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The Influence of Frailty on Infant and Child Mortality in Rural Nigeria

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Abstract **Background:** Infant and child mortality remains a major public health challenge in Nigeria and other parts of the developing world with rural areas sharing the largest burden which of course have devastating effects on concerned mothers and the population at large. This study was conducted to determine the effect of frailty and which of infant or child mortality is most affected by unobserved heterogeneity in Rural Nigeria. **Methods:** Data from 2013 Nigeria Demographic and Health Survey were analyzed. Weibull frailty models were fitted. The frailty effects, Hazard ratio (HR) and its 95% confidence interval (CI) were estimated. **Results:** The frailty value in infant and child mortality are 51.8 and 56.5 percent respectively, which means that the covariates in infant and child models explained 48.2 percent and 43.5 percent family variation in infant and child deaths in rural Nigeria. **Conclusion***:* Child mortality is more affected by unobserved heterogeneity than infant mortality in rural Nigeria.

Keywords: *mortality determinants, Frailty, Under-five mortality, Rural Nigeria, Weibull Model*

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1. Introduction

It is a known fact that infant and child mortality remains a major public health issue in Nigeria and other low and middle income countries with rural areas sharing the largest burden which of course have devastating effects on concerned mothers and the population at large. Child mortality reduction has become a common agenda of public health and international agencies [1]. It is also an important indicator of living conditions of a country and children’s well-being. According to UNICEF reports, approximately 18,000 children under-five years die every day with huge variation across region and countries as well as urban and rural areas [2].

Children in rural areas are faced with higher mortality than their urban counterparts [3]. Higher rates in infant mortality in rural areas are derived from both observed and unobserved disadvantages in household characteristics and these explain for two-thirds of the differentials, less than one-quarter of the differentials is explained by Community characteristics, with about two-thirds coming from community unobserved heterogeneity while the most contributing factors are the environmental factors (such as electricity, a safe source of drinking water, and quality of housing materials) [4]. There are significant spatial differences in infant mortality rates and under-five mortality rates among the Nigerian six geo-political regions and by rural urban residence [5]. Also, a study in rural Nigeria shows that access to good health facilities and antenatal care, birth interval, maternal education, mother source of income, where babes are delivered and mothers age at birth are factors responsible for high rate of child mortality in rural Nigeria [6].

Because of the challenge infant and child mortality pose to public health in Nigeria and other developing countries, researchers have made considerable efforts to understand factors motivating the phenomenon. Many studies have shown that infants and child mortality rates vary by socio-economic and bio-demographic characteristics [7-13].

In Nigeria, according to 2013 NDHS report, Infant mortality is 43 percent higher in rural areas (i.e. 86 deaths per 1,000 live births) than in urban areas (60 deaths per 1,000 live births) and child mortality is 89 deaths per 1,000 live births in the rural areas as against 42 deaths per 1,000 live births in urban areas [14]. Data from a different environment indicate that the incidence of death in children are not randomly distributed families but, rather, that there is a positive association of sibling deaths [9,15]. A natural explanation of this would be that families in which child deaths are concentrated share some environmental or genetic risk factors that predispose their children to higher risks of death. These associations with infant and child mortality even after accounting for different observed factors of mortality in rural areas have been attributed to unobserved heterogeneity (such as genetic, behavioral and environmental factors, occurring at individual, family and community levels [15]. Some of these factors (covariates) are not observed or captured in a social survey like NDHS which is the dataset that most researchers in Nigeria utilize. Therefore, this study will determine which of infant or child mortality is most affected by unobserved heterogeneity in rural Nigeria.

2. Methods

2.1. Setting

The population of Nigeria based on 2006 population and housing census was 140,431,790 with an estimated growth rate of 3.2% per annum [14]. But United Nation population Fund in 2011 put Nigeria population at 167 million which is the sixth largest in the world after Brazil, Indonesia, USA, India and China.

Administratively and politically, Nigeria is divided into six geo-political zones: South- South, South East, South West, North Central, North West, and North East and it is subdivided into 36 states and a Federal Capital Territory. Presently, Nigeria is governed by democratically elected leaders both at national and state levels.

The Nigeria fertility rate has remained high since 2003 with a Total Fertility Rate (TFR) of 5.5 births per woman. The North West Zone has the highest TFR of 6.7 while the lowest is the South -South Zone with TFR of 4.3 births per woman. Also, the rural areas have higher TFR than the urban areas (6.2 versus 4.7) [14].

2.2. Data Sources

This study involved secondary analysis of nationally representative data from the 2013 Nigerian Demographic and Health Survey. The 2013 NDHS used the sampling frame for the Nigerian 2006 National Population and Housing Census. The survey covered all the 36 states and the Federal Capital Territory, Abuja. Information on deaths and births of children aged less than five years was obtained from 23403 eligible rural women, aged 15–49 years who were either permanent residents in the selected households or visitors that slept in the selected households on the night preceding the survey. From these women, a total (weighted) of 20702 live-born infants were obtained. The analyses were restricted to live births and most recent births during the five years preceding the surveys to limit mothers' potential for differential recall of events, as deliveries had occurred at different points in time prior to the interview. For detailed sampling procedures of 2013 NDHS contact [14].

2.3. Variables Measurement

The outcome variables in this study are the risk of infant death and the risk of child death. The risk of death in infancy or childhood is measured as the duration of survival since birth (in months). Independent Variables: these are bio-demographic variables (Sex of the Child, Maternal age at birth of the child, Type of marriage of respondent, Birth interval, Child year of birth, and Maternal age at first birth) and socio-economic variables (Maternal education, Socioeconomic status, Type of toilet facility, Source of drinking water, Marital status of respondents, Religion and Region).

2.4. Statistical Analysis

Analyses were done using Stata statistical package (version 12). In this study, univariate analysis was used to present the percentage distribution of the respondents according to the selected variables. And Frailty model was employed to identify which of infant/child mortality is mostly affected by unobserved heterogeneity in rural Nigeria. Also, design weights were calculated to account for the complex nature of sample design of NDHS data.

In all there are two models, for both infant and child mortality. The models are classified as follows:

Model 1 – This is frailty model of the selected socioeconomic variables and outcome variable

Model 2 – This is frailty model of the combination of selected socioeconomic and bio-demographic variables and outcome variable.

The hazard ratios, p-value < 0.05 and confidence intervals were used to measure the significant effect of unobserved variables on infant and child mortality in rural Nigeria.

The various survival models are based on the distribution that the timing function is assumed to follow [16]. In this study we will utilize the Weibull frailty model. This model is chosen because it is suitable to model hazards that are either increasing or decreasing monotonically [17]. Mortality in human population follow Weibull, because it is generally high in the first years of life, it declines in other ages of childhood, then increasing slowly in adult ages to old age [17]. Based on this point, many researches on childhood mortality used Weibull model [9,11].

The frailty α being an unobserved multiplicative effect on the hazard function which is assumed to follow gamma distribution g(α) with α > 0 and the mean of g(α) equal to 1. The variance of g(α) is a parameter θ (theta) that is usually estimated from the data. The model assumes that the individual risk of death is a function of measured (covariates) factors. The model is of the form:

$$h_{ij}\left(t/x_{ij},\alpha_j\right)=\alpha_j h_{ij}(t/x_{ij}). \tag{1}$$

The indices i and j correspond to observations in children and mothers, respectively. If the variance estimate θ is different from zero it indicates that unobserved and unmeasurable family factors affect the risk of death hence their survival risks are correlated. And if the variance estimate θ is zero, then, all families have the same risk of death. Also, individuals with frailty α > 1 have a higher hazard and decreased chance of survival compared to those with frailty α = 1. And individuals with frailty α < 1 have a decreased hazard and higher chance of survival compared to those with frailty α = 1 [18].

Further, at the multivariate level, analyses were run separately for infant mortality and for child mortality, to examine the effect of some selected covariates on infant and child mortality and to find out how unobserved heterogeneity affect survival chance in infancy and childhood.

3. Results

Table 1 shows the distribution of selected socioeconomic and bio-demographic variables based on the 2013 NDHS data.

Table 2 presents the result from the fitted hazard models for infant and child mortality. From the table a total of 1,382 children died in infancy and a total of 677 children died between 12 and 59 months. For all the models, the chi-squared statistics and log likelihood ratios describing the model goodness of fit are all significant.

The estimated variance parameters associated with the frailty effect, θ, in the Weibull frailty model in infant mortality are 0.507 and 0.518 in Model I and Model II, respectively.

The estimate in model II implies that one infant death in a family is related to about 51 percent increase in the risk of the index infant dying comparative to what it would have been assuming the infant were alive.

The Weibull frailties in child mortality are 0.602 and 0.565 in Model I and Model II respectively. These parameters are very significant and the standard errors (not included) associated with the hazard ratios of the variables are constantly higher, which in turn result to wider confidence intervals.

Effects of Unobserved heterogeneity on Infant and Child mortality

This indicated that the increase is generally small and does not alter the significance of any of the parameter estimates.

The results show that all the biodemographic and socioeconomic variables, after controlling for each other, are significantly related to child survival. Like in infant mortality, these estimates are significant and show that the risks of child death between families keep on differing even after controlling for a number of observed determinants of childhood mortality.

The estimate in model II imply that one child death in a family is related to about 57 percent increase in the risk of the index child dying comparative to what it would have being assuming the child were alive. These results imply that, in contrast to infant mortality, there is huge difference between families in the risk of child mortality that is not accounted for by the measured and observed factors.

Table 1. Percentage distribution according to selected factors

Variables	Frequency	Percentage
Sex of the child		
Male	10431	50.4
Female	10271	49.6
Type of marriage		
Monogamous	11635	56.2
Polygamous	9067	43.8
Maternal age at child birth		
<20 years	3719	18.0
20-35 years	13887	67.1
>35 years	2427	11.7
Birth interval		
First birth	3776	18.2
<24 months	3963	19.1
24-35 months	6775	32.7
>35 months	6188	29.9
Maternal age at first birth		
< 20years	11097	53.6
20-35years	7172	34.6
>35years	48	0.2
Child year of birth		
2012-2013	5347	25.8
2010-2011	7225	34.9
2008-2009	5746	27.8
Maternal education		
None	13144	63.5
Primary	3763	18.2
Secondary and higher	3790	18.3
Socioeconomic status		
Poor	8972	43.3
Middle	3555	17.2
Rich	5790	28.0
Marital status		
Never married	2796	13.5
Married	17906	86.5
Religion		
Catholic	1814	8.8
Other Christian	6199	29.9
Islam	10026	48.4
Others	199	1.0
Source of drinking water		
Unimproved	11215	54.2
Improved	9487	45.8
Type of toilet facilities		
Unimproved	13050	63.0
Improved	7652	37.0
Region		
North-west	9125	44.1
North-east	4213	20.4
North-central	3368	16.3
South-east	860	4.2
South-south	1908	9.2
South-west	1228	5.9

Table 2. Hazard ratios of Infant and Child mortality associated with selected factors

Variables	Frailty model for Infant Mortality		Frailty model for Child Mortality	
	Model I	Model II	Model I	Model II
Sex of the child				
Male	1.00	1.00	1.00	1.00
Female	0.75 (0.64, 0.89)*	0.75 (0.63, 0.89)*	0.82 (0.65, 1.03)	0.83 (0.66, 1.05)
Type of marriage				
Monogamous	1.00	1.00	1.00	1.00
Polygamous	1.02 (0.85, 1.22)	1.06 (0.88, 1.28)	1.08 (0.84, 1.37)	1.09 (0.84, 1.42)
Maternal age at child birth				
<20 years	1.00	1.00	1.00	1.00
20-35 years	1.01 (0.78, 1.32)	1.07 (0.81, 1.40)	0.88 (0.61, 1.26)	1.06 (0.73, 1.54)
>35 years	1.63 (1.16, 2.30)*	1.67 (1.18, 2.38)*	1.32 (0.83, 2.10)	1.44 (0.90, 2.31)
Birth interval				
First birth	1.00	1.00	1.00	1.00
<24 months	1.20 (0.91, 1.59)	1.10 (0.83, 1.47)	1.57 (1.05, 2.36)*	1.22 (0.81, 1.86)
24-35 months	0.54 (0.41, 0.71)*	0.50 (0.37, 0.66)*	1.05 (0.71, 1.56)	0.83 (0.55, 1.25)
>35 months	0.33 (0.25, 0.45)*	0.31 (0.23, 0.42)*	0.54 (0.35, 0.84)*	0.44 (0.28, 0.70)*

Variables	Frailty model for Infant Mortality		Frailty model for Child Mortality	
	Model I	Model II	Model I	Model II
Maternal age at first birth				
< 20years	1.00	1.00	1.00	1.00
20-35years	1.04 (0.87, 1.24)	1.03 (0.85, 1.24)	1.04 (0.82, 1.32)	1.03 (0.80,1.33)
>35years	4.19 (1.15, 15.21)*	4.45 (1.23, 16.11)*	0.49 (0.03, 8.95)	0.45 (0.02, 9.02)
Child year of birth				
2012-2013	1.00	1.00	1.00	1.00
2010-2011	1.20 (0.97, 1.47)	1.19 (0.97, 1.47)	1.14 (0.86, 1.52)	1.16 (0.88, 1.54)
2008-2009	1.15 (0.93, 1.44)	1.14 (0.91, 1.47)	0.86 (0.64, 1.17)	0.85 (0.63, 1.15)
Maternal education				
None		1.00		1.00
Primary		1.08 (0.85, 1.38)		0.78 (0.56, 1.11)
Secondary and higher		0.88 (0.65, 1.19)		0.32 (0.19, 0.52)*
Socioeconomic status				
Poor		1.00		1.00
Middle		0.93 (0.73, 1.18)		0.93 (0.67, 1.30)
Rich		0.88 (0.70, 1.10)		1.10 (0.81, 1.49)
Marital status				
Never married		1.00		1.00
Married		1.25 (0.68, 2.31)		0.93 (0.41, 2.07)
Religion				
Catholic		1.00		1.00
Other Christian		1.46 (1.04, 2.03) *		1.21 (0.79, 1.86)
Islam		1.34 (0.80, 1.61)		1.14 (0.72, 1.81)
Other religion		1.28 (0.54, 3.01)		4.12 (1.47, 11.48)*
Source of water				
Unimproved		1.00		1.00
Improved		1.04 (0.88, 1.26)		0.92 (0.72, 1.18)
Type of toilet facilities				
Unimproved		1.00		1.00
Improved		0.76 (0.63, 0.91) *		0.95 (0.74, 1.21)
Region				
North-central		1.00		1.00
North-east		1.42 (1.07, 1.90) *		2.06 (1.36, 3.13)*
North-west		1.64 (1.23, 2.18) *		2.41 (1.59, 3.66)*
South-east		1.40 (0.88, 2.24)		1.89 (0.90, 3.96)
South-south		1.07 (0.71, 1.63)		1.47 (0.76, 2.82)
South-west		1.05 (0.70, 1.56)		1.37 (0.67, 1.24)
Sample size	18697	18605	18697	18605
Number of failures	1382	1369	1382	1369
Negative log likelihood	7139	7061	7224	7143
Likelihood ratio chi-square	150	184	157	197
Degree of freedom	11	25	11	25
Theta	0.507 (0.36, 0.71)	0.518 (0.36, 0.73)	0.602 (0.39, 0.92)	0.565 (0.35, 0.90)
Likelihood ratio chi-square of theta = 0	170.54	163.07	117	106

* significant at p< 0.05.

4. Discussion

The purpose of this study was to determine which of infant or child mortality is more affected by unobserved heterogeneity in rural Nigeria.

It had been shown from result that infant and child mortality vary due to the measured socioeconomic, and biodemographic factors even though the relationships between the covariates and mortality were often not statistically significant. In this section we discuss the findings on frailty models. Frailty, in the infant and child mortality models, represents a child's vulnerability to the risk of death. It captures the total effect of all factors that influence the child's risk of death that are not included in the baseline hazards presented in the model [19].

The frailty effects presented in frailty model represent unmeasured effects on infant and child mortality. In this study, almost all biodemographic variables are significantly related to infant while most socioeconomic variables are significantly related to child mortality in the frailty model. We observed that the risk of infant mortality is about 5 times more likely for children of mother greater 35 years old at their first birth compared with children of whose their mother's age as at the time of their first birth was less than 20 years. This is in consistent with the study in Kenya by Omariba [9]. This high effect of maternal age at first birth to infant mortality may be due to physiological and sociopsychological factors. The reproductive systems of older mothers are depleted compared to younger mothers [20] and depression associated with late child delivery is also related to infant mortality [21,22].

It was established from the study that there is marginal difference between the effect of frailty for both infant and child mortality. The frailty effects at the family level for infant and child mortality were 51.8 and 56.5 percent, respectively. The frailty effects were statistically significant.

This implies that the risks of infant and child deaths between families differ significantly even after controlling for a number of known determinants of infant and child mortality in rural Nigeria. It further implies that the variables in the infant and child mortality model explained 48.2 and 43.5 percent of the family variation in infant and child deaths. Though, the variation was more in infant mortality than child mortality. These results, was in agreement with previous findings. [9,15,22]

The fact that the risk of childhood death is not totally captured by NDHS makes frailty model more interesting and points to unobserved/unmeasured factors. The exclusion of important variables like healthcare, breastfeeding and HIV/AIDS increased the level of the frailty effect, as these are known determinants of child mortality [22].

5. Conclusions

The findings revealed that the bio-demographic variables account more for mortality during the infant age (0-11 months) while socioeconomic variables account more for mortality during the childhood age (12-59 months) in rural Nigeria.

Also, family frailty for both infant and child mortality is 51.8 and 56.5 percents respectively in rural Nigeria. The magnitude of the unexplained variation in infant and child mortality by the measured covariates represents infant and child vulnerability to the risk of death. Therefore, child mortality is more affected by unobserved heterogeneity than infant mortality in rural Nigeria even though the difference is minimal.

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