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Modeling Maternal Factors for Predicting Birth Outcomes in Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

This study was conducted to identify the various maternal and neonatal factors that influence birth outcomes. Maternal and neonatal factors are key determinants of birth outcomes and the health of a newborn baby is very crucial in the first six months of the baby's life. Neonatal mortality and low birth weight are worrying problems for stakeholders in the health sector. Logistic regression and multilevel regression were used to study various factors that influence birth outcomes. Secondary data was therefore collected from the War Memorial Hospital, Navrongo for the purpose of the study. The results show that weight, birth weight, gestation weeks and hemoglobin were observed as significant risk factors for birth outcomes whilst age, weight, hemoglobin, mode of delivery and gestation weeks were identified as significant factors that influence birth weight. The study identified weight, hemoglobin, birth weight, gestation weeks and age as factors that influence birth outcomes in the Kassena-Nankana Municipality.

Keywords: Maternal factors; birth outcome; birth weight; binary logistic; mixed effects model.

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1 Introduction

Maternal health is very crucial not only for the health of the mother but also for the development of the fetus and the well-being of the newborn. There is a growing health concern about the effects of maternal factors on the health of newborn babies. An adverse birth outcome is defined by the World Health Organization as events of low birth weight, preterm birth, stillbirth, or perinatal death Agbozo et al. [1]. An estimated 15 million infants worldwide are born preterm, representing 5% to 18% of all live births, which are responsible for more than one million deaths among children under five years [2]. A study conducted by Kazaura et al. [3] reported that, several risk factors influences neonatal mortality. These include parity, maternal age, marital status, smoking, birth weight, gestation age, labour complications, poor antenatal care, and previous unfavourable birth outcomes. Africa had about 62 deaths per 1000 live births, Asia had 50 deaths per 1000 live births and Oceania, 42 deaths per 1000 live births. Olack et al. [4] identified low birth weight, preterm, birth asphyxia, neonatal sepsis, respiratory distress syndrome and hypothermia as the leading risk factors of neonatal mortality in Kenya. Wubetu et al. [5] reported that maternal nutrition, age of mother, family average monthly income, single parent, alcohol consumption, education, female sex were significant predictors of low birth weight. Abdullah et al. [6] used a logistic regression model to predict the significant risk factors associated with neonatal death in Indonesian. The study identified neonatal complication during birth, maternal health condition during the first 28 days of pregnancy, low Apgar score, delivery at home as high-risk factors of neonatal mortality. Weng et al. (2014) revealed that infants born to teenagers and women at advanced age possess greater risk for skill birth, preterm birth, neonatal death, congenital anomaly and low birth weight. Progress made in reducing neonatal mortality has been slower in Sub-Sahara Africa compare to other regions in the world [7]. Adverse birth outcomes still remain a public health problem in many parts of the world especially in developing countries like Ghana, and are associated with a range of health problems resulting in many maternal mortalities and neonatal mortalities. This study therefore seeks to identify the maternal factors that influence birth outcomes in the Kassena-Nankana Municipality.

2 Materials and Methods

2.1 Source of Data

The study pooled data from the War Memorial Hospital, Navrongo. A total of 311 nursing women were extracted from the maternity department. The data consist of different maternal history of women in relation to their pregnancy, occupation, mode of delivery and health of neonate. Birth outcome was categorized as (death=1) or (alive=0) depending on the delivery outcome.

2.2 Methodology

The binary logistic regression model is a statistical method which is used to predict binary outcome based on a set of independent variables.

$$\text{logit}(p) = \log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k \quad (1)$$

The most frequent used information criteria for comparing the goodness of fit of a model is the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). The information criterion chooses models with smaller values of AIC and BIC for a given model.

The equation for the information criteria used in the study are

$$\text{AIC} = 2k - 2\log(l)$$

$$\text{BIC} = \log(nk - 2\log(l))$$

The model fitness was checked by the Hosmer and Lemshow goodness of test. The receiver operative characteristic curve was plotted to determine the correct classification of birth outcomes. A sensitivity analysis was conducted to test the predictive power of the model. The possible outcome of a sensitivity analysis includes:

1. True Positive (TP) = Positive test result when the condition is present.
2. True Negative (TN) = Negative test result when the condition is not present.
3. False Positive (FP) = Positive test result when the condition is not present.
4. False Negative (FN) = Negative test result when the condition is present.

Mixed Effects Model. A mixed effects model is a regression model which combines both fixed and random effects. Factors used for fixed effect include maternal age, hemoglobin, diastolic and systolic. Random effects variables are maternal weight, birth weight, gestation weeks.

The mixed effects model was used to investigate the maternal factors that influence birth weight. The general form of the mixed effects model is given below.

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + e_{ij}, \ldots\ldots\ldots\ldots \quad (2)$$

where,

$$\beta_{0j} = \gamma_{00} + \gamma_{01}Z_j + U_{0j}$$
$$\beta_{1j} = \gamma_{10} + \gamma_{11}Z_j + U_{1j}$$

A log-likelihood is a scalar value that measures the goodness of fit of a statistical model in a given set of data. It was used in this study to determine the model with the higher log-likelihood as the best model.

Log-likelihood function is given below

$$l(\theta, \varepsilon) = -\frac{n}{2}In(2\pi) - \frac{n}{2}In(\sigma^2) - \frac{1}{2\sigma^2}\sum_{i=1}^{n}(x_i - \mu)^2$$

Deviance is a measure of goodness of fit of a model. The smaller the deviance, the better the model fit.

$$D_x = -2\log\left(\frac{L_x}{L_s}\right) = -2(\log L_x - \log L_s)$$

3 Results and Discussion

3.1 Descriptive statistics

A total of 311 mothers were included in the study. The descriptive statistics are recorded in Table 1. The mean maternal age was (30.48∓ 0.13), the mean maternal weight was (79.45∓ 0.20), the mean maternal hemoglobin was (11.19 ∓ 0.03), details of the rest of the factors are contained in Table 1.

Table 1. Descriptive statistics of maternal factors

Variable	Mean	Sd	Skew	Kurtosis	Se
Age	30.48	6.77	-0.20	-0.92	0.13
Weight	79.45	10.50	-0.07	-0.24	0.20
Hemoglobin	11.19	1.35	-1.14	5.67	0.03
Gestation week	37.47	1.19	-0.11	-0.74	0.02
Systolic	116.04	7.16	-0.23	-0.70	0.14
Diastolic	83.32	6.87	-0.35	1.01	0.13
Birth weight	2.48	0.37	1.16	1.22	0.01

The results of the logistic regression are contained in Table 2.

Table 2. Estimated coefficients of logistic model

Variable	Coefficient	Std. Error	Z-value	P-value
Intercept	8.39	6.91	1.22	0.2200
Age	0.03	0.02	1.50	0.1300
Weight	-0.06	0.02	-3.37	0.0007*
Hemoglobin	0.39	0.12	3.21	0.0010*
Gestation week	-0.33	0.14	-2.35	0.0200*
Occupation	0.30	0.26	1.17	0.2400
Mode of delivery	0.47	0.63	0.74	0.4600
Birth weight	3.10	0.63	4.93	0.0100*
Diastolic	-0.01	0.03	-0.53	0.5900
Systolic	-0.01	0.02	-0.50	0.6200

*AIC = 347.48 BIC = 395.87 * = significant (p<0.05)*

The results in Table 2 revealed that there is a significant impact of maternal weight on birth outcomes. Neonatal weight was a significant risk factor for birth outcomes. Hemoglobin level of a mother was also found to be a significant risk factor for birth outcomes. Gestation week was also found to be a significant risk factor for birth outcomes.

3.2 Adjusted odds ratio of the logistic regression

The adjusted odds ratios (OR) of the variables based on the logistic regression are given in Table 3.

Table 3. Adjusted odds ratio

Variables	Odds Ratios	Confidence Interval (CI)
Intercept	396.16	0.00 – 5366
Age	1.04	0.99 – 1.08
Weight	0.95	0.92 – 0.98
Hemoglobin	1.48	1.16 – 1.88
Birth Weight	21.76	6.69 – 77.81
Mode of delivery	1.61	0.54 – 6.98
Gestation week	0.72	0.54 – 0.94
Occupation	1.32	0.82 – 2.20

Adjusted odds ratios for maternal factors associated with neonatal mortality include neonatal weight (21.76, 95% CI: 6.69 to 77.81), Hemoglobin (OR 1.48, 95% CI: 1.16 to 1.88) was a significant risk factor for neonatal mortality. Maternal weight was also found to be a significant factor for neonatal mortality with an OR (0.95, 95% CI: 0.92 to 0.98). The study results in Table 2 revealed that maternal weight, hemoglobin, gestation weeks and neonatal weight were found to be predictors for birth outcomes.

Fig. 1 shows the receiver operating characteristic curve.

The results of the multilevel regression model for birth weight are presented in Table 4.

In Table 4, maternal weight was found to be a significant risk factor for birth weight. Occupation was not significantly associated with neonatal weight in the model but hemoglobin, maternal age, gestation weeks and mode of delivery were found to be significant factors for birth weight. Diastolic and systolic were not significantly associated with birth weight. The AIC and BIC were found to be 853.30 and 920.90 respectively.

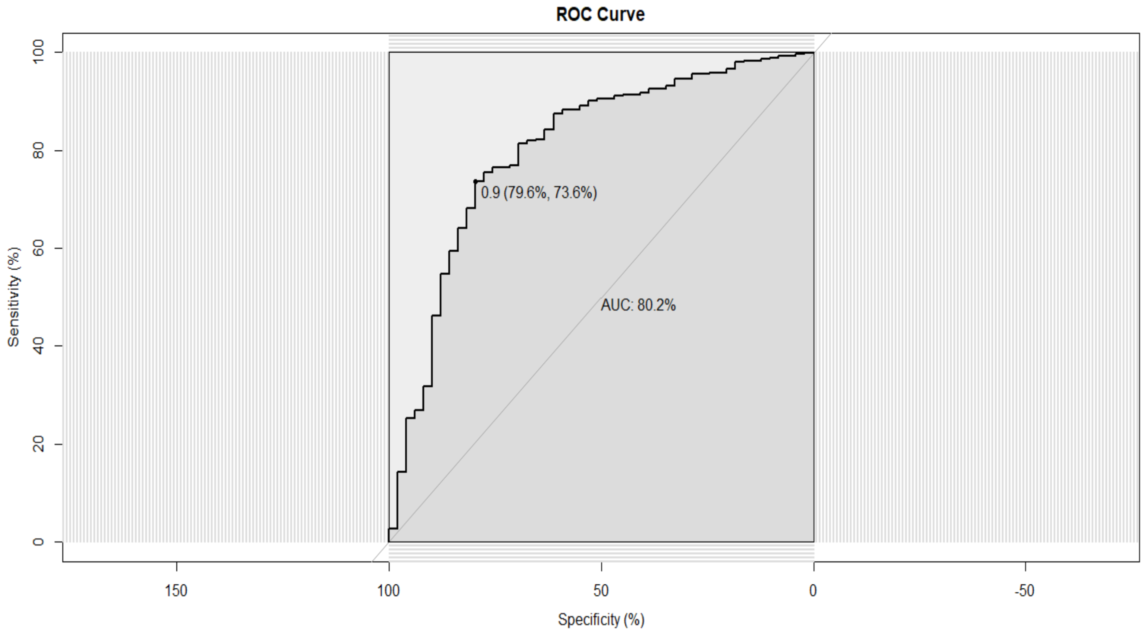

Fig. 1. Plot of the receiver operating curve

Table 4. Estimated coefficients of fixed effect

Variable	Estimate	Se	t-value	P-value
Intercept	3.927	0.4922	7.9771	0.0001
Weight	0.002	0.0010	2.2229	0.0265
Hemoglobin	-0.020	0.0100	-2.2770	0.0331
Occupation	-0.030	0.0176	-1.4568	0.1455
Age	-0.010	0.0019	-2.6537	0.0081
Birth Outcome	0.071	0.0553	1.2871	0.1984
Gestation week	-0.030	0.0104	-2.7643	0.0058
Mode of delivery	0.087	0.0445	1.9640	0.0498
Diastolic	-0.003	0.0018	-1.9099	0.0565
Systolic	0.001	0.0017	0.0586	0.9533

AIC=853.3, BIC= 920.9, Deviance = 825.3, loglikehood= -412.6

3.3 Discussion

In this study, maternal weight was found to be a significant risk factor for birth outcomes, with an odd ratio (AOR 0.95, 95% CI: 0.91 – 0.98). The risk of neonatal mortality decreases by 5% with a one unit increase in weight, which is consistent with a pervious study conducted by Melchor et al. [8]. Hemoglobin was a significant risk factor for birth outcomes with odds ratio (1.48, 95% CI 1.16 – 1.88). For each additional unit in hemoglobin, there will be 48% increase in the odds of neonatal mortality. This result is consistent with previous studies conducted by Haile et al. [9]. However, previous study conducted by Nair et al. [10], found that the risk of neonatal death decreased with an increase in hemoglobin. The results of this study revealed a statistically significant association between birth weight and birth outcomes. Neonatal mortality increases significantly with an increase in birth weight and was found to have a higher odd of neonatal mortality as compared to the other factors. This result was found to be consistent with a study conducted by Annan and Aseidu [11], who found a significant association between birth weight and neonatal mortality. Tamirat et al. [12] and Nontarah et al. [13] also found that birth weight was a significant predictor of neonatal mortality.

Gestational week was found to be a negative significant risk factor for birth outcomes. An increase in gestational age resulted in 28% decrease for neonatal death (AOR 0.72, CI 0.54-0.94). Adjei et al. [14], also found gestational age as a significant predictor for neonatal mortality. Annan and Aseidu [11] also found gestational age as a significant factor for neonatal death which is consistent with this study. This study revealed that maternal age, occupation, mode of delivery, diastolic and systolic blood pressure were not significant predictors of birth outcomes, which is consistent with previous studies conducted. Nonterah et al. [13] also found that age and occupation were not significant predictors of neonatal mortality.

The results in Table 4 indicated that weight was positively and significantly associated with birth weight. These findings suggest that an increase in weight resulted in an increase in birth weight which is consistent with a previous study conducted by Ramakrishnan [15]. Hemoglobin was found to be inversely and significantly associated with neonatal weight, which implies that an additional one unit of hemoglobin, there is a 0.02 reduction in birth weight while holding other variables constant. These results are in line with previous studies conducted. Ahankari et al. [16] found that hemoglobin was highly associated with birth weight and Jwa et al. [17] also found that hemoglobin at mid and late pregnancy were negatively and significantly associated with birth weight.

Maternal age in this study was found to be significantly associated with birth weight. Maternal age is considered one of the risk factors of birth weight in many previous studies [18,19,20]. The result of this study revealed a significant association with birth weight. For each year increase in age, there is a decrease in birth weight. Various studies have reported the effects of advanced maternal age, and its risk on low birth weightand the general welfare of women [18,19,21]. The results of the study revealed that advanced age contributed 50% to 100% increase in the risk of low birth weight. The increased in age comes with its concomitant challenges including increased poverty, comorbidities, and increased spending [22,23]. Mode of delivery and gestation weeks were also found to be significantly associated with birth weight. Several previous studies are consistent with this study. Chen et al. [24] in their study reported that mode of delivery was positively and significantly associated with birth weight and Saki et al. [25] also found a strong association between mode of delivery and neonatal weight. Annan and Aseidu [11] found that gestational week was a significant risk factor for birth weight. Tshotetsi et al. [26] also found gestational week as a significant risk factor for neonatal weight. The results of the study showed that occupation, diastolic and systolic blood pressure were not significant risk factors for birth weight, which is consistent with other previous studies.

4 Conclusion

The results revealed that weight, birth weight, gestation weeks and hemoglobin were identified as significant predictors of birth outcomes. Significant factors that influence birth weight in this study were age, weight, hemoglobin, gestation weeks and mode of delivery. The study sends a clarion call to policy makers and stakeholders to develop and implement appropriate clinical and health interventions to prevent neonatal mortality and low birth weight.

Ethical Approval

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

Competing Interests

Authors have declared that no competing interests exist.

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