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Treatise on Anaemia in Pregnancy in Women of Reproductive Age in the Bolgatanga Municipality, Upper East Region, Ghana

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Abstract This study investigated the prevalence of anaemia in pregnancy and the determinants of haemoglobin levels and anaemic status among pregnant women. The results showed that 50.4% of the subjects were anaemic. The GLM and the binary logistic regression results revealed that Blood pressure, Gestational Age and BMI are useful in determining the haemoglobin level and the anaemic status respectively. The binary logistic regression revealed that a subject with normal blood pressure is 64.4% less likely to be anemic compared to a subject with abnormal blood pressure. Also, for a unit change in BMI a subject is 7.3% less likely to be anaemic while for a unit change in gestational age a subject is 6.5% more likely to be anaemic. The results revealed that as the Gestational age increases the probability of a subject becoming anaemic increases. It is therefore recommended that medical experts should advise pregnant women to take in foods and or supplements that will increase their Haemoglobin level as the Gestational age increases.

Keywords Anaemia in pregnancy, Bolgatanga, Haemoglobin level, GLM, Logistic regression

1. Introduction

Anaemia in pregnancy is one of the detrimental diseases that have usurped the minds of Public Health Workers globally. It is one of the major causes of high maternal mortality and morbidity, neonatal mortality and high percentage of low birth-weight worldwide [5, 3]. According to [14], anaemia is a result of having haemoglobin levels of less than 11g/dl and affects nearly half of all pregnant women in the world: 52% in developing countries and 23% in the developed countries.

In Ghana, the prevalence of anaemia among pregnant women increased from 65% to 70% between 2003 and 2008. Anaemia in pregnancy is one of the major causes of the unacceptable high maternal mortality ratio of 451 per 100, 000 live births in the country. It is responsible for 20% of the maternal deaths in the country [6].

In order to address this canker, the determination of factors that contributes to anaemia in pregnancy in a population is imperative for the implementation of control measures. Various risk factors including inadequate nutrition, infection, age, sickle cell status and poor health status among others are found to be associated with the prevalence of anaemia [8, 9, 11]. This study therefore investigated the factors associated with anaemia in pregnancy among women within the reproductive age group (15-49 years) in the Bolgatanga municipality of the Upper East Region of Ghana.

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2. Materials and Methods

2.1. Study Area

The study was carried out in the Bolgatanga municipality. The Bolgatanga municipality is the regional capital of the Upper East region of Ghana with a total population of 66,685 (2010 census).

2.2. Data and Source

The study employed secondary data, obtained from the 2012/2013 registers of the antenatal clinic of the Upper East Regional Hospital in the Bolgatanga municipality, where routine records of all pregnant women (subjects) who report at the facility for maternal care services are taken. The study made use of variables such as Maternal age group, Parity, Gravidity, Blood Pressure (normal or abnormal), Gestational age (in weeks), Haemoglobin level, Sickle cell status (positive or negative) and Season of the year (dry or wet). The study consisted of 617 pregnant women within the reproductive age group (15-49 years).

2.3. Generalized Linear Model (GLM)

The GLM is an extension of the traditional linear model. It differs from a linear model in the sense that it assumes that the response distribution is related to the linear predictor through a function called the link function. The GLM has a linear component

$$\boldsymbol{\eta} = \boldsymbol{\eta_0} + \boldsymbol{X\beta}$$

and a monotonic differentiable function, $\boldsymbol{g}$, that links the expected response, $\boldsymbol{\mu}$, to the linear predictor $\boldsymbol{\eta}$:

$$\boldsymbol{\eta} = \boldsymbol{g}(\boldsymbol{\mu})$$

The response $\boldsymbol{y}$ is assumed to have a distribution from the exponential family. In this study the normal distribution was used. The vector $\boldsymbol{\eta_0}$ is called an offset variable. $\boldsymbol{X}$ is the design matrix and $\boldsymbol{\beta}$ is a vector of unknown parameters.

2.4. Binary Logistic Regression

The binary logistic regression model is used for modeling response variables that are binary or dichotomous in nature. For a binary response, $Y\epsilon(0,1)$, let $\boldsymbol{x}$ be a vector of k regressors, and π_i be the probability, $P(Y = 1 \setminus \boldsymbol{x})$. The logistic regression model is a linear model for the log odds, or logit that $Y = 1$, given the values in $\boldsymbol{x}$. The model is given by;

$$P(Y = 1) = \frac{e^{\beta_0+\beta_1 x_{i1}+\beta_2 x_{i2}+\ldots+\beta_k x_{ik}}}{1 + e^{\beta_0+\beta_1 x_{i1}+\beta_2 x_{i2}+\ldots+\beta_k x_{ik}}}$$

and gives the probability of the event of interest occurring.

2.5. Multinomial Logistic Regression

The Multinomial Logistic Regression, models the probabilities of m categories as $m - 1$ logits comparing each of the first $m - 1$ categories to the reference category. The logits for any pair of categories are calculated from the $m - 1$ fitted ones. With k predictors, $x_1, x_2, \ldots, x_k$, for $j = 1,2,\ldots,m-1$. The logit is given by

$$log\left(\frac{\pi_{ij}}{\pi_{im}}\right) = \beta_{0j} + \beta_{1j}x_{i1} + \beta_{2j}x_{i2} + \ldots + \beta_{kj}x_{ik} = \boldsymbol{\beta_j^T x_i}$$

Each coefficient, β_{hj}, gives the effect on the log odds of a unit change in the predictor $x_h, h = 1, 2, \ldots, k$ that an observation belongs to category j versus category m. The probabilities are calculated as

$$\pi_{ij} = \frac{\exp(\boldsymbol{\beta_j^T x_i})}{1 + \sum_{i=1}^{m}\exp(\boldsymbol{\beta_j^T x_i})}$$

3. Results and Discussion

The results revealed that the minimum, maximum and the average Haemoglobin level of the 617 pregnant women were 6.1g/dl, 16.6g/dl and 10.8g/dl respectively. Out of the 617 pregnant women, 311 (50.4%) were anaemic (Haemoglobin < 11g/dl) and 306 (49.6%) were non-anaemic (Haemoglobin >11g/dl). This prevalence rate of 50.4% is consistent with [15] estimated prevalence rate of 40% to 60% in developing countries. However, the prevalence is considerably lower compared to 57.1% in the Sekyere West District of Ghana [8], 76.9% in South Eastern Nigeria [13] and 62.6% in Eastern Sudan [1]. This may be attributable to geographical variations that influence certain anaemic influencing factors and improvement in health policies with time. Also, 163 (26.4%) had mild anaemia (Haemoglobin between 10.0 to 10.9g/dl), 144 (23.3%) had moderate anaemia (Haemoglobin between 7.0 to 9.9g/dl) and 4 (0.6%) had severe anaemia (Haemoglobin less than 7g/dl). The results revealed that mild anaemia was common followed by moderate anaemia. This is consistent with findings in Africa and elsewhere in the world [16, 10, 4, 7]. A Chi-square test of association showed that the Blood Pressure and the Age Group were significantly associated with the subjects' anaemic status as shown in Table 1. Also, the Chi-square test indicated that there was no association between the Sickle Cell Status and the Season of the year, with the subjects' anaemic status at the 5% significance level.

Table 1. Chi-square test of association

Variable	Test Statistic	df	*P*-value
Blood Pressure	22.641	1	0.000
Age Group	26.274	6	0.000
Sickle Cell Status	1.430	1	0.232
Season	0.009	1	0.923

In order to investigate the determinants of the Haemoglobin level of the subjects', a Generalized Linear Model (GLM) was used. The results indicated that the overall model was significant (*F*-value =14.74 and *P*-value =0.001) at the 5% significance level. However, an individual test of significance of the parameters of the model revealed that Age, Parity, Gravidity, Sickle cell status and Season were not significant while Blood pressure, Gestational age and Body Mass Index (BMI) were significant at the 5% significance level. The insignificant variables were dropped from the model and a reduced model was fitted with the significant variables. The results indicates that the reduced model was significant (*F*-value =24.05 and *P*-value =0.001). Table 2 shows the individual parameters of the reduced model with all parameters significant at the 5% significance level. The results show that having normal Blood pressure was positively related with the Haemoglobin level. This means that pregnant women with normal blood pressure have a 0.577g/dl higher Haemoglobin level than those with abnormal blood pressure. Also, the *P*-value of 0.0002 for the Blood pressure (normal) indicates that the difference between the Haemoglobin level of a subject with normal blood pressure and a subject with abnormal blood pressure is significant. The Gestational age was negatively related to the Haemoglobin level: The Haemoglobin level decreases by 0.048g/dl for every one week increase in gestational age. The BMI was positively related to the Haemoglobin level indicating that a unit increase in BMI is likely to increase the Haemoglobin level by 0.058g/dl. Similar studies by [12] also reported that low BMI, and gestational age more than 16 weeks, are associated with maternal Haemoglobin concentration.

Table 2. Parameter estimates of the reduced GLM

Parameter	Estimates	Std. Error	T-value	*P*-value
Intercept	9.615	0.290	33.150	0.0001
Blood Pressure (normal)	0.577	0.155	3.720	0.0002
Blood Pressure (abnormal)	0.000	.	.	.
Gestational age (weeks)	-0.048	0.007	-6.76	0.0001
BMI	0.058	0.010	5.57	0.0001

The reduced model is given by;

$$\text{Haemoglobin} = 9.615 + 0.577 BloodPressure\ (normal) - 0.048 Gestationalage + 0.058 BMI$$

Figure 1 is a diagnostic plot of the residuals of the reduce GLM. Clearly, the histogram of the residuals and the quantile plot indicates that the residuals are normally distributed. Also, the plot of the residuals and the predicted values revealed that the residuals are random. Thus the residuals of the reduced model are well behaved indicating that the model is adequate.

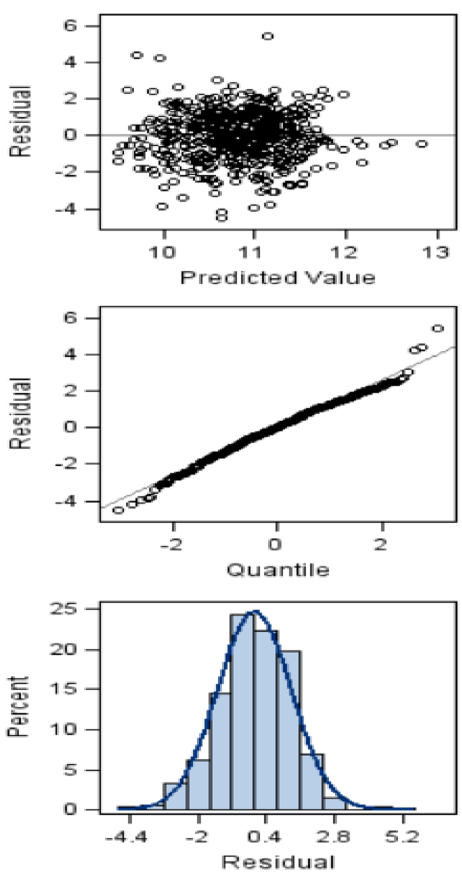

Figure 1. Diagnostic plots of residuals

Furthermore, to model the probability of a subject being anaemic, the Haemoglobin level was considered as dichotomous (anaemic or non-anaemic) and a binary logistic regression was fitted to the data using the stepwise algorithm. The results (Table 3) again indicated that only Blood pressure, Gestational age and BMI are useful in determining the probability of a subject being anaemic. Studies in Burkina Faso [10], Sudan [1], and Jimma [2] reported that Gravidity did not have a statistically significant contribution for difference in anaemia prevalence. The parameter estimates of the Blood pressure (normal) and BMI were negative indicating that, a pregnant woman with normal Blood pressure and a unit increase in BMI are likely to reduce the probability of a subject being anaemic. The positive parameter estimate, of the Gestational age, indicates that as the Gestational age increases, the probability of the subject being anaemic is higher. The odds ratio estimates revealed that a subject with normal blood pressure is 64.4% less likely to be anaemic compared to a subject with abnormal blood pressure. Also, for every unit increase in the BMI a subject is about 7.3% less likely to be anaemic and for every additional week in gestational age a subject is about 6.5% more likely to be anaemic.

Table 3. Parameter estimates of reduced binary logistic regression model

Parameter	Estimates	Std. Error	Wald Chi-square	*P*-value	Odds ratio
Intercept	1.3448	0.4770	7.9472	0.0048	NA
Blood pressure (normal)	-0.5166	0.1370	14.2278	0.0002	0.356
Gestational age	0.0628	0.0119	27.7765	0.0001	1.065
BMI	-0.0757	0.0188	16.2329	0.0001	0.927

The reduced binary logistic regression model is given by;

$$P(anaemic = 1) = \frac{e^{1.3448 - 0.5166 Bloodpressure + 0.0628 Gestationalage - 0.0757 BMI}}{1 + e^{1.3448 - 0.5166 Bloodpressure + 0.0628 Gestationalage - 0.0757 BMI}}$$

A diagnostic test of the binary logistic regression model with the Hosmer and Lemeshow test gave a test statistic of 17.3742 with a *P*-value of 0.2064 indicating that the logistic regression model was adequate. Also, the Deviance and Pearson goodness-of-fit tests (Table 4) further affirmed that the model was correctly specified. The sensitivity test indicated that about 60 percent of the events of interest (anaemic) were correctly classified by the model while the specificity test indicated that about 66% of the non-event (non-anaemic) was correctly classified.

Table 4. Deviance and Pearson Goodness-of-Fit Statistics

Criterion	Values	DF	Value/DF	Pr > Chi Square
Deviance	754.3156	582	1.3476	0.2061
Pearson	610.9008	582	1.0497	0.1968

In addition, to model the probability of a subject suffering from various levels of anaemia (severe, moderate or mild), the Haemoglobin level of subjects was considered multichotomous (non-anaemic, severe anaemia, moderate anaemia and mild anaemia) and a multinomial logistic regression was fitted to the data using the stepwise algorithm. The model was fitted without the intercept because the intercept was not significant at the 5% significance level. From Table 5, only the Blood pressure, Gestational age and BMI are useful in modeling the probability of the various levels of anaemia. From Table 5, the Blood pressure and the Gestational age were useful in predicting the probability of a subject suffering from moderate and mild anaemia but not useful in predicting the probability of a subject suffering from severe anaemia; The BMI was useful in predicting the probability of the various levels of anaemia. The normal Blood pressure and the BMI have negative coefficients indicating that the normal Blood pressure and an increase in BMI are likely to reduce the probability of a subject suffering from the various degree of anaemia. The Gestational age has a positive coefficient indicating that as the Gestational age increases, the probability of the subject suffering from the various degree of anaemia increases.

Table 5. Parameter estimates of the reduced multinomial logistic regression model

Parameter	Severe versus non-anaemic	Moderate versus non-anaemic	Mild versus non-anaemic
Blood Pressure (normal)	-0.53669 (*P*-value=0.3816)	-0.5651 (*P*-value=0.0002)	-0.4255 (*P*-value=0.0051)
Gestational age	0.1347 (*P*-value=0.0525)	0.0879 (*P*-value=0.0001)	0.0481 (*P*-value=0.0003)
BMI	-0.2683 (*P*-value=0.0001)	-0.0696 (*P*-value=0.0001)	-0.0401 (*P*-value=0.0001)

Table 6 presents the odds ratio of the parameter estimates of the logistic regression model. From Table 6, a subject with normal blood pressure is 65.8%, 67.7% and 57.3% less likely to suffer from severe, moderate and mild anaemia respectively, as compared to a subject with abnormal blood pressure. In addition, as the Gestational age increases by one week, a subject is 14.4%, 9.2% and 4.9% more likely to suffer from severe, moderate and mild anaemia respectively. Again, as the BMI increases by one unit, the subject is 23.5%, 6.7% and 3.9% more likely to suffer from severe, moderate and mild anaemia respectively.

Table 6. Odds ratio estimates of the parameters of the multinomial logistic regression relative to No Anaemia

Parameter	Severe	Moderate	Mild
Blood Pressure (normal) relative to abnormal	0.342	0.323	0.427
Gestational age	1.144	1.092	1.049
BMI	0.765	0.933	0.961

4. Conclusions

In this study, the determinants of Haemoglobin levels and anaemia status (anaemic or non-anaemic) of pregenant women (subjects) in the Bolgatanga municipality of the Upper East Region of Ghana were investigated. The results revealed that Blood pressure, Gestational age and BMI were useful in determining the Haemoglobin level and the anaemic status of the subjects. The study revealed that subjects with normal blood pressure and high BMI are less likely to be anaemic as their Haemoglobin is likely to be high. However, the studies revealed that as the Gestational age increases the subjects are likely to have low Haemoglobin levels which results in anaemia in pregnancy. It is therefore recommended that medical experts should advise the pregnant women to take in foods and or supplements that will increase their Haemoglobin level as the Gestational age increases and also engage in activities that will ensure that they have a normal blood pressure.

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