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A Bayesian quantile regression approach for determining risk factors of low birth weight of under five children in Cambodia

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Birth weight (BW) is a key indicator of a newborn's health, survival, and development. It is associated with the risk of childhood mortality and is also related to health, physical growth, emotional well-being, and academic success throughout both childhood and adulthood. Therefore, it is crucial to pinpoint the sociodemographic characteristics that have an impact on BW. This study aimed to explore the risk factors associated with children's low birth weight using the latest nationwide secondary data extracted from the Cambodia Demographic and Health Survey (CDHS) 2021/22. The study included a weighted sample of 4701 children from the CDHS 2021–22 data. Multivariable simultaneous quantile regression models in a Bayesian setting were used to determine the factors associated with Cambodian children's low birth weight. The average BW is 3.064 (SD 0.483 kg) kg. It is observed that there are some outliers in the target variable and the birth weight of the child is deviated from normal distribution. Women who are young (15–17 years) for their first baby have more low BW infants overall than women who have their first babies later. For mothers aged 18–24 years, children's birth weight increases by 0.068 to 0.149 points when moving from the 10th to the 50th quantile. For overweight mothers, children's birth weight increases by 0.123 to 0.348 points when moving from the 10th to the 90th quantile. It is observed that the prevalence of smaller size of children comes from illiterate mothers and the prevalence decreases as the mother's education increases. More small children are born in rural areas than in urban areas in Cambodia. Our study findings show that the mother's poor economic status is one of the major risk factors for LBW. Moreover, the birth weights of children from the richest families in the 10th, 20th, 50th, 75th, and 90th quantiles are increased by 0.075, 0.058, 0.111, 0.114, and 0.053 points respectively. The child's sex and birth order, the mother's age at first birth, her education level and BMI, the number of ANC visits during pregnancy, drinking water sources, types of bathroom facilities, place of residence, and wealth index are all related to the child's size. Furthermore, mothers who have low education levels and grew up in low-income households require special consideration. To lessen the number of low birth weight babies, the authors suggest that the Cambodian government may prioritize food and health education in its school system. Additionally, the authors think that the policymakers will benefit from these findings in order to achieve SDG-3.

Keywords Birth weight, Bayesian approach, Cambodia, Quantile regression

Birth weight (BW) is a crucial indicator of a newborn baby's health, survival, and development. It is also linked to academic success in both childhood and adulthood BW is a combination of foetal growth and gestational duration, each of which has various influences[1]. Infants born in rural areas, whose antenatal care (ANC) visits had started later than average, and whose mothers had low economic status were shown to have considerably lower BW[2–8]. Infants born weighing less than 2.5 kg are more likely to suffer from malnutrition and childhood illnesses including pneumonia and diarrhoea[5,9]. The sex of a child is also linked with the birth weight[10]. Low birth weight (LBW) is regarded as the single most significant determinant of child mortality, particularly for deaths that occur within the first month of life[11,12]. The high prevalence of stunting has also been connected to LBW in low-income nations[13]. In Cambodia, 6% of births (1% of all births) for which the mother was able to report the baby's weight were categorized as low birth weight in 2000[14]. In 2010, the prevalence of low birth weight was 8% and across provinces, the percentage of low birth weight babies ranged from 5 to 12%. However,

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there was a wide range in the percentage having a recorded birth weight, ranging from a low of 38% in Mondol Kiri/Rattanak Kiri to a high of 96% in Phnom Penh[15]. In 2021–2022, the prevalence of low birth weight was 6% in Cambodia[16].

Several studies have examined the connection between birth weight and maternal education and undernutrition, obstetrics, maternal medical complications during pregnancy, or lifestyle variables that could potentially affect birth weight[13,17–21]. Birth weight can also be affected by a mother's education level, body mass index (BMI), occupation, and lifestyle choices like her eating habits or her use of tobacco or caffeine, inadequate minimum dietary diversity score of mothers[10,13,22–25]. Low birth weight was linked to household child hunger, mother hypertension, and alcohol use[26]. In underdeveloped nations, low birth weight is a significant public health concern. Therefore, it is crucial to pinpoint the factors that have an impact on BW so that the proper policy interventions can be developed to further enhance child survival and health.

Furthermore, previous studies available in the literature have mostly used binary or linear regression techniques to investigate the factors that affect birth weight. However, at various points and in the presence of outliers, the mean and standard deviations of the covariates may be over or underestimated[27–29]. Compared to other regression models, the quantile regression (QR) modelling approach produced more unbiased estimates for skewed data and in the presence of outliers[30]. Several researchers have also used the QR model in their studies in the field of health sciences[31–39]. However, there is a scarcity of exploring the risk factors of low birth weight of children in Cambodia using quantile regression in a Bayesian setting. The use of Bayesian inference brings some advantages, e.g., we can incorporate prior information or beliefs about the parameters of interest in our research by using Bayesian inference. It also provides a full probability distribution for the parameters of interest, which includes not only point estimates (like the MLE) but also information about the uncertainty associated with those estimates. Therefore, to fill up this backdrop, the authors intended to identify the risk factors linked with the low birth weight of children using the most recent countrywide CDHS-2021/22 data in the Bayesian setting.

Materials and methods

Data source

The research is based on the secondary dataset from Cambodia's most recent Demographic and Health Survey (CDHS)-2021/22. In this survey, 241 and 468 urban and rural enumeration areas (a counting unit created for the population census, defined by the census in the country) respectively were chosen via the probability proportional size sampling approach for the first stage of the two-stage stratified sample of households utilized in the survey. A comprehensive list of each household in the chosen enumeration areas was created in the first phase for the second phase's family selection. Using a systematic sampling procedure, 30 houses from each enumeration area were chosen in the second phase, resulting in 20,806 households with 8153 children. Prior to the analysis, the weighted sample is used in this study for countrywide representation. The detailed sampling procedure is available in the final CDHS-2021/22 report[16]. After weighing the sample, the authors identify the potential covariates for the modeling. Then remove the missing values from the dataset. The final sample had 4701 children.

Variables

In quantile regression analysis, we use the birth weight of children as the dependent variable. However, in the bivariate analysis, we consider the child's size as it is categorized based on the birth weight. The size of a child at birth is categorized as smaller than average (very small and smaller than average), average, and larger than average (larger than average and very large). In this study, child characteristics including sex of children (male, female), child's birth order (1st, 2nd, 3rd, 4th or more), and parental characteristics such as mother's age at first birth in years (15–17, 18–24, 25–34, 35–49 years), mothers' education level (no education, primary, secondary or higher), fathers education level (no education, primary, secondary or higher), mothers' body mass index (underweight, normal, overweight) are considered as covariates. Moreover, household characteristics, e.g., source of drinking water (safe, unsafe), toilet facility (modern, pit latrine, others), family wealth index (poorer, poorest, middle, richer, richest), religion (Buddhist, non-Buddhist), number of antenatal care (ANC) visits during pregnancy (no visits, 1–3, 4–7, 8 or more) and place of residence (rural, urban) considered as covariates. The choice of the covariates depends on the existing literature, self-efficacy, and availability in the CDHS-2021/22 dataset.

Statistical methods

The χ^2 test is used in bi-variate analysis for identifying the significant socioeconomic and demographic variables of the size of children. The authors consider a 5% level of significance for identifying the significant covariates of child size at birth. Relations among some variables with the size of the child at birth are presented by a Sankey diagram[40]. The boxplot and quantile-quantile (QQ) plot are used for checking the presence of outliers and normality of the birth weight of children. Moreover, quantile regression (QR) is used for modeling the birth weight in a Bayesian setting. Even for a small sample, the Bayesian approach allows for accurate and full inference. Koenker and Basset first presented the QR model in 1978[41]. Recently, there has been a lot of interest in Bayesian inference on quantile regression. The details of this method are presented in the Supplementary Material. The author used "Brq" software package available in R[42]. The 0.10, 0.20, 0.50, 0.75, and 0.90 quantile levels were taken into account in this study which is consistent with previous studies[34,43–46].

Ethical approval

Not necessary because this study used secondary data that is readily available to the public. Additionally, the survey was approved by the ethics committees of the ICF Macro in Calverton, USA, and Cambodia.

Results

The percent distribution of the size of children at birth by different demographic and socioeconomic characteristics is given in Table 1. The percentage of average-sized male and female children was 41.72% and 48.39%, respectively. It is observed that approximately 52.16% of male children and around 44.87% of female children were larger than normal at birth. Mothers whose age at first birth is between 15 and 17 years have more children having smaller than average size compared to the other age group of mothers at first birth (Table 1).

Findings depict that underweight mothers give more births of size smaller than average compared to normal and overweight mothers. Mothers' education also plays a significant role in the birth weight of children. More than 7% of newborns delivered to illiterate mothers were smaller than average in size. It is observed that the prevalence of smaller size of children comes from illiterate mothers and the prevalence decreases as the mother's education increases. The association between the size of the child at birth with the father's education and religion is statistically insignificant at a 5% level of significance. More small children are born in rural areas compared to urban areas in Cambodia. Findings revealed that healthy babies are born in wealthier families (Table 1). Further relations among the sex of the child, place of residence, wealth index, and size of the child at birth are presented in Fig. 1.

Compared to urban areas, it has been noted that a higher proportion of children reside in rural regions. More children who live in urban regions come from the wealthiest and most affluent households, whereas a greater proportion of children who live in rural areas are from the poorest and most impoverished families. A greater proportion of babies born into wealthy households are average-sized or larger than average (Fig. 1).

Characteristics	Labels	Size of child at birth (%)			p-value of χ^2
		Smaller than average	Average	Larger than average	
Sex of child	Male	6.11	41.73	52.16	< 0.001
	Female	6.74	48.39	44.87	
Birth order	1	7.68	48.65	43.68	< 0.001
	2–3	5.49	42.73	51.78	
	4 or more	7.40	45.24	47.36	
Mother's age at first birth (years)	15–17	12.82	43.59	43.59	0.001
	18–24	7.86	48.57	43.57	
	25–34	5.56	43.77	50.67	
	35 or more	6.69	44.02	49.29	
Body mass index	Underweight (< 18.5)	10.11	57.45	32.45	< 0.001
	Normal (18.5–24.9)	6.04	45.75	48.21	
	Overweight (≥ 25)	5.78	40.33	53.88	
Mothers education	No education	7.31	46.67	46.02	0.094
	Primary	7.20	44.49	48.32	
	Secondary or above	5.62	45.01	49.38	
Fathers education	No education	6.04	45.86	48.10	0.285
	Primary	7.23	45.86	46.91	
	Secondary or above	5.85	44.48	49.67	
Religion	Buddhist	6.42	44.86	48.71	0.669
	Non-Buddhist	6.45	48.39	45.16	
Place of residence	Urban	5.83	43.34	50.83	0.035
	Rural	6.81	46.05	47.14	
Number of antenatal visits during pregnancy	No antenatal visits	5.77	48.08	46.15	0.007
	1–3	10.27	44.30	45.44	
	4–7	5.60	45.68	48.71	
	8 or more	5.91	44.21	49.88	
Source of drinking water	Unsafe	5.88	45.54	48.58	0.005
	Safe	7.78	43.63	48.59	
Type of toilet facility	Modern	6.08	45.12	48.80	0.046
	Pit latrine	0.00	46.15	53.85	
	Others	9.35	43.70	46.95	
Wealth index	Poorest	8.41	46.52	45.07	< 0.001
	Poorer	6.38	47.26	46.36	
	Middle	6.13	46.54	47.33	
	Richer	6.81	46.89	46.30	
	Richest	4.17	37.65	58.18	

Table 1. Percent distribution of the size of child at birth by different background characteristics.

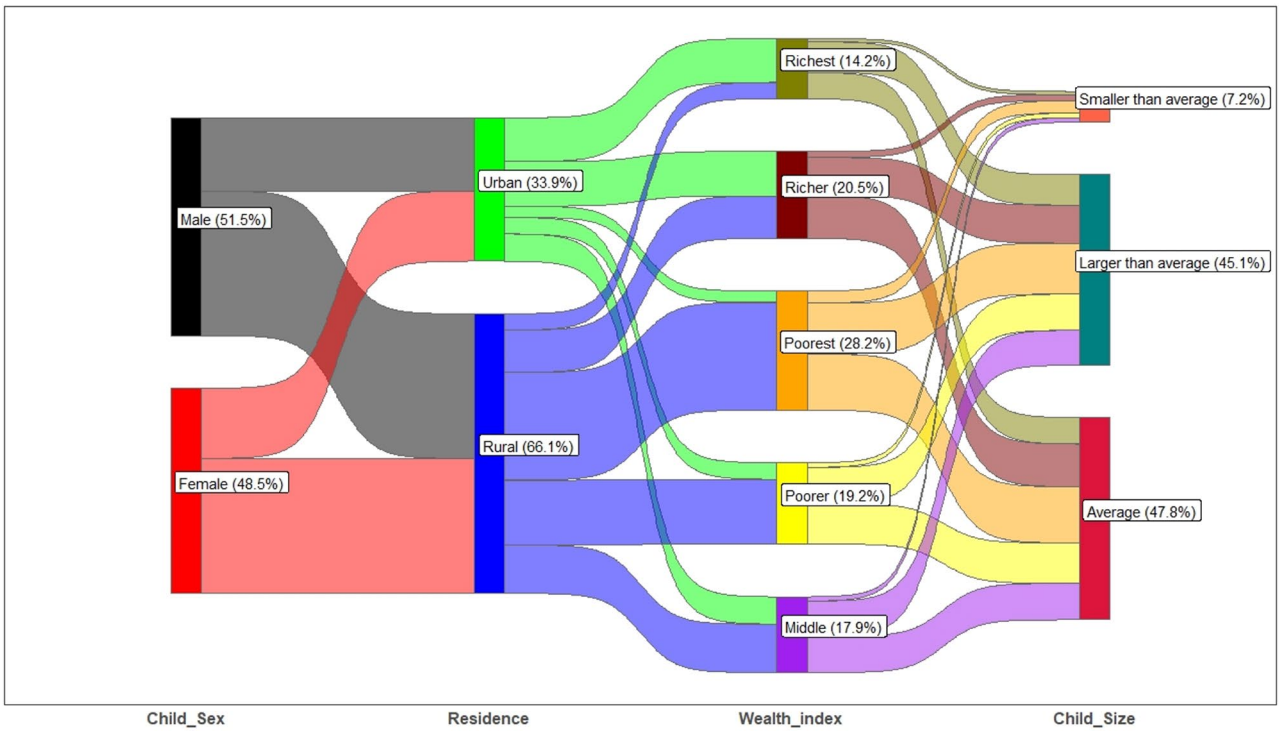


Fig. 1. Relation among the sex of the child, place of residence, wealth index, and size of child at birth.

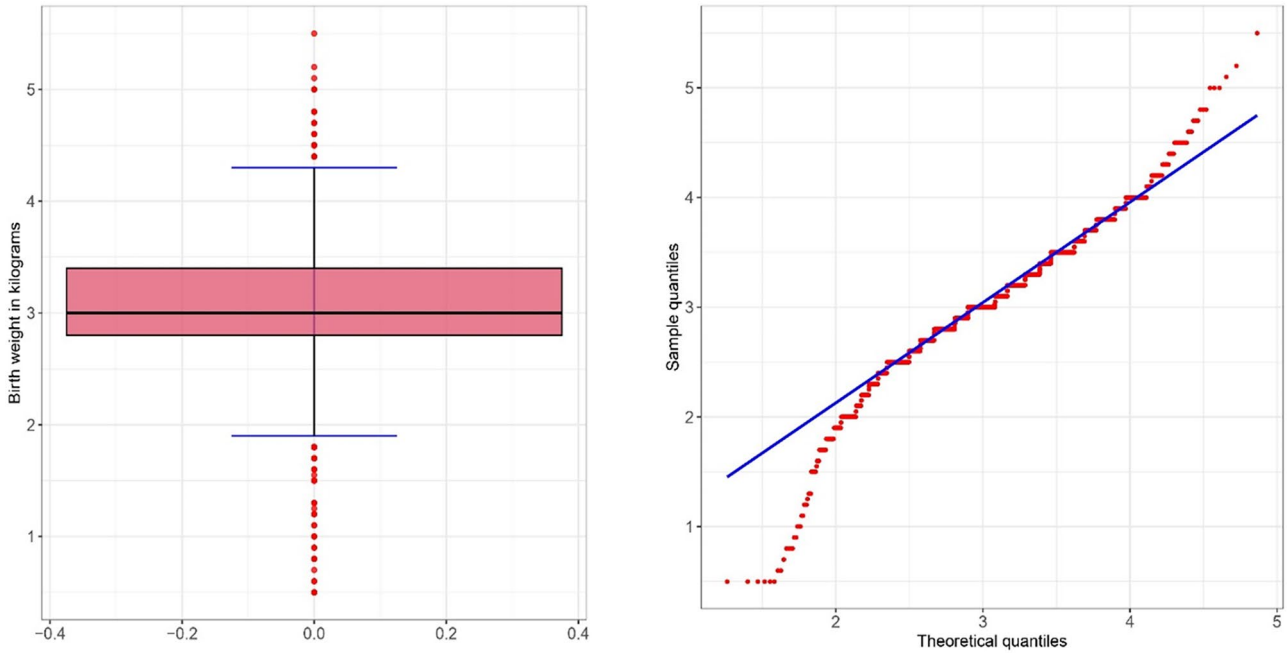


Fig. 2. Boxplot (left panel) and QQ plot (right panel) of birth weight of children.

The authors also check the presence of outliers and whether the distribution of birth weight of children is normal or not. The boxplot and QQ plot are presented in Fig. 2. It is observed that there are some outliers in the target variable and the birth weight of the child is deviated from normal distribution which justifies the use of quantile regression in this study.

From the findings presented in Table 1, it is concluded that the sex of the child, child's birth order, mother's age first birth, mother's education and BMI, number of ANC visits during pregnancy, sources of drinking water, types of toilet facility, place of residence, and wealth index were identified as the factors of the size of the child.

These factors are used in the quantile regression in a Bayesian setting. We consider 20,000 iterations and take every 10th observation after deleting the first 5,000 observations as a burn-in as the posterior sample. The diagnostic plots including trace plots, ACF plots, and density plots of posterior distribution for all parameters are observed. A few plots for 0.1 quantile are presented in Fig. 3 and other plots are presented in Figs. S1 to S4. The trace plots depict that the posterior samples are mixing well. All the ACF plots ensure that no autocorrelation is present in posterior samples.

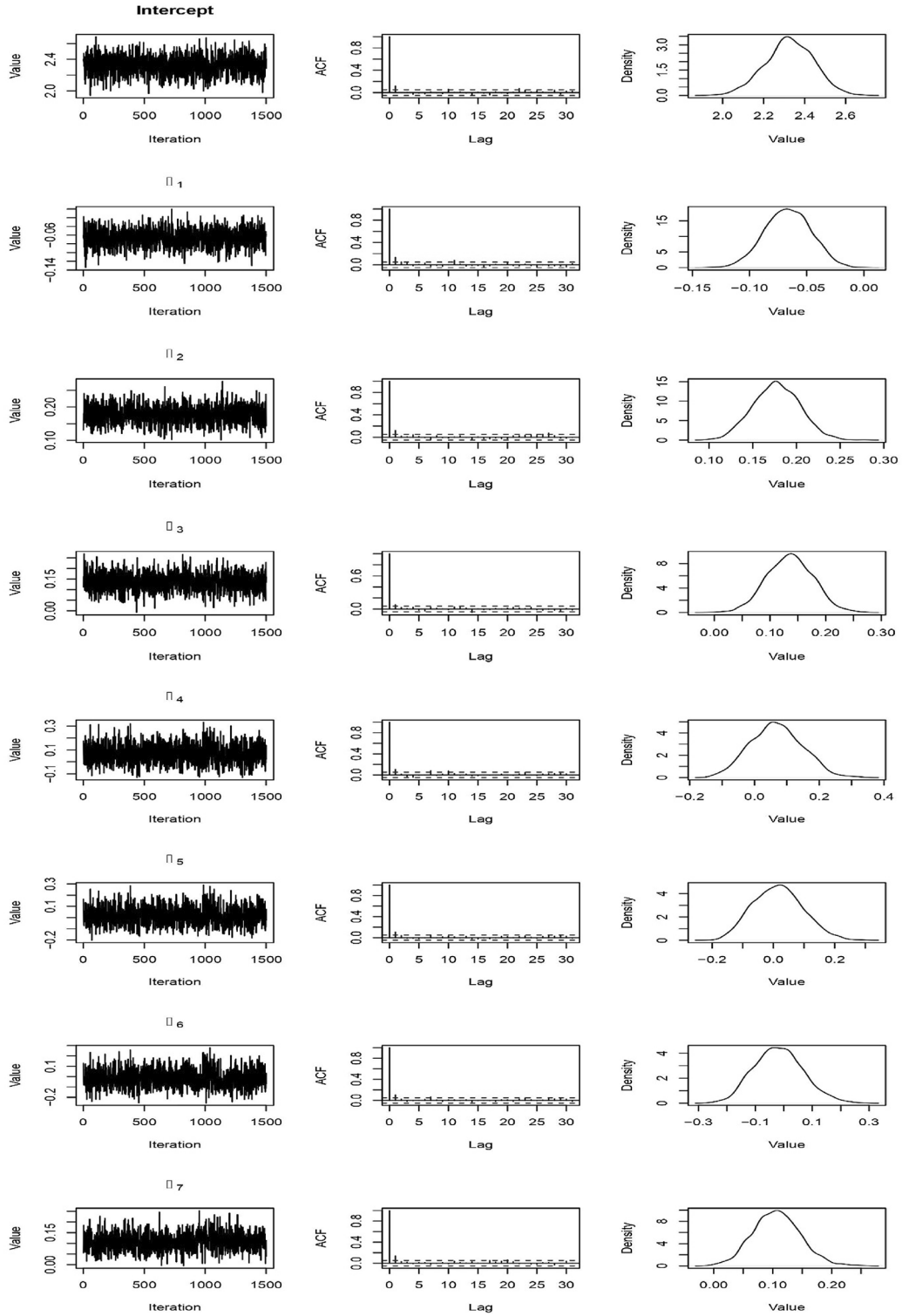


Fig. 3. Trace plots, ACF plots, and density plots of the selected variables for 0.1 quantile.

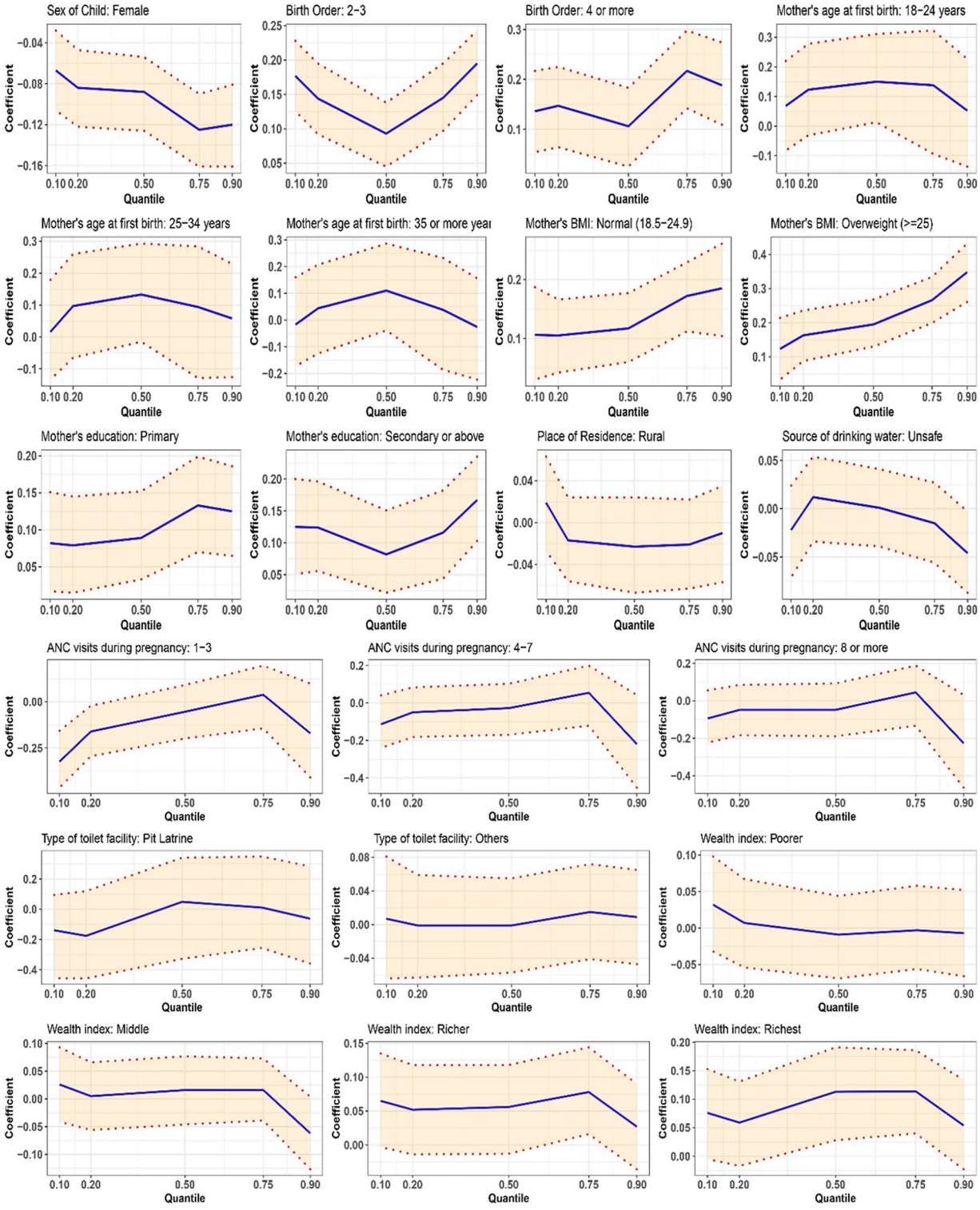


Fig. 4. Posterior mean (blue lines) of different coefficients for the selected variables with 95% credible interval (dashed red lines).

The estimate of all posterior means and their standard deviations are presented in the S1 Table. In addition, the estimate of posterior means and their 95% credible intervals (CI) are illustrated in Fig. 4. The coefficients of different variables vary in different quantiles considered in this study. The birth weight of female children decreased by 0.088 (95% CI: − 0.126 to − 0.054) and 0.125 (95% CI: − 0.161 to − 0.09) points at the 50th and 75th quantiles of the conditional distribution respectively. In the case of birth order of children for 2–3, the birth weight of children decreased from 0.177 (95% CI: 0.126 to 0.228) points to 0.093 (95% CI: 0.045 to 0.138)

points from the 10th to 50th quantile, however, after that it increased again and reached 0.195 (95% CI: 0.149 to 0.243) points at the 90th quantile. The weight of children at birth is increased by 0.068 (95% CI: − 0.083 to 0.22) points to 0.149 (95% CI: 0.013 to 0.311) points if it is moved from the 10th quantile to the 50th quantile for mothers aged 18–24 years. For overweight mothers from the 10th quantile to the 90th quantile, the birth weight of children moved from 0.123 (95% CI: 0.033 to 0.214) points to 0.348 (95% CI: 0.261 to 0.432) points. The birth weight of children is varied in different quantiles by the education of the mother. For example, at the 50th quantile, the coefficient for secondary or above-educated mothers is 0.083 and if we move from the 50th to the 90th quantile the coefficient is reached at 0.167 (Fig. 4 and S1 Table).

For children who lived in rural areas the birth weight decreased by 0.016 points at the 20th quantile, however, the birth weight declined by 0.021 points at the 75th quantile. Moreover, the birth weights of children from the richest families in the 10th, 20th, 50th, 75th, and 90th quantiles are increased by 0.075 (95% CI: − 0.005 to 0.153), 0.058 (95% CI: − 0.017 to 0.131), 0.111 (95% CI: 0.028 to 0.191), 0.114 (95% CI: 0.04 to 0.186), and 0.053 (95% CI: − 0.023 to 0.134) points respectively (Fig. 4 and S1 Table).

Discussion

The objective of this study was to investigate the correlates that influence BW in Cambodia using the latest nationwide demographic and health survey data. The average BW was determined to be 3.064 (SD 0.483 kg), which is at least 380 g less than the newborns in the USA, which is the WHO's reference standard[47]. The findings of this study also suggest that a relationship exists between the sex of a child and birth weight. A previous study found that compared to male children, low birth weight was far more common in female babies[48]. Nowadays, with advancements in medical technologies, parents can know the sex of their unborn child which may have a link with the birth weight of a child. Researchers pointed out that son preference affects birth weight, and females are more likely to have low birth weights when their parents have a stronger preference for sons[49]. The findings reveal that the birth weight of female children decreased by 0.12 points at the 90th quantile of the conditional distribution. Compared to female infants, male infants are larger at birth than the average and this finding is supported by a previous study[10]. Male children are preferred by many couples and they take good care of mothers during pregnancy[21]. According to the results, the birth weight increased by 0.132, and 0.149 points at the 20th and 50th quantile among mothers aged 18–24 compared with mothers aged 15–17 years i.e., mothers under the age of 18 years had a considerably greater chance of giving birth to LBW babies than mothers above the age of 18 years. This finding is supported by the findings of another study[10]. This may be because young mothers are still developing biologically and may not be emotionally or physically mature enough to understand the value of childbearing, self-care, and healthy eating throughout pregnancy[50]. Other experts explain this by pointing to the physiological and biological immaturity of teenage mothers and their battle with the fetus for resources and growth[51].

Results presented in the S1 Table indicate that the birth weight of a child is increased by 0.125 points and 0.167 points at the 10th and 90th quantile of mothers who have secondary or higher education compared to illiterate mothers. Child size and maternal education were both correlated and the percentage of babies who are smaller at birth decreases with each level of maternal education. This findings is supported by a previous study[12]. Higher educated women may be more concerned with their health, which makes them more likely to start and keep up regular contact with healthcare professionals. Additionally, they might embrace preventative practices including choosing qualified healthcare providers, eating healthfully, and abstaining from alcohol and smoke[3,52]. Mothers from rural areas gave birth to a higher proportion of smaller-than-average children than mothers from urban areas which is in line with earlier studies' findings[12].

Children from the wealthiest families have birth weights that are 0.111 and 0.114 points higher in the 50th and 75th quantiles, respectively. Our study findings show that the mother's poor economic status is one of the major risk factors for LBW which is consistent with a prior study[2]. Due to high costs, poorer families might not be able to buy healthful foods for expectant mothers. Additionally, undereating during pregnancy can stunt a baby's growth, which can result in low birth weight and undernourished babies[53]. The effect of low economic status may linked to different unfavorable conditions that raise the likelihood of having an undesirable pregnancy outcome. For instance, mothers with low economic status are more likely to experience nutritional deficits, which are crucial for foetal growth, and are less likely to obtain proper prenatal care[6,54,55]. In order to lower the number of low-birth children, government-subsidized healthcare programs for pregnant women must be established so that they can afford prenatal and delivery care. To track foetal growth and maternal health during pregnancy, we must also ensure routine prenatal checkups. Additionally, putting community education initiatives into action to increase knowledge of the value of healthy eating, prenatal care, and pregnancy-related behaviors. Government and non-governmental organization (NGO) food support programs for pregnant women from low-income families in rural areas need to be expanded.

Strengths and limitations

The primary strength of this study is its use of the most recent nationwide dataset and the application of quantile regression within a Bayesian framework. However, it has some limitations including causal inference is not possible because the data were collected through a cross-sectional study. In addition to the covariates considered, many other factors may influence birth weight that are not considered in this study. There is a chance of bias in the data collection and the result may be different due to the sampling variability,

Conclusion

The results of the bivariate analysis demonstrate that the sex of the child and birth order, mother's age at first birth, mother's education and BMI, number of ANC visits throughout pregnancy, drinking water sources, types

of bathroom facilities, place of residence, and wealth index is related to the size of the child. The findings of quantile regression suggest that the birth weight of children is different at different quantiles. A healthier mother may give birth to healthy children, hence having more educated and healthy women can help to reduce the prevalence of smaller size of children at delivery. We should reduce teenage pregnancies and educate mothers about the consequences of low birth weight. It is also important to ensure pregnant women have access to a balanced diet rich in essential nutrients, including iron, folic acid, calcium, and protein for gaining proper weight during pregnancy. Moreover, we have to encourage mothers to have regular prenatal check-ups to monitor fetal growth. Different awareness campaigns about the risks and prevention of LBW should be continued and for reducing early pregnancies, individuals and governments should continue programs that keep girls in school. Policymakers and health professionals must focus on the small-sized and/or low-birth-weight children to leave the group of nations with high newborn and child mortality rates. Thus, investing more money in pregnant women's health is one of the best ways to lower infant mortality and advance the general health of the country. In addition to lowering newborn, child, and maternal mortality, this will also lower the price of premature deliveries and the initial treatment given to them. Furthermore, mothers who grew up in low-income households require special consideration. Additionally, the authors think that the policymakers will benefit from these findings in order to achieve SDG-3.

Data availability

"The data is available on the DHS Program website and one can access the data set at http://dhsprogram.com/data/available-datasets.cfm".

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Author contributions

"MMH is sololy done this reserach. MMH did all tasks including conceptualization, data curation, data analysis, visualization, manuscript writing, review and editing."

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