC	1.14 (0.92-1.42)	1.05(0.79 to 1.39)
ST	1.00(0.76-1.30)	0.81(0.53 to 1.17)
OBC	1.04 (0.86-1.27)	0.96(0.76 to 1.22)
Others	Ref	Ref
Wealth index		
Poorest/Poorer	1.24 (1.06-1.45) **	1.18 (0.92 to 1.51)
Middle	0.95(0.79-1.15)	0.87(0.68 to 1.11)
Rich/Richest	Ref	Ref
Geographic region		
Northern states	1.07 (0.83-1.37)	1.01(0.73 to 1.42)
Central states	1.99 (0.94-1.52)	1.05(0.78 to 1.42)
Eastern states	0.62 (0.47-0.81) *	0.47(0.33 to 0.67) ***
North Eastern States	0.71 (0.52-0.98) *	0.77 (0.50 to 1.18)
Western states	Ref	Ref
Southern States	0.72(0.54-0.07) *	0.71 (0.49 to 1.03)
Anaemia		
Severe/Moderate	1.75 (146-2.09) ***	1.61(1.34 to 1.94) ***
Mild	1.30(1.05-1.63) *	1.3(0.92 to 1.54)
Not anaemic	Ref	Ref

	VLBW-Normal Birth Weight, (n= 94,705)	
	Unadjusted Odds Ratio (95% Conf. Interval)	**Adjusted Odds Ratio (95% Conf. Interval)**
Tobacco Use		
Users	0.93(0.72-1.18)	1.18(0.84 to 1.65)
Non-user	Ref	Ref
Alcohol drinking		
Yes	1.00 (0.49-2.04)	0.81(0.33 to 1.95)
No	Ref	Ref
Recommended ANC[a]		
No	1.63 (1.36-1.96) ***	1.47(1.31 to 1.90) **
Yes	Ref	Ref
Pregnancy type		
Multiple	25.09 (19.30-32-60) ***	21.34 (14.70 to 30.96) ***
Singleton	Ref	Ref
Height		
<150 cm	1.53 (1.33-1.76) ***	1.54 (1.29 to 1.85) ***
> 150 cm	Ref	Ref

*p<.05

**p<.01

***p<.001

[a]ANC in first trimester, at least four antenatal visits, at least one tetanus toxoid (TT) injection and iron folic acid tablets or syrup taken for 100 or more days.
SC- Scheduled Caste, ST- Scheduled Tribe, OBC- Other Backward Class, ANC- Antenatal Care

Table 4. Logistic regression of the selected characteristics with birth weight 1500-2499 g as outcome compared with normal birth weight (Model 2).

	LBW-Normal Birth Weight, (n= 111,266)	
	Unadjusted odds ratio (95% Conf. Interval)	**Adjusted Odds Ratio (95% Conf. Interval)**
Gender		
Male	Ref	Ref
Female	1.18 (1.14-1.23) ***	1.21(1.15 to 1.26) ***
Birth order		
One to three	Ref	Ref
>4	1.09 (1.03-1.15) **	0.86(0.80 to 0.92) ***
Age of the mother		
13–19 years	1.19 (1.11 -1.28) ***	1.17(1.06 to 1.26) **
20–24 years	Ref	Ref
>35 years	1.04(0.95-1.15)	1.1 (0.96 to 1.25)

	LBW-Normal Birth Weight, (n= 111,266)	
	Unadjusted odds ratio (95% Conf. Interval)	**Adjusted Odds Ratio (95% Conf. Interval)**
Education		
No education	1.23(1.18-1.29) ***	1.08(1.02 to 1.15) *
Primary	1.25(1.17-1.32) ***	1.16(1.08 to 1.25) **
Secondary	Ref	Ref
Social group		
SC	1.16(1.09-1.24) ***	1.07(0.99 to 1.16)
ST	1.25(1.16-1.34) ***	1.13(1.03 to 1.24) **
OBC	1.06(1.01-1.12) *	1.02 (0.95 to 1.10)
Others	Ref	Ref
Place of residence		
Rural	1.08 (1.03-1.13) **	1(0.94 to 1.06)
Urban	Ref	Ref
Wealth index		
Poorest/Poorer	1.22(1.17-1.28) ***	1.11(1.03 to 1.19) **
Middle	1.13(1.07-1.19) ***	1.06(0.99 to 1.14)
Rich/Richest	Ref	Ref
Geographic region		
Northern states	1.10(1.02-1.18) *	1.09(0.98 to 1.20)
Central states	1.07(0.99-1.14)	0.97(0.88 to 1.06)
Eastern states	0.82(0.76-0.88) ***	0.75(0.68 to 0.82) ***
North Eastern States	0.71(0.65-0.77) ***	0.61 (0.55 to 0.69) ***
Western states	Ref	Ref
Southern States	0.84(0.77-0.91) ***	0.90(0.82 to 0.99) **
Anaemia		
Severe/Moderate	1.30(1.24-1.37) ***	1.20(1.13 to 1.26) ***
Mild	0.99(0.94-1.05)	0.95(0.89 to 1.01)
Not anaemic	Ref	Ref
Tobacco Use		
Users	0.84(0.78-0.91) ***	0.96 (0.87 to 1.06)
Non-user	Ref	Ref
Alcohol drinking		
Yes	0.91(0.75-1.10)	0.94(0.76 to 1.16)
No	Ref	Ref
Recommended ANC[a]		
No	Ref	Ref
Yes	0.74(0.70-0.78) ***	0.78(0.73 to 0.83) ***

	LBW-Normal Birth Weight, (n= 111,266)	
	Unadjusted odds ratio (95% Conf. Interval)	**Adjusted Odds Ratio (95% Conf. Interval)**
Multiple Pregnancy		
Multiple	8.51(7.24-10.00) ***	8.68 (7.05 to 10.68)
Singleton	Ref	Ref
Height		
<150 cm	1.35 (1.30-1.41) ***	1.36(1.29 to 1.43) ***
> 150 cm	Ref	Ref

*p<.05

**p<.01

***p<.001

[a]ANC in first trimester, at least four antenatal visits, at least one tetanus toxoid (TT) injection and iron folic acid tablets or syrup taken for 100 or more days.

SC- Scheduled Caste, ST- Scheduled Tribe, OBC- Other Backward Class, ANC- Antenatal Care

the causal pathway. The study confirms that, VLBW is associated with several explanatory variables across different domains in the conceptual model, except the socio-economic determinants.

In our study girl children reported higher odds of presenting with LBW phonotypes as compared with boys. This is consistent with findings from other studies[12,13]. Male children in general have a tendency for higher birth weights and they are about 150 g heavier when compared to a female child and this difference in weight occurs often after 28 weeks of gestation[14,15]. Stunting in mothers is a significant predictor of both the LBW phenotypes. Comparison of our findings with those from other studies confirms that stunted mothers give birth to LBW child more often[16,17] and it could be related to the growth restriction of the fetus in the smaller uterus of stunted mothers[15].

Our study showed association between birth order and LBW and age of the mother with both LBW and VLBW. Similar studies conducted elsewhere showed consistent findings related to the influence of maternal age and birth order on the birth weight of the child[18–20]. Maternal undernourishment and anaemia may have reflective effects on maternal weight gain and thereby birth weight of the child[21,22]. In our study, moderate to severe anaemia was associated with higher propensity for VLBW.

We demonstrate that educational status is an independent predictor of LBW. The odds of LBW were higher among mothers with “no education or primary level education” when compared with mothers with secondary level education. Educational level of the mother is one of the predictors of LBW in low-income countries[12,23,24]. However, we could not determine consistent association between educational status of mother with VLBW. Similarly, our study did not establish relationship between child’s wealth quintile and VLBW. In contrast, a previous study from Brazil suggested an inverse association between family income with prevalence rates of VLBW[25]. Further, belonging to a Scheduled Tribe increased the odds for LBW in our study. However, no evidence for increased risk of VLBW was detected for Scheduled Tribe population in our study and this is in contrast to the previous findings[19,26].

Similar to the results of previous studies, our study demonstrates the association between lack of appropriate ANC and LBW phonotypes[27–29]. Evidence suggest that social determinants of health play a major role in access to health care, especially maternal health care in India. In India, the most pertinent social determinants influencing maternal health service utilization include socio-economic status, caste/ethnicity, education, gender, and religion[30–33]. Along with the above determinants, reports from NFHS-4 also points towards the influence of lack of husband’s participation in ANC and unintended pregnancies on lowering the odds for ANC utilization[33]. Furthermore, the interaction between wealth and literacy is found to have a very strong role in maternal health care utilization indicators in India[34]. The utilization of ANC and their determinants need to be explored in detail to recognize the barriers and opportunities to advance maternal health services in India.

Multiple pregnancies increased the odds of LBW and VLBW in our study. In India, there has been a progressive increase in availability of assisted reproductive technology (ART) services along with the advances in ART[35–37]. ART facilities like *in vitro* fertilization has raised the incidence of multiple pregnancy in the country due to preference for multiple embryo transfer, which increases the chance of a pregnancy[38,39]. Additionally, maternal parity is known to influence the incidence of LBW and VLBW infants[40–43].

Our study has some limitations. Firstly, birth weight was missing for more than 30,000 deliveries. The missing data were more from mothers who were from the marginalized communities. Mothers from lower socio-economic strata and disadvantaged population are known to have higher occurrence of LBW. Thus, our analysis could underestimate the various socio-economic factors associated with LBW in India. Secondly, information collected from the mothers on the antenatal and natal factors were from the past five years. Hence, the data quality is likely to be affected by recall bias.

Conclusion

Despite having several common risk factors with the phenotypes of LBW and VLBW, the relationship is different in both the groups. For example, the social and economic determinants are unique to LBW. The VLBW is prominently associated with several genetic, nutritional, and demographic factors. The increasing trend in rate of multiple pregnancy and its association with VLBW poses a public health concern. Taken together, our results suggest that interventions geared towards improvements in antenatal care access, maternal health and nutritional status may reduce the number of VLBW infants in India. Interventions focused on reducing the number of VLBW infants can ultimately reduce infant mortality. Further, it may reduce the future burden of cardiovascular and metabolic disease conditions that are associated with VLBW.

Data availability

Our study used data from the from individual recode file IAIR74DT, of the Demographic and Health Survey of India. The file mainly includes information on women in reproductive age group. Access to the data from DHS could be done using the link: https://www.dhsprogram.com/data/dataset/India_Standard-DHS_2015.cfm?flag=0 which needs prior registration of the research proposal. We registered our study with the DHS program and got access to the data. A guide for how to apply for dataset access is available at: https://dhsprogram.com/data/Access-Instructions.cfm. Supplementary Table 1 is available at 10.6084/m9.figshare.18393749). Supplementary Table 2 is available at 10.6084/m9.figshare.18393758)

Additional supplementary tables generated during the article revision process is available at Supplementary Table 3: 10.6084/m9.figshare.19556461, Supplementary Table 4: 10.6084/m9.figshare.19556470 and Supplementary Table 5: 10.6084/m9.figshare.19556476.

Author contributions

Liss Maria Scaria: Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft Preparation

Biju Soman: Methodology, Supervision, Writing –Review & Editing

Babu George: Methodology, Resources, Supervision, Writing –Review & Editing

M Zulfikar Ahamed: Methodology, Resources, Supervision, Writing –Review & Editing

Sankar Vaikom Hariharan: Methodology, Resources, Supervision, Writing –Review & Editing

Panniyammakal Jeemon: Conceptualization, Funding Acquisition, Methodology, Resources, Supervision, Writing –Review & Editing

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Open Peer Review

Current Peer Review Status: ✔ ✔

Version 2

Reviewer Report 06 June 2022

https://doi.org/10.21956/wellcomeopenres.19825.r50617

✔

Malinee Laopaiboon
Department of Epidemiology and Biostatistics, Faculty of Public Health, Khon Kaen University, Khon Kaen, Thailand

I am happy with the updated version and approve it.

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 11 March 2022

https://doi.org/10.21956/wellcomeopenres.19311.r48917

✘

Malinee Laopaiboon
Department of Epidemiology and Biostatistics, Faculty of Public Health, Khon Kaen University, Khon Kaen, Thailand

1. This study was aimed to describe the determinants of very low birth weight (VLBW) in India based on the National Family Health Survey. However, the authors present the results of determinants of both VLBW (bw<1500 gm) and LBW (BW between 1500 and 2499 gm) infants. The results of LBW are out of this study's aim.

I would suggest to analyse determinants of VLBW using infants with BW 1500-2499 gm to be another reference group compared to the results with the reference of normal BW infants. It may give more information to the readers.

2. We could call this data set a historical cohort. There was only 1.2 % of VLBW, which was rare. I would suggest using Poisson or negative binomial regression.

3. The authors present some errors,
   3.1 LBW in the methods of abstract section as BW <2500 gm.

   3.2 prevalence of categories of some factors should be in reverse categories as they are not consistent to adj OR, e.g. prevalence of multiple pregnancy (15.6%) versus single pregnancy (58.01%) while adjOR of multiple pregnancy was 8.68 for LBW, etc.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: maternal and child health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 10 May 2022

Panniyammakal Jeemon, Sree Chitra Thirunal Institute for Medical Sciences and Technology, Trivandrum, India

We thank the reviewer for their detailed comments. Please find below our response to the comments.

Comment: This study was aimed to describe the determinants of very low birth weight (VLBW) in India based on the National Family Health Survey. However, the authors present the results of determinants of both VLBW (BW<1500 gm) and LBW (BW between 1500 and 2499 gm) infants. The results of LBW are out of this study's aim.
Response: Thank you, we have modified the objective statement of the study as;
"We aim to describe the determinants of very low birth weight (VLBW) in India and compare it with the determinants of Low Birth Weight (LBW) based on the National Family Health Survey – 4 (NHFS-4)"
Comment: I would suggest analysing determinants of VLBW using infants with BW 1500-2499 gm to be another reference group compared to the results with the reference of normal BW infants. It may give more information to the readers.
Response: Thank you. As suggested, we analysed the determinants of VLBW using infants with BW 1500-2499 gm as another reference group and compared the results with the reference of normal BW infants. The results are included as supplementary table 4 (10.6084/m9.figshare.19556461) and supplementary table 5 (10.6084/m9.figshare.19556470).
The results show that in the multivariable logistic regression model, mothers aged 13–19 years had higher odds for VLBW when compared with mothers aged 20–34 years (aOR: 1.35, 95% CI: 1.02–1.77). The odds of VLBW were 1.34 -times higher in mothers with severe or moderate anaemia *versus* non-anaemic mothers (aOR: 1.34, 95% CI: 1.10–1.62). Children from Eastern states had lower odds for VLBW (aOR: 0.62, 95% CI: 0.43–0.88) as compared with children from Western states. The odds of having VLBW was 2.20-times higher (aOR: 2.21, 95% CI: 1.53–3.17) among children of mothers with the multiple pregnancy *versus* singleton pregnancy. Preterm birth had higher odds of VLBW compared to term birth (aOR: 3.55, 95% CI: 2.90–4.33).
Comment: We could call this data set a historical cohort. There was only 1.2 % of VLBW, which was rare. I would suggest using Poisson or negative binomial regression.
Response: Thank you, we have done a Poisson Regression model and the results are added as supplementary table 3 (10.6084/m9.figshare.19556476). The Poisson model yielded similar results that of logistic regression model. Children who belonged to **scheduled tribe** had lower Incidence Rate Ratio (IRR) for VLBW versus children from other forward caste (IRR: 0.56, 95% CI: 0.45–0.69), (Logistic regression model: aOR: 0.82, 95% CI: 0.56 to 1.19). Children from **rich or richest wealth quintiles and middle wealth quintiles** had lower IRR of VLBW versus those from poorest/poorer wealth quintiles (IRR: 0.77, 95% CI: 0.65–0.91), (Logistic regression model: aOR: 0.89, 95% CI: 0.69 to 1.15).
Comment: The authors present some errors
3.1 LBW in the methods of abstract section as BW <2500 gm.
Response: Thank you, we have corrected the LBW as Birth Weight 1500-2499 gm.
3.2 Prevalence of categories of some factors should be in reverse categories as they are not consistent to adj OR, e.g., prevalence of multiple pregnancy (15.6%) versus single pregnancy (58.01%) while adjOR of multiple pregnancy was 8.68 for LBW, etc.
Response: Thank you, the prevalence of LBW in single pregnancies is 15.6% and the prevalence of LBW in multiple pregnancies is 58.8%. Therefore, the adjusted OR of multiple pregnancy is 8.68 for LBW. Thus, the results are consistent with the data.

Competing Interests: No competing interests were disclosed.

Reviewer Report 07 March 2022

https://doi.org/10.21956/wellcomeopenres.19311.r48520

Aditi Apte
Vadu Rural Health Program, KEM Hospital Research Centre, Pune, Maharashtra, India

1. Title - Informative and balanced summary of what was done but does not mention about study design.

2. Introduction:

   Background & rationale - explains scientific background and rationale of study.

   Study design and setting - explained well.

   Selection criterion - well explained.

   Variables - clearly defined all outcomes, exposure, predictors but does not mentioned about potential confounders and effect modifiers. Also, number of USGs done in ANC period not taken into consideration.

3. Data sources - provided information about from where the data was extracted.

4. Bias - Not explained about efforts to address potential bias.

5. Study Size - explained well about sample size.

6. Statistical Methods - Multivariate analysis used but not mentioned how missing data was addressed.

7. Results - details about participants, descriptive and outcome data give. But, in the main results, the unadjusted estimates not given. Which confounders were adjusted for and why they were included is not mentioned in the study?

8. Discussion - Key results are summarised.

9. Limitations of study explained.

10. Generalisability – External validity of study results not discussed.

Above study has not taken into consideration one of the important social determinant i.e. about familial pressure on the woman for the want of male child which is responsible for higher birth order and subsequently LBW baby.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Maternal and child health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 10 May 2022

Panniyammakal Jeemon, Sree Chitra Thirunal Institute for Medical Sciences and Technology, Trivandrum, India

Thank you very much for approving our manuscript. Our responses to the comments are given below.

Comment: Title - Informative and balanced summary of what was done but does not mention about study design.

Response: The study title mentions NFHS-4, which indicates that it is a secondary data analysis of an existing national survey.

Comment:
Introduction: Variables - clearly defined all outcomes, exposure, predictors but does not mention about potential confounders and effect modifiers. Also, number of USGs done in ANC period not taken into consideration.
Response: Number of USGs done were classified into less than four and more than four and was used to calculate the variable ‘Antenatal care appropriate or not’. The confounders were adjusted in Model-1 and Model-2.

Comment: Data sources -provide information about from where the data was extracted.
Response: We have provided the source of NFHS-4 data.

Comment: Bias - Not explained about efforts to address potential bias.
Response: We used secondary data analysis for this study. National Family Health Survey data were collected by standardized techniques. This dataset was used widely in the Indian context. We have absolutely no control to address for any bias in the design or data collection. We have however identified potential confounding factors and included them in the multivariable model.
Comment: Study Size - explained well about sample size.
Response: Thank you.
Comment: Statistical Methods - Multivariate analysis used but not mentioned how missing data was addressed.
Response: The missing data in this study were considered missing and excluded from analysis. However, it was only a small fraction and may not have any significance in changing the effect estimates.

Comment: Results - details about participants, descriptive and outcome data given. But, in the main results, the unadjusted estimates not given. Which confounders were adjusted for and why they were included is not mentioned in the study?
Response: We have modified Table 3 and Table 4 to include unadjusted estimates. We used the following variables in the model as potential confounders, gender, birth order, mother's age, education, social group, wealth index, geographic region, anaemia, tobacco use, alcohol use, ANC care, pregnancy type and height.

Comment: Generalisability – External validity of study results not discussed. Above study has not taken into consideration one of the important social determinants i.e., about familial pressure on the woman for the want of male child which is responsible for higher birth order and subsequently LBW baby.
Response: Thank you, NFHS-4 is a large database. It covers 28 states and 6 Union Territories. It is one of the large databases in India. Therefore, the findings are externally valid in the Indian population.
Our study shows that birth order is a determinant of LBW. Further data and investigation are required to establish relationship between familial pressure on the woman for the want of male child which leads to higher birth order and subsequently having LBW baby.

Competing Interests: No competing interests were disclosed.