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Bayesian modeling of maternal mortality in Ghana

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Abstract

Maternal mortality is a critical measure for quality of health system in any country and hence many countries have made concerted efforts to check its occurrence. Various stakeholders involved in the management of health system in Ghana have been tasked to ensure women do not die whilst giving birth. This study was conducted on a sample of 1,052 women selected from all the ten administrative regions of Ghana in which 188 maternal deaths occurred. Bayesian logistic modeling was used. Age at death, marital status, age, season, region, place of death, place of residence, religion and ethnicity emerged as the most significant determinants of maternal mortality in Ghana. It was realized that high numbers of maternal deaths were recorded in the least developed regions in the northern region. It is therefore important for stakeholders to devise a road map of getting health workers to accept postings to the rural areas and also provide well resourced health facilities to stem this menace. *(Afr J Reprod Health 2023; 27 [2]: 57-66).*

Keywords: Age; Bayesian logistic modeling; marital status

Résumé

La mortalité maternelle est une mesure essentielle de la qualité du système de santé dans n'importe quel pays et, par conséquent, de nombreux pays ont déployé des efforts concertés pour vérifier son apparition. Diverses parties prenantes impliquées dans la gestion du système de santé au Ghana ont été chargées de veiller à ce que les femmes ne meurent pas pendant l'accouchement. Cette étude a été menée sur un échantillon de 1 052 femmes sélectionnées dans les dix régions administratives du Ghana dans lesquelles 188 décès maternels sont survenus. Une modélisation logistique bayésienne a été utilisée. L'âge au décès, l'état matrimonial, l'âge, la saison, la région, le lieu du décès, le lieu de résidence, la religion et l'ethnicité sont apparus comme les déterminants les plus importants de la mortalité maternelle au Ghana. On s'est rendu compte qu'un nombre élevé de décès maternels était enregistré dans les régions les moins développées de la région du nord. Il est donc important que les parties prenantes élaborent une feuille de route pour amener les agents de santé à accepter des affectations dans les zones rurales et fournissent également des établissements de santé dotés de ressources suffisantes pour endiguer cette menace. *(Afr J Reprod Health 2023; 27 [2]: 57-66).*

Mots-clés: Âge; modélisation logistique bayésienne; état civil

Introduction

Maternal mortality refers to death of either a pregnant woman or death of a woman within 42 days of delivery, miscarriage, termination or ectopic pregnancy. The death may have resulted from pregnancy and its related complications and management (Mann *et al.*[1]). Maternal mortality is an important health indicator of any country that stakeholders consider when managing maternal and child outcomes. Insufficient data on mortality has hindered the success in fighting against maternal mortality even in the developed countries (Main and Menard[2]). In Africa and most parts of the developing world, major causes of maternal mortality are largely due to socio-economic variables such as poverty, education, inadequate skilled birth attendants and inadequate health facilities among others which limit access to health services. Other causes of maternal mortality can be grouped into direct and indirect causes. The direct causes are hemorrhaging (uncontrolled bleeding or severe bleeding), sepsis (infection), hypertensive disorders, eclampsia, prolonged or obstructed labor, and unsafe abortion. The indirect causes are anemia, malaria, hepatitis, heart diseases, and HIV/AIDS (WHO[3,4], Aden *et al.*[5], Makuei *et al.*[6]). Various African governments have hugely invested in enhancing maternal outcomes over the years but results are still far from meeting the global target of 70 deaths per 100,000 live births. The recent prevalence of maternal mortality in some African

countries are Sudan (295), south Sudan (1,150), Ethiopia (401), Egypt (37), Libya (72), Algeria (112), Mauritania (766), Senegal (315), Nigeria (917), Cote d'Ivoire (617) and Ghana (308). Clearly, the figures are really alarming in most African countries (WHO, UNICEF, UNPF, and the World Bank[6]).

There has been considerable efforts by stakeholders in reducing the prevalence of maternal mortality over the years but the aforementioned factors including the delays in the decision to seek care, in reaching care, and in receiving care still post a major challenge in combating this menace. To stem this problem, the government of Ghana has established Community-Based Health Planning and Services (CHIPS) compounds in most rural and hard-to-reach areas and in peri-urban areas staffed with midwives and other health professionals to promote health education and improve access to skilled delivery services. These efforts notwithstanding have not succeeded in eradicating maternal deaths in the country, not even meeting the Sustainable Development Goals target of 70 deaths per 100,000 population by 2030.

The aim of this paper is to provide the most up-to-date statistical analysis of the maternal mortality data from Ghana. There have not been many papers on this topic. The ones we are aware of are the following. Asamoah *et al*.[8] analysed the 2017 Ghana Maternal Health Survey (GMHS) data using frequency tables, cross-tabulations and logistic regression. The analysis showed among others that "Haemorrhage was the highest cause of maternal mortality. Married women had a significantly higher risk of dying from haemorrhage, compared with single women. On the contrary, married women showed a significantly reduced risk of dying from abortion compared to single women. Women aged 35-39years had a significantly higher risk of dying from haemorrhage, whereas they were at a lower risk of dying from abortion compared to their younger counterparts. The risk of maternal death from infectious diseases decreased with increasing maternal age, whereas the risk of dying from miscellaneous causes increased with increasing age". Barbi *et al*.[9] noted that the "Volta Region of Ghana registered the highest rate of maternal mortality, the lowest percentage of antenatal care coverage and the lowest percentage of skilled delivery". Sumankuuro *et al*.[10] fitted binary and multivariate logistic regression models to the 2017 GMHS data. The fitting showed that women aged 20-29 years bled during labour/delivery and those who used traditional/herbal medicines during pregnancy were more likely to die compared to others. Tawiah *et al*.[11] fitted zero-inflated hierarchical Poisson models to maternal mortality data in Ghana. The fitting revealed that "maternal mortality in hospital facilities is influenced by the number of referrals (into and out) of the hospital facility, number of antenatal visits exceeding four, number of midwives, and number of medical doctors at the facility". Boafor *et al*.[12] provided a five-year review of maternal mortality at the Korle Bu Teaching Hospital, Accra, Ghana. They found that the significant factors associated with maternal mortalities were "women with no formal education, women who had less than four antenatal visits and emergency cesarean section".

All of these papers are limited to specific locations in Ghana or not up-to-date. Besides, the methods used are frequentist in nature. Frequentist methods never use or calculate the probability of the hypothesis (for example, if material mortality is higher during rainy seasons), also they do not demand construction of a prior and depend on the probabilities of observed and unobserved data. Bayesian methods are preferable because they use probabilities of data and probabilities of both hypothesis (for example, probabilities corresponding to maternal mortality in rainy seasons and maternal mortality in non-rainy seasons). In this paper, we use a Bayesian logistic regression to determine how the number of maternal deaths per household in Ghana depends on the number of people in the household, number of visits to the woman, region, marital status, education, work status in the last 12 months, season, occupation, religion, ethnicity, place of death of the woman and the usual place of residence of the woman. The data on these variables, their description, the method used fit the Bayesian logistic regression, a discussion of the results of the fit and conclusions are given in the subsequent sections.

Methods

Data

The data used for this study was obtained from the Ghana Statistical Service Demographic and Health survey conducted from March - July, 2020 and covered the whole country (Service [13]). The response variable is the number of maternal deaths per household in 2020. If there is a delivery in the household, the particulars of the woman such as individual line number, region, supervisor number, marital status, highest educational level, occupation, religion, ethnicity, place of death, usual place of residence, place of burial and relation to the respondent are taken for analysis. Also, due to high number of monogamous marriages, it is rare to find more than one woman giving birth in one household in a calendar year. Hence, the response values are either one or zero.

Some of the independent variables are factors. The others are covariates. The details of all of the independent variables are:

• cluster=cluster number.
• household=number of people in the household.
• line=individual line number.
• interview number=number for the interview.
• day=day of the interview.
• month=month of the interview.
• visits=number of visits to the woman.
• region (code for the 10 administrative regions): 1=western, 2=central, 3=greater Accra, 4=Volta, 5=eastern, 6=Ashanti, 7=Brong Ahafo, 8=northern, 9=upper east, 10=upper west.
• supervisor number (code for differentiating supervisors assigned to different enumerating areas of the survey).
• marital status (code for marital status of the respondent): 1=never married, 2=married, 3=living with a partner, 4=separated, 5=divorced, 6=widowed.
• education (code for highest educational level attained by the respondent): 1=primary school, 2=middle school, 3=junior high school / junior secondary school, 4=secondary / vocational / technical / community school, 5=SSS / SHS / tech / voc / vomm, 6=higher, 7=never attended school, 8=do not know.
• work status in the last 12 months: 1=yes, 2=no.
• season: 1=non-rainy season, 2=rainy season.
• occupation (code for occupation of the respondent): 12=administrative and commercial managers, 22=health professionals, 23=teaching professionals, 24=business and administrative professionals, 26=legal, social and cultural professionals, 32=health associate professionals, 33=business and administration associate professionals, 41=general and keyboard clerks, 44=other clerical support workers, 51=personal sales workers, 53=personal care workers, 63=subsistence farmers, fishers, hunters and gatherers, 71=building and related trades workers, excluding electricians, 72=metal, machinery and related trades workers, 73=handicrafts and printing workers, 75=food processing, wood working, garment and other craft and related trades workers, 83=drivers and mobile plant operators, 91=cleaners and helpers, 92=agricultural, forestry and fishery laborers, 93=laborers in mining, construction, manufacturing and transport, 94=food preparation assistants, 95=street and related sales and service workers, 97=other occupations.
• religion (code for religion of the respondent): 1=Catholic, 2=Anglican, 3=Methodist, 4=Presbyterian, 5=Pentecostal / Charismatic, 6=other Christian, 7=Islam, 8=Traditional / Spiritualist, 9=no religion, 98=do not know.
• ethnicity (code for ethnic group that the respondent belongs to): 1=Akan, 2=Ga / Dangme, 3=Ewe, 4=Guan, 5=Mole-Dagbani, 6=Grusi, 7=Gurma, 8=Mande, 96=other.
• place (code for place of death of the woman): 1=her home, 2=other home, 3=health facility, 4=en route to health facility, 5=shrine / prayer camp, 6=other.
• residence (code for the usual place of residence of the woman): 1=in this house, 2=in this locality, 3=in a different village / town, 6=other.
• burial (code for the place where the deceased was buried): 1=in this house, 2=in this locality, 3=in a different town / village, 4=burial not performed yet, 6=other.
• relation (code for the relationship with the main respondent): 1=husband / partner, 2=parent, 3=child, 4=sibling, 5=other family member, 6=friend, 7=another relationship.

Before the data collection procedure, the survey was reviewed and approved by an ethics committee

Table 1: Regional mortality distribution

Region	Number of households	Number of maternal deaths	Mean age of mother per region
Western	104	24	30.65
Central	100	21	33.94
Greater Accra	179	21	35.23
Volta	80	17	34.44
Eastern	60	19	32.86
Ashanti	215	11	34.10
Brong Ahafo	103	18	31.62
Northern	102	31	31.82
Upper east	50	11	36.30
Upper west	40	15	34.34

at the C. K. Tedam University of Technology and Applied Sciences, Ghana. The participant consent was informed and obtained in verbal form. No administrative permissions were required to access the raw data. The data used were anonymized before its use.

Descriptive analysis

Table 1 details the mortality situation. A total of 188 maternal deaths were recorded representing (17.87%). The highest number of deaths was recorded in the northern region (31) followed by the western region (24). The least number of maternal mortality in the country was recorded in Ashanti and upper east regions with 11 each. The mean age of mother was smallest in the western region followed by the Brong Ahafo region. The mean age was largest in the upper east region.

Figures 1 and 2 show boxplots of maternal mortality versus the following factors: supervisor number, place of burial, place of residence and place of death, religion, occupation, marital status and individual line number.

We can observe the following. The maternal mortality appears higher when: the supervisor number is 300 or 500; the place of burial is other; the usual place of residence is other; the place of death is en route to health facility; the religion is not known; the occupation is either a teaching professional or a metal, machinery and related trades worker; the marital status is living with a partner; the individual line number is 6.

Model

Let y_i denote the number of maternal deaths for the ith household. We assume y_i is a Bernoulli random variable with probability π_i; that is, $P(y_i = 1) = \pi_i$ and $P(y_i = 0) = 1 - \pi_i$. The model we fitted is

$$\pi_i = \frac{\exp(\beta_0+\beta_1 x_{i,1}+\cdots+\beta_k x_{i,k})}{1+\exp(\beta_0+\beta_1 x_{i,1}+\cdots+\beta_k x_{i,k})}, \quad (1)$$

where β_0 is the intercept, $x_{i,j}$ is the ith observation on the jth independent variable, and β_j is the corresponding regression coefficient.

The model in (1) was fitted to the data in Section 0 by using the package brms (Buerkner [14,15]) in the R software (R Core Team [16]). We assumed flat, weakly informative priors for $\beta_0, \beta_1, \ldots, \beta_k$.

Results

Some of the results of fitting (1) are shown in Tables 2 to 4. The following factors / covariates are not significant: number of people in the house, day of the interview, month of the interview, number of visits to the woman and work status in the last 12 months. The remaining factors / covariates are significant. The cluster number has a positive effect on maternal mortality; that is, larger values of the number correspond to higher maternal mortality. The interview number has a negative effect on maternal mortality; that is, larger values of the number correspond to lower maternal mortality. Age also has a negative effect on maternal mortality; that is, older women correspond to lower maternal mortality. Season has a positive effect on maternal mortality; that is, maternal mortality is higher during rainy days.

The individual line number has a negative effect on maternal mortality when the respondent is third or fourth in line. The individual line number has a positive effect on maternal mortality when the respondent is sixth in line. The other line numbers do not have significant effects. Maternal mortality

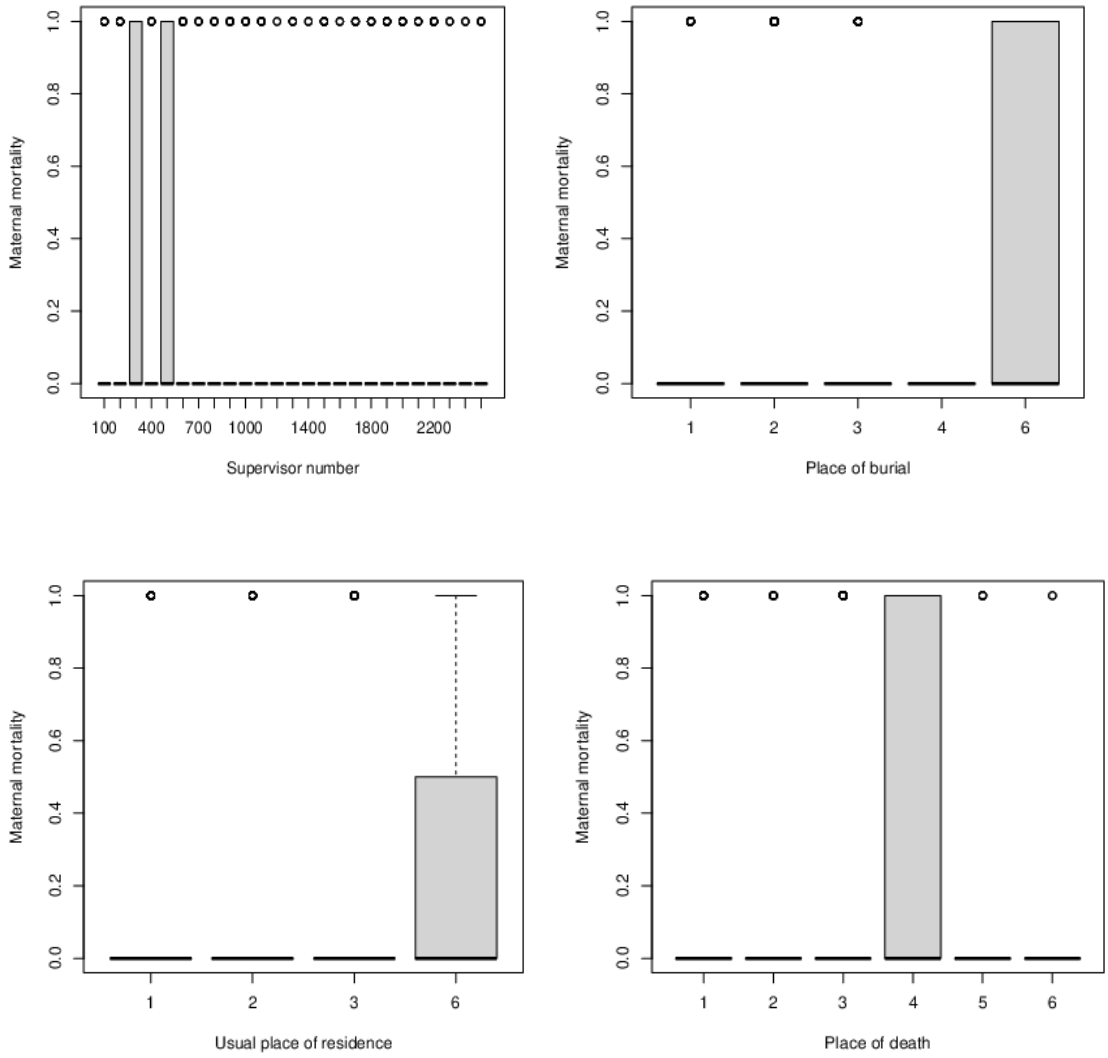

Figure 1: Boxplots of maternal mortality versus supervisor number, place of burial, place of residence and place of death

is significantly higher if the woman belonged to the eastern, northern and upper east regions. Belonging to other regions does not affect maternal mortality significantly.

The supervisor number has a negative effect on maternal mortality when it is 700 or 1200. The supervisor number has a positive effect on maternal mortality when it is 300, 1300 or 1400. The other supervisor numbers do not have significant effects. Being married or living with a partner has a positive impact on maternal mortality. Being separated, divorced or widowed has a negative impact on maternal mortality. Having a middle school education, a secondary/vocational/technical/community school education or the level of education being unknown has a negative impact on maternal mortality. Having a higher education has a positive impact on maternal mortality. Other levels of education do not have significant effects.

The occupation being a legal, social and cultural professional, subsistence farmer, fisher, hunter, gatherer, laborer in mining, construction, manufacturing and transport or a food preparation

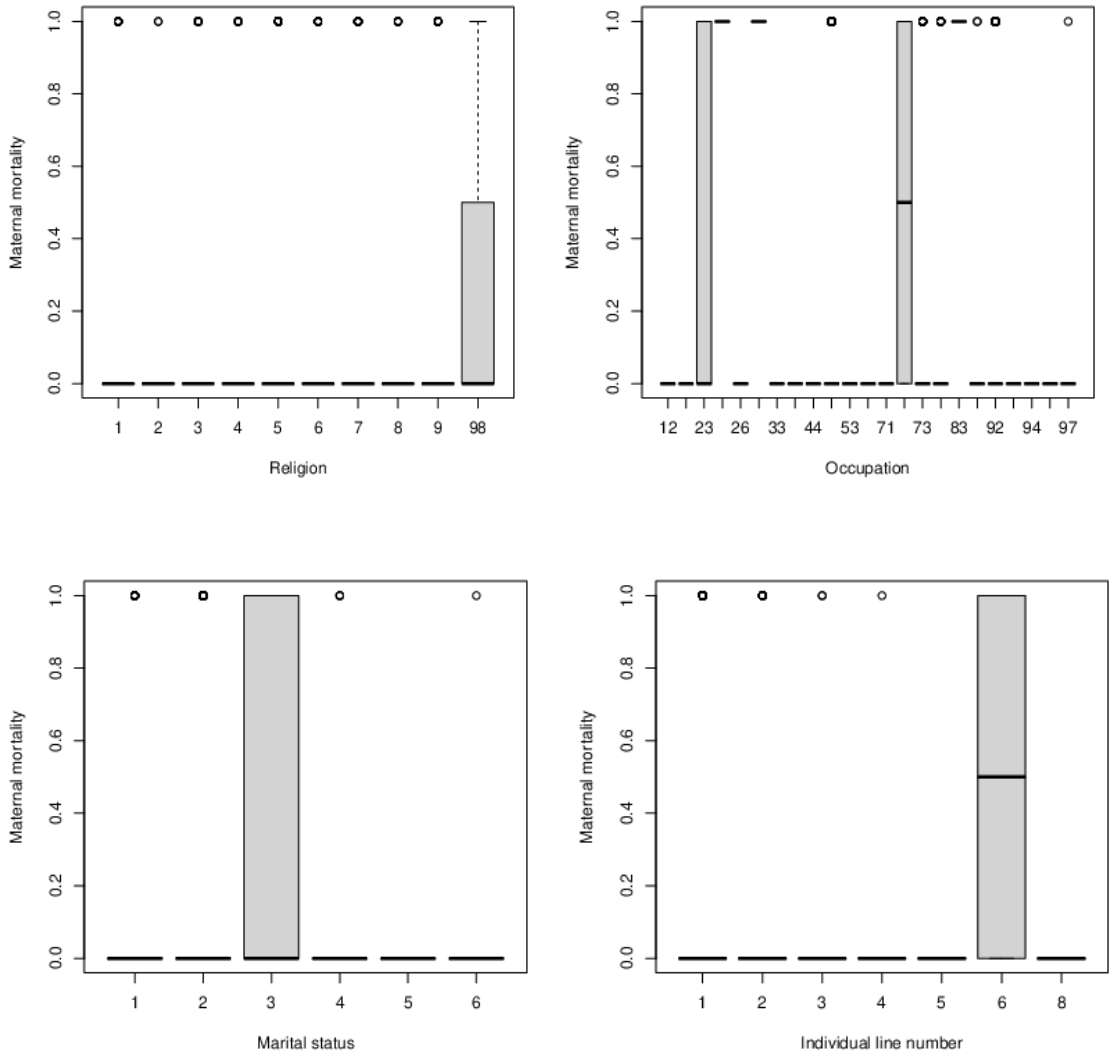

Figure 2: Boxplots of maternal mortality versus religion, occupation, marital status and individual line number

Table 2: Estimates, estimated errors and 95% credible intervals of the regression coefficients corresponding to the covariates

	Estimate	Estimated error	95% credible interval	
			Lower	Upper
Intercept	-692.34	299.82	-1249.43	-258.75
cluster	0.32	0.13	0.10	0.63
household	0.15	0.15	-0.15	0.44
day	-0.05	0.05	-0.14	0.04
month	0.59	0.56	-0.49	1.76
interview number	-1.27	0.29	-1.74	-0.79
visits	-0.24	0.88	-2.21	1.49
age	-0.21	0.04	-0.30	-0.15

Table 3: Estimates, estimated errors and 95% credible intervals of the regression coefficients corresponding to the marital status of the respondent

	Estimate	Estimated error	95% credible interval	
Martial status			Lower	Upper
2	3.44	1.06	1.47	5.50
3	5.33	1.30	3.08	8.28
4	-2404.69	1006.26	-4838.54	-750.03
5	-4969.55	4576.95	-18283.05	-505.40
6	-12082.17	11207.36	-37456.95	-2249.18

Table 4: Estimates, estimated errors and 95% credible intervals of the regression coefficients corresponding to ethnicity of the respondent

	Estimate	Estimated error	95% credible interval	
Ethnicity			Lower	Upper
2	-3.53	1.89	-7.44	0.45
3	-5.86	1.79	-9.70	-2.59
4	-2.59	2.18	-7.02	1.36
5	0.24	1.72	-2.78	3.64
6	-1.55	2.44	-6.45	3.03
7	0.89	1.54	-2.04	3.68
8	1.70	3.16	-3.86	8.06
96	1.92	2.60	-3.80	6.57

assistant has a negative impact on maternal mortality. The occupation being a teaching professional, sales worker, metal, machinery and related trades worker, handicrafts and printing worker, food processing, wood working, garment and other craft and related trades worker, driver, mobile plant operator or an agricultural, forestry and fishery laborer has a positive impact on maternal mortality. The other occupations do not have significant effects. Being an Anglican, Presbyterian or a Pentecostal/charismatic has a negative impact on maternal mortality. Other religions do not have significant effects.

Being an Ewe has a negative impact on maternal mortality. Belonging to other ethnicity does not have significant effects. The place of death being a health facility or en route to a health facility has a positive impact on maternal mortality. The place of death being others does not have significant effects. The usual place of residence being a village / town different from her parents has a positive impact on maternal mortality. The usual place of residence being a locality of her parents' village does not have significant effects. The usual place of residence being others has a negative impact on maternal mortality.

The burial not performed yet has a negative impact on maternal mortality. The burial performed in a different town / village or the burial place being other has a positive impact on maternal mortality. The burial performed in the locality of her parents' village does not have significant effects. Being a friend or in another relationship with the respondent has a negative impact on maternal mortality. Being a parent or another family member to the respondent has a positive impact on maternal mortality. The other relationships do not have significant effects.

Plots of the predicted posterior densities based on the data and the fitted model (not shown here) did not show any major systematic discrepancies of the data from what can be predicted from the model. Plots of residuals versus cluster number, number of people in household, day of interview, month of interview, interview number, number of visits to woman and age of woman (not shown here) appeared random and scattered around zero.

Discussion

Maternal deaths continue to be on the rise despite efforts of various stakeholders to stem this menace. It is a major indicator of the performance for health systems in any country. Therefore the Government of Ghana, Ministry of Health and the Ghana Health

Service in collaboration with relevant stakeholders have been relentless in curbing this menace to improve the quality of life in the country. The high numbers of maternal deaths across the 10 regions is a testament of the worrying status of our health system as a country. Another important revelation in this study is the level of education emerging as a significant variable in determining the outcome of delivery. This is intrinsically linked to the decision making process regarding the occurrence of the types of delays in seeking healthcare (Aden *et al*.[5]). Thus occurrence of such delays complicates health conditions of such women and badly influences health outcomes of such expectant mothers. This is particularly common in rural and under served communities especially where both couple are illiterates and are more prone to resort to traditional methods of managing pregnancies and their related complications (Aden *et al*.[5], Makuei *et al*.[6]). The situation in Ghana is more precarious as most critical health staff such as doctors and nurses hardly accept postings to rural and deprived communities. It is important among others to investigate the causes of the high maternal mortality in these under served communities and institute policies and measures to curtail future occurrences (Michael *et al*.[17]).

Maternal mortality decreased with increasing age. Apart from the reduction in fitness level and other adverse health conditions associated with age, younger women are less experienced in managing pregnancies and related conditions and may also be experiencing their first child birth. The largest number of deaths occurred in the age groups from 20-34, largely because those are the ages at which women are most likely to give birth. This calls for efforts directed at this group for most effectively reducing the number of deaths (Blanc *et al*.[18]).

The season being rainy is another significant determinant of maternal mortality. Maternal mortality was higher during rainy seasons. This maybe due to transport problems during the rainy season, causing delays in health workers accessing the woman or the woman accessing health facilities. The significance of season has been supported by other researchers. For example, Romagosa *et al*.[19] noted that "the malaria-specific maternal mortality rate was significantly higher during the rainy seasons" while investigating seasonal variations in maternal mortality in Maputo, Mozambique.

The woman belonging to the eastern, northern and upper east regions is another significant determinant of maternal mortality. Maternal mortality was higher when the woman belonged to these regions. Region as a determinant has been supporting by many researchers. Liang et al. [20] found regional differences in maternal mortality in China, stating that it was "highest in remote areas followed by inner lands and coastal regions". While modeling maternal mortality in Bangladesh, Ahmed and Hill [21] found that it "was consistently higher in the eastern and northern regions, which are known to be culturally conservative and to have poor transportation systems". While investigating maternal mortality in eastern Sudan, Mohammed *et al*.[22] found wide discrepancies between rural and urban areas.

The place of death being a health facility or en route to a health facility is another significant determinant of maternal mortality. Maternal mortality was higher when the place of death was a health facility or en route to a health facility. While investigating maternal deaths in Nigeria, Adegoke *et al*.[23] stated that "most deaths were said to have occurred in the hospital or private clinic", consistent with our finding. Burgess *et al*.[24] also found place of death as a determinant while investigating pregnancy-related mortality in the United States.

The place of residence being different from the usual place of residence is another significant determinant of maternal mortality. Maternal mortality was higher when the place of residence was different from the usual place of residence. Abdullah *et al*.[25] showed that "residence (in villages versus city), and illiteracy" were significantly associated with increased risk of maternal death in Assiut, Egypt. Kramer *et al*.[26] stated that "risk of maternal death in the United States is higher than peer nations and is rising and varies dramatically by the race and place of residence of the woman". Meh *et al*.[27] found that "contraceptive method, residence type and wealth index were associated" with maternal death in southern Nigeria. While investigating maternal mortality in Florianopolis, Brazil, de Souza[28] found that the death rates were higher for women who lived in other places as compared with the capital.

The religion being an Anglican, Presbyterian or a Pentecostal/charismatic or the ethnicity being an Ewe are also significant determinants of maternal mortality. Maternal mortality was higher when the religion was an Anglican, Presbyterian or a Pentecostal/charismatic or the ethnicity was an Ewe. Meh *et al*.[29] also found ethnicity and religion as determinants of maternal mortality in the northern and southern regions of Cameroon. While investigating cases in Nigeria, Konwea and Fabamise[30] showed that there was high maternal mortality cases in Ekiti state and it is as a result of erroneous religious believes and holding to old practice of female genital mutilation.

Conclusion

We have used a Bayesian logistic regression to investigate the relationship between maternal deaths in Ghana and various factors / covariates. The cluster number, the interview number, age, season, the individual line number, region, the supervisor number, marital status, occupation, religion, ethnicity, the place of death, the usual place of residence and the place of burial were found to be significant. The remaining factors / covariates were not significant. The goodness of the fit of the model was assessed by residual plots and a plot of predicted posterior densities.

A future work is to fit a Bayesian logistic regression to model maternal deaths for the entire African continent. A spatial component and a temporal account may be taken account of while modeling.

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Contribution of authors

DJ wrote part of the paper; SN performed the analysis and wrote part of the paper; MJA wrote part of the paper.

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Competing interests

None declared.

Ethics approval

Ethical approval for data collection in was granted by C. K. Tedam University of Technology and Applied Sciences, Ghana, number R124051. Participants gave informed consent to participate in the study before taking part.

Data availability statement

Data are available on reasonable request.

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