International Journal of Statistics and Applications 2014, 4(4): 192-197
DOI: 10.5923/j.statistics.20140404.03

Analysis of Under-five Mortality in Ghana Using Logit Model

Kwaku F. Darkwah*, **Sampson Boachie-Yiadom, Richard Tawiah**

Department of Mathematics, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Abstract This paper examines the key predictors of under-five mortality (UFM) in the Tano South district of Ghana. In order to obtain data for the study, 200 mothers of the aforementioned district were surveyed to elicit information on whether or not they have ever experienced UFM. Moreover, information on environmental and clinical factors were gathered. The responses provided by mothers on their status of UFM was measured on a dichotomous scale and modeled using the binomial distribution. The logit regression was then used to model this probability distribution as a function of the environmental and clinical factors. Of the entire sample 22.5%, 44.0% and 33.5% were aged 15-24, 25-34, and 35 years and older respectively. The model revealed grandmultigravida parity (OR=2.243), anaemia (OR=12.073) and malaria (OR=12.182) are significantly associated with increased odds of UFM. Moreover, use of treated bed-nets (OR=0.075), child vaccination (OR=0.560), practice of exclusive (0.018) and not exclusive breast feeding (OR=0.025) are significantly associated with lower odds of UFM. The model provided a reasonable fit and explained a moderate proportion of total variance in the data used (Cox and Snell R square = 0.423 and Nagelkerke R Square = 0.531).

Keywords Under-five Mortality, Mothers, Logit Model, Dichotomous Variable, Odds Ratio

1. Introduction

Under-five mortality refers to the death of infants and children under the age of five. It is estimated that the number of children under the age five dying globally has dropped remarkably from 12.6 million in 1990 to 6.6 million in 2012 [1]. Despite this reduction it is argued that the world is unlikely to achieve the Millennium Development Goal (MDG) 4 which targets a two-third reduction of the 1990 mortalities by 2015 [1].

In Ghana, statistics indicates that under-five mortality rate is on the decrease; 118.1, 99.1 and 74.4 per 1000 live birth for the years 1990, 2000, and 2010 respectively [2]. Moreover, a recent study in the Kassena Nankana district of the country shown that under-five mortality rate has declined [3]. However, under-five deaths are increasingly concentrated in sub-Saharan Africa and South Asia despite the marked decline in under-five mortality globally [4].

Efficient interventions can be made to further reduce under-five mortality globally if the potential determinants are well researched. To improve child survival in developing countries, Mosley and Chen [5] provided analytical framework based on the premise that all social and economic determinants of child mortality operate through a common set of biological mechanisms, or proximate determinants to exert an impact on mortality. Furthermore, in order to study the determinants of under-five mortality in Nigeria, research was carried out to identify the maternal, child, family and other risk factors associated with under-five mortality [6]. Infant mortality has been found to be higher in mothers with secondary education compared to uneducated mothers in the Ondo state of Nigeria [7]. Findings of a recent study based on the South African Demographic and Health Survey data revealed that the duration of breastfeeding, marital status and ownership of flush toilet are key predictors of under-five mortality [8]. In addition, high parity has been found to be associated with under-five mortality [9]. Sonneveldt et al. [10] explained that this association is partly due to low coverage of key health interventions among children born to mothers of high parity. One study done in the Builsa district of Ghana revealed that children of mothers with previous child deaths are about 8 times more likely to die (OR 7.45), while those who had not had vitamin A supplementation were about 10 times more likely to die (OR 9.57) [11]. It is also known that short birth intervals (less than or equal to 18 months), high parity (6 or more children), low maternal age (less than 20 years) and high maternal age (35 and more years) adversely impact infant and child mortality [12].

However, other risk factors including exclusive breastfeeding (OR 0.72), use of insecticide-treated bed-net (OR 0.12), the number of live children a mother had (OR 0.54) and immunization (OR 0.53) have been identified as

* Corresponding author:
fordarkk@gmail.com (Kwaku F. Darkwah)
Published online at http://journal.sapub.org/statistics

protective factors of under-five mortality in the Builsa district of Ghana [11]. In the Chokwe district of Gaza province, Mozambique, a child survival program which covered 80% of bed net use, 94% of oral rehydration therapy for children with diarrhoea and prompt care-seeking from trained providers for children with danger signs was implemented and this resulted to 66% reduction in infant mortality and 62% reduction in under-five mortality [13]. Research has shown that health seeking behaviour, breastfeeding children for > 18 months, use of contraception, small family size, having one wife, low birth order, normal birth weight, child spacing, living in urban areas, and good sanitation reduces the odds of under-five mortality in Nigeria [6]. Similarly, higher national incomes are known to be associated with lower under-five mortality [14].

The study of the causal relationship between under-five mortality and potential risk factors has extensively been considered within the framework of statistical modeling. The logit regression model provides a mathematical framework that allows for functional relationship between a dichotomous response and one or more predictor variables. Within the context of the background of this paper, under-five mortality with the categories Yes or No represents the response variable and the risk factors denote the predictor variables. The aim of this study is to use the logit model to determine the key predictors of under-five mortality in the Tano South district of Ghana.

2. Materials and Methods

2.1. Study Setting

This study was carried out in the Tano South district of the Brong Ahafo region in Ghana to study the factors associated with under-five mortality in the area. The study was restricted to mothers. The district was divided into four zones and the target populations were identified using the purposive sampling. A total sample size of 200 mothers aged 15 years or older was used, of which 50 was selected randomly from each zone. Questionnaires were designed to obtain data from mothers. The study variables; including environmental factors such as parity of mother, use of treated bed-net, and clinical factors, specifically diseases in children, child vaccination and breastfeeding as well as information about under-five mortality status of mothers were captured in the questionnaires.

Data gathered was organized in the SPSS software package and the logit regression model was implemented to study the predictors of under-five mortality. In this framework the factors such as parity of mother, use of treated bed-net, diseases, child vaccination and breastfeeding were used as predictor variables. Under-five mortality which was measured on a dichotomous scale (Yes or No) was used as the response variable.

2.2. The Logit Model

The Logit regression model is appropriate when the response variable is categorical with two possible outcomes known as dichotomous or binary outcomes. We define a dichotomous variable as

$$Y = \begin{cases} 1 \; if \; outcome \; is \; a \; success \\ 0 \; if \; outcome \; is \; a \; failure \end{cases}$$

The dichotomous variable, Y was binary valued, taking on values 0 or 1, and modeled using the binomial distribution

$$\Pr(Y = y) = \binom{n}{y} \gamma^{y} (1-\gamma)^{n-y} \qquad n = 0,1,2,\ldots,n$$

with probabilities

$\Pr(Y = 1) = \gamma$ and $\Pr(Y = 0) = 1-\gamma$ denoting success and failure respectively. The logit which is the ratio of the probability of success to the probability of failure of the binomial random variables were found as

$$\log it(\gamma) = \frac{\gamma}{1-\gamma} \qquad (1)$$

The logit regression model was built by expressing the logit in Equation 1 as a function of several predictor variables. This model is given by

$$\log it(\gamma) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p$$

where:

α is the intercept and $\beta' s$ are the regression coefficients associated with the predictor variables

$$X_1, X_2, \ldots, X_p.$$

The measure of effect was obtained by the odds ratio denoted (OR) which is defined as the ratio of the odds for $x = 1$ to the odds for $x = 0$ and is given by the equation

$$OR = \frac{\gamma(1)/[1-\gamma(1)]}{\gamma(0)/[1-\gamma(0)]}$$

Moreover, a p-value less than 0.05 indicate that the coefficient, β is significant at 5% level in predicting the response variable. The measure of variance in data explained by the model is based on the pseudo-R square. Specifically, the Cox and Snell pseudo-*R* square which is given by Equation 2 was used

$$R_{cs}^2 = 1 - \left(\frac{l_0}{l_M}\right)^{2/n} = 1 - e^{-1/2n[\ln(l_M) - \ln(l_0)]} \qquad (2)$$

For a normal generalized linear model this formula has a maximum of one, but for logit regression its maximum is 0.75 or lower. A correction to the Cox and Snell pseudo-*R* square known as the Nagelkerke pseudo-*R* square given in Equation 3 was also used. It adjusts Equation 2 to range between zero and one. The corrected formula is

$$R_N^2 = \frac{R_{cs}^2}{1 - l_0^{2/n}} = \frac{R_{cs}^2}{1 - e_0^{2/n \ln(l_0)}} \quad (3)$$

3. Results

To facilitate the progress of this study, the age of mothers was grouped into three categories as found in table 1.

Table 1. Frequency Distribution of Mothers stratified by Age

Age (years)	Frequency	Percentage
15-24	45	22.5
25-34	88	44.0
35+	67	33.5
Total	200	100.0

Of the 200 mothers used in the study, 22.5%, 44.0% and 33.5% were aged 15-24, 25-34 and 35+ respectively.

Table 2 below shows the descriptive statistics of the environmental and clinical factors of mothers. The table gives the responses on the environmental and clinical factors in relation to under-five mortality.

Table 2. Descriptive Statistics of Environmental and Clinical Factors

Explanatory Variables	Categories (Coding)	Response Variable: Under-five Mortality	
		Yes (1)	No (0)
Parity	Primigravidae (0)	9 (8.8%)	25 (25.5%)
	Multigravidae (1)	27 (26.5%)	58 (59.2%)
	Grandmultigravidae (2)	66 (64.7%)	15 (15.3%)
Treated Bed-net use	No (0)	78 (79.6%)	46 (45.1%)
	Yes (1)	20 (20.4%)	56 (54.9%)
Disease	Diarrhoea (0)	2 (2.0%)	7 (7.1%)
	Anaemia (1)	32 (31.3%)	13 (13.3%)
	Malnutrition (2)	6 (5.9%)	10 (10.2%)
	Malaria (3)	59 (57.8%)	61 (62.2%)
	Pneumonia (4)	3 (2.9%)	7 (7.1%)
Use of child vaccine	No (0)	67 (68.4%)	61 (59.8%)
	Yes (1)	31 (31.6%)	41 (40.2%)
Breast feeding	None (0)	37 (48.1%)	29 (23.6%)
	Exclusive (1)	17 (22.1%)	46 (37.4%)
	Not-exclusive (2)	23 (29.9%)	48 (39.0%)

From Table 2, under-five mortality was common among mothers of grandmultigravida parity (64.7%). Among those of multigravida parity 26.5% experienced under-five mortality and fewer among those of primigravida parity (8.8%). Mothers who practiced exclusive breast feeding experienced fewer cases of under-five mortality (22.1%) than those who practiced not exclusive breast feeding (29.9%). The mothers who did not practice any of these had more cases (48.1%), compared to those who practiced exclusive and not exclusive breastfeeding.

Moreover, under-five mortality was fewer among mothers who vaccinated their children (31.6%), than does who did not (68.4%). The respective cases of under-five mortality for children who sleep under treated bed-net and those who do not are 20.4% and 79.6%. Malaria alone accounted for 57.8% of under-five mortality, compared to diarrhoea (2.0%), anaemia (31.3%), malnutrition (5.9%) and pneumonia (2.9%).

Table 3 shows results of omnibus test for logit regression model fitted for the environmental and clinical factors of mothers associated with under-five mortality. The table provides a test for the hypothesis stated below:

Hypothesis for Logit Model Coefficients

H_0: Information about the environmental and clinical factors do not allow for better prediction of under-five mortality.

H_A: Information about the environmental and clinical factors allow for better prediction of under-five mortality.

Table 3. Omnibus Tests of the Logit Model for Under-five Mortality

	Chi-square	d.f	P-value
Step	77.968	43	0.001
Block	77.968	43	0.001
Model	77.968	43	0.001

From Table 3, the Chi-square value and its corresponding p-value are 77.968 and 0.001 respectively for the entire Omnibus test criterion. These results suggest that the entire tests are statistically significant at 5% level, therefore leading to the rejection of the null hypothesis. This brings out the implication that the information about the environmental and clinical factors allow for better prediction of under-five mortality within context of the logit model.

In Table 4, the estimated coefficients, standard errors, odds ratio and p-values of the logit regression model for the environmental and clinical factors related to under-five mortality are presented.

The intercept of 3.714 with odds ratio of 41.018 is not significant (p-value=0.307) at 5% level. For the parity factor only high parity, specifically grandmultigravida with estimated coefficient of 0.808 and corresponding p-value of 0.037 is significantly associated with under-five mortality. The OR of grandmultigravida parity is 2.243. This suggests that mothers of grandmultigravida parity are 2.243 times more likely to experience under-five mortality compared to those of primigravida parity.

Furthermore, treated bed-net use is significantly associated with under-five mortality (coefficient=-2.587; p-value=0.000) with estimated OR of 0.075. The value of the OR gives an indication that under-five mortality is less likely to occur in mothers who uses treated bed-nets in their homes for their children, compared to those who do not use it. Whilst malnutrition (p-value=0.093) and pneumonia (p-value=0.378) with respective OR of 8.741 and 6.767 are not significant, anaemia (p-value=0.042) and malaria (p-value=0.039) are significantly associated with under-five mortality. Compare to diarrhoea, under-five mortality caused by malaria and anaemia are 12.182 and 12.073 times more likely. The use of child vaccine showed significant (p-value=0.000) negative association with under-five mortality with estimated odds ratio of 0.560. This depicts that under-five mortality is less likely to occur in mothers who vaccinate their children, compared to those who do not.

Table 4. Logit Regression Model for Factors associated with under-five Mortality

Variables	Estimate	Std. Error	Odds Ratio	P-Value
Intercept	2.714	1.183	15.089	0.307
Parity				
Primigravidae	0.000	0.000	1.000	
Multigravidae	0.511	1.017	1.667	0.435
Grandmultigravidae	0.808	0.798	2.243	0.037
Treated bed net use				
No	0.000	0.000	1.000	
Yes	-2.587	0.500	0.075	0.000
Diseases				
Diarrhoea	0.000	0.000	1.000	
Anaemia	2.491	1.281	12.073	0.042
Malnutrition	2.168	1.340	8.741	0.093
Malaria	2.500	1.381	12.182	0.039
Pneumonia	1.912	1.384	6.767	0.378
Use of child vaccine				
No	0.000	0.000	1.000	
Yes	-0.580	0.241	0.560	0.001
Breast feeding				
None	0.000	0.000	1.000	
Exclusive	-4.022	1.917	0.018	0.036
Not-exclusive	-3.699	1.769	0.025	0.037

Similarly, both exclusive (p-value=0.036) and not-exclusive (p-value=0.037) breastfeeding showed significant negative association with under-five mortality with respective odds ratio of 0.018 and 0.025. From the odds ratios it is evident that under-five mortality are less likely among mothers who practice exclusive and not-exclusive breastfeeding compared to those who do not breastfeed their children.

These findings clearly depicts that the key predictors of under-five mortality in the Tano South district are grand multigravida parity, treated bed-net use, anaemia, malaria, use of child vaccine, exclusive and not-exclusive breast feeding. Using these predictors, the fitted logit regression model for under-five mortality is

$$\log it\left(UFM\right) = 2.714 + 0.808GMP - 2.587TBN + 2.491ANA + 2.500MAL - O.580UCV - 4.022EBF - 3.699NEBF$$

Where
UFM- Under-five mortality
GMP- grandmultigravida parity
TBN- treated bed net
ANA- anaemia
MAL- malaria
UCV- use of child vaccine
EBF- exclusive breastfeeding
NEBF- not exclusive breastfeeding

Table 5 shows the result of multiple coefficient of determination of the logit regression model. Specifically, this is given by the Cox and Snell Pseudo R square, and Nagelkerke R Pseudo Square.

Table 5. Pseudo R Square of the Logit Regression Model for Under-five Mortality

Statistic	Value	Proportion of Total Variance
Cox and Snell R Square	0.423	0.75
Nagelkerke R Square	0.531	1.00

From Table 5 the Cox and Snell pseudo R square is 0.423 out of 0.75 for total variance explained. Moreover, Nagelkerke pseudo R square is 0.531 out of 1.00 for total explained variability in data. These imply that the proportion of the total variance in the study data explained by the fitted model is larger than the proportion which is unexplained. In conclusion, these findings depict that the fitted model is consistent with the data used in this research.

From the logit model, the estimated odds of under-five mortality among mothers of grandmultigravida parity (GMP=2), controlling the effect of other factors in the model is

$$\log it\left(UFM\right) = 2.714 + 0.808\times 2 - 2.587\times 0 + 2.491\times 0 + 2.500\times 0 - 0.580\times 0 - 4.022\times 0 - 3.699\times 0$$

$$\log it\left(UFM\right) = 4.330$$

$$Odds\ of\ UFM = \exp\left(4.330\right) = 75.944$$

Therefore, from the odds the estimated probability is

$$\frac{75.944}{1+75.944} = 0.987$$

In addition, controlling the effect of other factors, the estimated odds of under-five mortality among mothers who uses treated bed nets (TBN=1) is

$$\log it\left(UFM\right) = 2.714 + 0.808\times 0 - 2.587\times 1 + 2.491\times 0 + 2.500\times 0 - 0.580\times 0 - 4.022\times 0 - 3.699\times 0$$

$$Odds\ of\ UFM = \exp\left(0.127\right) = 1.135$$

with estimated probability of

$$\frac{1.135}{1+1.135} = 0.532$$

Similarly, the estimated odds of under-five mortality among mothers with children infected with anaemia (ANA=1), controlling the effect of other factors in the model is

$$\log it\left(UFM\right) = 2.714 + 0.808\times 0 - 2.587\times 0 + 2.491\times 1 + 2.500\times 0 - 0.580\times 0 - 4.022\times 0 - 3.699\times 0$$

$$Odds\ of\ UFM = \exp\left(5.205\right) = 182.2$$

The probability is given by

$$\frac{182.2}{1+182.2} = 0.995$$

3.1. Discussions

The frequency of under-five mortality recorded globally has dropped from 12.6 million in 1990 to 6.6 million in 2012 [1]. Yet, this reduction in under-five mortality is still not sufficient to reach the Millennium Development Goal (MDG) target of a two-thirds reduction of 1990 mortality levels by the year 2015 [1]. This has resulted to a growing interest in understanding the underlying determinants or predictors of under-five mortality in recent studies [6, 8, 9, 11, 14].

This study investigated the determinants of under-five mortality in the Tano South district of Ghana. It was found that low parity, specifically primigravida and multigravida are not significantly associated with under-five mortality. However, this study and that by Bicego [12] and Kozuki et al. [9] consistently showed that high parity is significantly associated with increased odds of under-five mortality. This association has been partly ascribed to low coverage of key health interventions among children born to mothers of high parity [10].

Secondly, the results suggest that anaemia, malnutrition, malaria and pneumonia adversely affect under-five mortality. However, only the effect of anaemia and malaria are statistically significant. The estimated effect of malaria (OR=12.182) and anaemia (OR=12.073) on under-five mortality are comparable, but malaria appears to be the most important risk factor that increases the likelihood of under-five mortality. To the best of our knowledge, there are no studies that researched the association of under-five mortality and diseases, therefore making it impossible to compare these finding with literature.

Moreover, we found that the likelihood of under-five mortality among mothers with children who sleep in treated bed-nets (OR=0.075) was lower than those who did not sleep in treated bed-nets (OR=1.00). Under-five mortality is less likely among mothers who vaccinated their children, compared to those who did not. Similarly, a lower likelihood of under-five mortality was observed in mothers who practiced exclusive and not-exclusive breastfeeding, compared to those who did not practice any of these. These findings are similar to those of one research conducted in Nigeria [6]. However, they are consistent with the study done in the Builsa district of Ghana [11] and may give partial explanation to the decreasing pattern of under-five mortality observed in the country [2, 3].

4. Conclusions

The underlying predictors of under-five mortality are well researched in a probabilistic context if we make an assumption that not all mothers have ever experienced this phenomenon. The present study accommodated with this assumption by choosing a logit model with probability of responses under the binomial distribution for studying the predictors of under-five mortality in the Tano South district of Ghana. This study revealed that grandmultigravida parity, malaria and anaemia are associated with increased likelihood of under-five mortality. Moreover, treated bed-net use, use of child vaccine, exclusive and not-exclusive breast feeding are associated with lower odds of under-five mortality. The evidence of increased likelihood for under-five mortality associated with the grandmultigravida parity, malaria and anaemia highlights the need to tailor interventions to address these factors in the district. Moreover, we recommend that the residents of the district will be more aware of the possible benefits of using treated bed-net, child vaccine, and practicing either exclusive or not-exclusive breast feeding. Research is still needed concerning the key predictors of under-five mortality. Future studies should especially focus on interactions between the risk factors and also capture the frequency of under-five mortality a mother has ever experienced in the framework of statistical modeling. In recognizing the full complexity of under-five mortality we might improve our ability to predict needs and achieve better interventions to further control the burdens of under-five mortality in modern societies.

REFERENCES

[1] World Health Organization (2014). Millennium Development Goals (MDGs). http://www.who.int/mediacentre/factsheets/fs290/en/ (accessed: June 27, 2014).

[2] World Bank Indicators - Ghana - Mortality. http://www.tradingeconomics.com/ghana/mortality-rate-under-5-per-1-000-wb-data.html (accessed: January 3, 2014).

[3] Adjuik, M, Kanyomse, E, Kondayire, F, Wak, G, Hodgson, A (2010). Clustering of under-five mortality in the Navrongo HDSS in the Kassena-Nankana District of Northern Ghana. Global Health Action Supplement. DOI: 10.3402/gha.v30.5233.

[4] UNICEF REPORT (2012). Under 5 Mortality rates declining. http://ghanahealthnest.com/2012/09/13/under-5-mortality-rates-declining-unicef-report/ (accessed: June 27, 2014).

[5] Mosley, W. and Chen, L. (1984). An analytical framework for the study of child survival in development countries. Bulletin of the World Health Organization 2003, 81 (2); Extracted from: Population and Development Review 1984; 10 Suppl: 25–45.

[6] Kayode, G.A, Adekanmbi, V. T. and Uthman, O. A (2012). Risk factors and a predictive model for under-five mortality in Nigeria: evidence from Nigeria demographic and health survey. BMC Pregnancy and Childbirth 12:10.

[7] Adetunji, J. A. (1995). Infant mortality and mother's education in Ondo State, Nigeria. Social Science and Medicine; 40(2):253-263.

[8] Zeleke, W. (2009). Factors that affect under-five mortality among South African children: Analysis of the South African demographic and health survey data. Proceedings of the World Congress on Engineering and Computer Science, vol.II San Francisco, USA.

[9] Kozuki N, Sonneveldt E and Walker N (2013). Residual confounding explains the association between high parity and child mortality. BMC Public Health, 13(Suppl 3):S5.

[10] Sonneveldt E, Plosky W. D. and Stover J (2013). Linking high parity and maternal and child mortality: what is the impact of lower health services coverage among higher order births? BMC Public Health13 (Suppl 3):S7.

[11] Osei-Kwakye K., Otupiri E., Owusu Dabo E, Browne E.N.L and Adjuik M (2010). Determinants of Under-five mortality in Builsa District, Upper East Region, Ghana. Journal of Science and Technology; 30 (1): 45-53.

[12] Bicego, G (1990). Trends, age patterns and determinants of childhood mortality in Haiti. [PhD. Dissertation]. Baltimore: The John Hopkins University.

[13] Edward A, Ernst P, Taylor C, Becker S., Mazive E. and Perry H (2007). Examining the evidence of under-five mortality reduction in a community-based programme in Gaza, Mozambique. Transactions of the Royal Society of Tropical Medicine and Hygiene; 101, 814-822.

[14] Houweling, T. A. J., Kunst, A, Looman, W. N. C., and Maackenbach, P.J. (2005). Determinants of under-5 mortality among the poor and the rich: a cross-national analysis of 43 developing countries. International journal of Epidemology 34:1257-1265.