Child's risk status at birth as a determinant of infant mortality in Nigeria

Elhakim A. Ibrahim, *Obafemi Awolowo University*
Sunday A. Adedini, *Obafemi Awolowo University and University of the Witwatersrand*
Amos O. Oyedokun, *Obafemi Awolowo University*
Ayotunde Titilayo, *Obafemi Awolowo University*

Abstract

Studies have linked infant mortality (IM) risks to maternal age at birth, inter-birth interval, and birth order; culminating into maternal and child's risk status classified, in aggregate, as not high-risk, unavoidable risk and avoidable high-risks. However, there is dearth of investigations either controlling for confounders in estimating mortality risks differential across the risk groups or quantifying the magnitude of IM attributable to risky status at birth. Hence, 2013 Nigeria Demographic and Health Survey data of 19,833 births were analyzed using Cox proportional hazards regression models. Results indicated that children having avoidable high-risk status at birth exhibited significantly consistent higher hazards of dying in infancy than infants with not high-risk birth status (Unadjusted hazard ratio:1.49,p<0.001; Fully adjusted hazard ratio:1.55,p<0.001). Findings further revealed that 19% of IM in Nigeria was attributable to high-risk birth status. The findings underscore the public health and development significance of fertility behaviour and family planning intervention.

1.0. Introduction

The IMR is undoubtedly a global population and health indicator of policies, programmes and research significance. It is one of the widely acknowledged demographic barometer for assessing a population's overall health status, quality of living condition, level of social and economic development and efficiency of a country's health system (OECD/WHO, 2014; MacDorman & Mathews, 2009; Syamala, 2004). For instance, the IMR is central to measuring and monitoring of progress towards achieving the Millennium Development Goals' (MDGs) which commits the global community to two-thirds reduction in the 1990's infant/child mortality rate by year 2015 (UNICEF, 2014). Furthermore, it is a key indicator in measuring the achievement of Sustainable Development Goals (SDGs)- specifically, the SDG 5- (Sustainable Development Solutions Network, 2014); a renewed commitment to complementing and sustaining the MDG achievements during the post-2015 period. Moreover, IMR is a vital component in the measurement of the Human Development Index (HDI) (Mustafa & Odimegwu, 2008; United Nations Development Programme [UNDP], 2014), a composite global indicator for assessing and comparing countries' level of achievement in three critical components of human development comprising measures of a long and healthy life, knowledge and a decent living standard.

Global accounts of under-five mortality emerging in recent times attest to the declining trends in the global and regional infant and child deaths owing to various child survival interventions embarked upon by different countries and their development partners (UNICEF, 2014). However, infant mortality rate (IMR), the yearly number of deaths among children prior to first birthday per 1,000 live births, has recorded slower improvements. As a result, greater number of childhood deaths concentrates gradually more in this age segment. The United Nations (2014) report on global childhood mortality put the estimate of number of infant deaths at around 4.6 million of the total 6.3 million under-five deaths recorded in 2013 (United Nations [UN], 2014); which is equivalent to nearly three-quarters of all documented cases of under-five mortality for the year.

However, the huge and striking differential in the number of infant deaths across geographic and socio-economic divides masked by this global total cannot be gainsaid. While the wide gap between low-income - and to some extent middle-income- and high income countries persists (Sartorius & Sartorius, 2014; Wang et al., 2014; Black, Morris, & Bryce, 2003), comparison by MDG regions revealed that developing regions accounted for more than 98% (4.57 million) of estimated infant deaths in 2013 compared to roughly 2% (73,000) in the developed region with corresponding IMR of 35 and 5 per 1000 live births respectively. Moreover, the highest burden of global infant mortality is continued to be observed particularly in the sub-Saharan Africa, and to a lesser extent in Southern Asia and Oceania, in sharp contrast to lowest burden found in Europe and America (the United States) (Sartorius & Sartorius, 2014; Wang et al., 2014; Black et al., 2003; Storeygard et al., 2008).

Significantly, moreover, high infant mortality rate remains a population and public health challenge in Nigeria, being a key contributor to infant mortality statistics within the sub-Saharan Africa region. It is a major factor in pitiable standing of Nigeria on global HDI ranking as well as key impediment to realization of the country's MDGs. With an estimated 518,000 infant deaths in 2013, second highest behind India, Nigeria shouldered 11.2% of the global infant mortality burden estimated at 4.6 million infant deaths (UN, 2014). In addition, emerging trends show that increasingly greater number of childhood mortality in the country now occurs during infancy as is observed at the global level. Assessment of IMR trend over the years indicated a sharp and significant drop in the tempo of IMR reduction in recent years: while IMR reduced by a quarter (25%) between 2003 and 2008, less than one-tenth (8%) decline was achieved between 2008 and 2013 (NPopC & ICF International, 2014). The implication of the foregoing is that Nigeria's IMR is yet more than double her 2015 MDG4 target for infant mortality of 30.3 per 1000 live births (FRN, 2013), and 1 in 15 Nigerian children still do not survive to their first birthday (NPopC & ICF International, 2014). These rank Nigeria the eighth country in the world with lowest chances for childhood survival (UN, 2014).

Empirical findings indicate that some key biodemographic risk factors relating to fertility behaviours and biological aspects of birth process- specifically maternal age at childbirth, birth interval and birth order- significantly influence child's health and survival outcomes (Adedini, Odimegwu, Imasiku, Ononokpono, & Ibisomi, 2014; Rutstein & Winter, 2014; Dube, Taha, & Asefa, 2013; Santos, Andrade, Silva, Carvalho, & Mesas, 2012; Kembo & Van Ginneken, 2009; Rutstein, 2008; Uddin & Hossain, 2008; The Alan Guttmacher Institute [AGI], 2002; UNICEF, 2000 cited in Rutstein, 2000; Sullivan, Rutstein, & Bicego, 1994; Hobcraft, McDonald, & Rutstein, 1985). Besides, these three biodemographic indicators of fertility behaviour have been used in classifying maternal and child's risks of adverse health and survival outcomes as not high-risk, unavoidable risk and avoidable (single and multiple) high-risk status (Rutstein & Winter, 2014; Stover & Ross, 2013; Rutstein & Rojas, 2006, p. 101). The summary implication of this broad risk status classification is that a child borne by a too young (< 18 years) or too old (> 34 years) mother, or too close to a previous birth (< 24 months), or of first- or high-order (> 3^{rd} order) birth rank is predisposed to some risks of poor health and survival outcomes.

It is, nevertheless, worrying that significantly larger proportion of births in Nigeria occurs within varying high-risk contexts of extreme maternal ages at birth, short preceding birth interval and/or higher birth order. Available data from 2003 an d 2013 NDHS reports revealed that the proportions of children in avoidable high mortality risk category, that is single and multiple combined, fell only marginally from 65.1% (41.2% single high-risk; 23.9% multiple high-risk) in 2003 to 63.3% (40.0% single high-risk; 23.4% multiple high-risk) in 2013 (National Population Commission [NPopC] & ICF International, 2014, p. 124; National Population Commission, Nigeria [NPC] & ORC Macro, 2004, p. 114). Coupled with characteristic high fertility with total fertility rate of 5.5 children per woman, it would, thus, be logical to maintain that the country's high infant mortality profile is deeply rooted in factors defining women's fertility behaviours aside other risk factors.

However, attempts to date at estimating country-specific childhood mortality risks differential across the aforesaid risk groups, as being routinely presented in Demographic and Health Surveys reports, have not taken into consideration the effects of potential factors of influence. Furthermore, there is dearth of investigations quantifying the extent to which the risk status at the time of birth, in aggregate, account for infant mortality at country level. A noteworthy effort in this direction, though, is a recent pooled analysis of DHS data from 45 countries including data from 2008 Nigeria DHS (Rutstein & Winter, 2014). However, the analysis of childhood mortality differential across risk classifications and the estimated size of attributable mortality were not country-specific due to the pooled analytical technique employed. In addition, the estimated sizes of mortality attributable to these risk factors were not measured vis-a-vis the aggregate risk status dimensions.

The thrust of this study, therefore, is to model, in aggregate, net mortality experience during infancy in Nigeria by child's risk status at birth characteristic while controlling for covariates of known influence and also to quantify the proportion of infant mortality attributable to the aggregated risk status groups. This is aimed at providing empirical explanation for differentials in risks of infant deaths across the risk status classification on which information is hitherto limited.

2.0. Data and Method

2.1. Study Design, Study Population and Sample Size

This study is cross-sectional by design as it conducts a secondary analysis of kids-recode dataset drawn from the 2013 NDHS implemented by the NPopC. In order to achieve the objectives of this study, analysis was generally restricted to live births to successfully interviewed women in the five years prior to the survey. As to the descriptive analysis, this translated to a weighted total of 31,828 children given birth to by a weighted sample of 20,467 women of the weighted total of 38,948 interviewed women. However, further restrictions were made apropos inferential analysis with study subjects constrained to only the most recent live births. Furthermore, allowance was made for 11 months of exposure to risk of mortality for all surviving children; thus, further confining the analysis to children born at least 12 months before the survey. It is worthy of note that few investigators such as Mustafa and Odimegwu (2008), Hosseinpoor et al. (2006) and Adetunji (1995) have allowed for this exposure period with a view to aptly censoring cases over the observation period.

Consequently, the study included only nationally representative weighted sample of 19,833 children had by weighted 13,962 women as to the chi-square and survival analyses. Of this total live births were 1,145 weighted observations representing total number of reported children deaths which occurred during the first year of life. In correcting for inherent design effects in the data, the primary sampling units and weighting factor (v005/100000) provided by the DHS were appropriately specified using "svyset" command embedded in Stata software. Generally, a child born alive to a woman is the unit of analysis in this study.

2.2. Variable Definition and Measurement

2.2.1. Outcome

Infant mortality is the outcome of interest in this study. This is operationalized as the child's risk of dying between age 0 to 11 month and the specific point in time during the interval a death actually occurred. Thus, the duration of survival is measured in months from birth to age at death or censoring (Jaadla & Klesment, 2014). The outcome status of an observation takes either of the dichotomized values 1 and 0: 1 for uncensored observation, indicating death occurring before age 1; and 0 for censored observation, representing those who survive through and beyond the period under consideration, 0 to 11 months.

The information on survival status and duration of survival of a child was obtained from birth history data which contained records on all live births with respect to their date of birth, survival status, and current age as at the interview date if alive or age at death if dead. These information form the basis for the calculation of infant mortality rate (IMR) drawing on synthetic cohort life-table (Rutstein & Rojas, 2006).

2.2.2. Explanatory Regressor

The main explanatory attribute whose influence on infant survival is being examined in this study is child's risk status at birth. The variable, as highlighted in Table 3.1., is grouped, in aggregate, into three major categories as *not high-risk*, *unavoidable risk* and *any high-risk* which comprises both *single high-risk* and *multiple high-risk* status groups. The variable is an aggregate index derived from three principal fertility-related variables: *Preceding birth interval, Birth order* and *Maternal age at birth*. The variable *Preceding birth interval* originally coded in months was grouped as "less than 24 months" (i.e. too close) and "24 months or more"; while variable *Birth order* was categorized into 3 groups; 1^{st}, 2^{nd}-3^{rd} and 4^{th} or higher order births (i.e. too many). *Maternal age at birth*, defined as the age of mother as at the birth of the last child prior to the survey, was derived by subtracting the century month code (CMC) of the date of birth of the child from the century month code of the date of birth of the mother as reported respectively. The derived single-year maternal age was further categorized into 3 broad age groups: "too young" (<18 years), "middle" (18-34 years) and "too old" (35+ years) age groups at birth.

Accordingly, a child was considered as having **"*not high*-risk"** status if s/he is of 2-3 order and was born by a middle aged mother, while those grouped as having **"*unavoidable risk*"** status comprise only the firstborns born by a middle-aged mother. Moreover, the third main category is those classified as being of **"*any high-risk*"** birth status group, consisting of **"*single high-risk*"** and **"*multiple high-risk*"** status groups. A child was classified as belonging to **"*single high risk*"** status group if s/he has only one of the component risky attributes such as being of 'too close' birth interval or 'too many' birth order, or being born by either a 'too young' or a 'too old' mother. However, a child was categorized as belonging to **"*multiple high-risk*"** status group if s/he combines at least two of the **"*single high-risk*"** status group's characteristics.

2.3. Statistical Analysis

2.3.1. Cox Proportional Hazards Regression Model

Cox Proportional Hazards Regression Model is a statistical technique developed by Cox (1972; 1970) which integrates the survival technique with regression model. The model both accounts for the probability of success or failure of an event occurring over a specified interval (censored time-to-event) and factor(s) associated with or producing such an event alongside the influence(s) of the identified factor(s).

The thrust of the model as a survival-predictor analytical technique lies in its ability in allowing for both censoring, lacking in linear regression, and time component, unaccounted for in logistic regression. It is the model employed in obtaining the individual's hazard function estimate and/or the hazard ratio between individuals or across groups. In Cox PH model, the general individual instantaneous hazard of an event is a product of a function *t* and a function of an exponentiated vector of regressors (Kleinbaum & Klein, 2005) modelled by the equation:

$$h_i(t_i; x_i) = h_0(t_i)\, e^{\beta_i X_i} = h_0(t) \exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n)$$

Where $h_0(t)$ symbolizes the unspecified baseline hazard function at time *t* for an individual whose covariates vector $X_i = 0$ i.e. all the covariates $x = 1, 2, \ldots, n$ assumes value 0; true regression coefficients vector β_i indicates relative effects $\beta_1 + \beta_2 + \ldots + \beta_n$; and covariate vector X_i represents a set of covariates $x_1 + x_2 + \ldots + x_n$ assumed to have multiplying effects on the hazard in estimating β_i. Model iii is a semiparametric model, comprising $h_0(t, x)$, a non-parameterized, non-estimated function and $\exp(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n)$, a parameterized, estimated relative effects of covariates. The relative effects $\beta_1 + \beta_2 + \ldots + \beta_n$ are estimated by Cox regression procedure.

The Cox PH model rests on the assumption of constant hazard ratio between individuals and/or across groups over time. That is, it does not require the choice of some specific probability distribution to represent survival durations (Allison, 2005). In other words, the hazard for an individual in one group, say *i*, at a point in time is proportional to the hazard for an individual in other group, say *j*, at that point in time.

2.3.2. The *punafcc* Package

According to Newson (2013) the punafcc, implementable in Stata, is a post-estimation statistical package that calculates a difference in ratios between two modelled scenarios: one which refers to actual scenario with exposure characteristic of interest, tagged "Scenario 0", and the other relating to desired or hypothesized scenario where subjects are assumed to be free from exposure characteristic, tagged "Scenario 1". Thus, while the exposure variable typically takes value 1 in the Scenario 0, the value of the exposure variable is hypothesized to be zero in Scenario 1. In both circumstances being considered, any other covariate(s) in the model is/are held to remain unchanged.

Essentially, the package was developed to estimate, for survival data, a log transformed mean between-scenario hazard ratio, referred to as population unattributable fraction (PUF), and its associated confidence intervals. This PUF estimate is achievable following multivariate Cox proportional hazards ratios estimations. The PUF and the confidence intervals are deducted from 1 to derive population attributable fraction (PAF). The population attributable fraction (PAF) is construed as the proportion of outcome of interest, in this case infant deaths, attributable to Scenario 0, the actual scenario, rather than Scenario 1, the fantasized scenario. Therefore, for Scenario $i \in \{0, 1\}$, the PAF is modelled with the equation:

$$\mathbf{c_1(\theta) = 1 - exp\ (log[\ p^{(1)}(\ \theta)]\ )\ ....\ i}$$

Where θ represents the parameter vector estimated by the originally fitted model from which the PUF and PAF are to derive; $p^{(1)}(\theta)$ denotes the population scenario mean for Scenario 1, the PUF; $\log[\ p^{(1)}(\ \theta)]$ indicates the log transformed population scenario mean for Scenario 1, the log PUF; and $c_1(\theta)$ symbolizes untransformed Scenario 1 parameter which derived from exponentiated log transformed PUF, the PAF.

The equation vi can then be simply represented as:

$$\mathbf{PAF = 1 - PUF\ ....\ ii}$$

In achieving the objectives of this study, analyses were conducted at univariate, bivariate and multivariate levels. Simple percentage distribution was used to characterize the study population. The Chi-square test was used to examine bivariate association between the explanatory variable and infant survival variable. The univariate and multivariate Cox PHR was used to investigate the nature of unadjusted and adjusted influences of the regressor variable on risk of infant mortality. The multivariate Cox PHR modelling technique was particularly employed to examine the effects of the explanatory factor on infant mortality while other covariates and possible confounders are controlled for. This adequately established the true influence beyond association/relationship assessed using Chi-square cross-tabulations and univariate Cox proportional hazards models.

Moreover, the extent to which risk status at birth accounts for infant mortality was investigated employing the punafcc post-estimation statistical package implementable in Stata. The punafcc package was developed to estimate population attributable fraction (PAF) subsequent to the multivariate Cox proportional hazards ratios estimations. The PAF provides estimates of proportion of a particular event attributable to a predisposing factor or attribute.

The Chi-square test and Cox proportional hazards regression ratios were estimated using Stata software for Windows version 12.0.

In general, three set of hazard ratios were estimated for each category of the fitted Models. This is done to adequately reflect the hazard ratios along the risk status dimensions both in various aggregate forms and by components as operationalized.

3.0. Results

3.1. Study Population Distribution by Risk Status

Table 1 presents the distribution of the study population by risk status characteristics. As revealed in the table, a total of 31,828 live births were recorded during the reference period. Table 1 and Figure 1 show that majority of the children (40%) belong to the single high-risk status group, while those of unavoidable risk status category constitute the minority (14%). Births in not high-risk status group and those in multiple high-risk statuses make approximately twenty-three percent each of the total live births, whereas overwhelming majority of the births (63%) fall into the high-risk status groups at birth.

Table 1.: Profile of the Study Population by Risk Status Characteristics, NDHS 2013

Characteristics	No. of Live Births	Percentage
Child's Risk Status		
Not High-Risk	**7,216**	**22.6**
Unavoidable Risk	**4,407**	**14.0**
Any High-Risk	**20,205**	**63.4**
Single High-Risk:	**12,737**	**40.0**
Mother too young	2,042	6.4
Mother too old	358	1.1
Birth interval too close	2,246	7.1
Birth order too high	8,091	25.4
Multiple High-Risk:	**7,468**	**23.4**
Mother too young & Birth interval too close	198	0.6
Mother too old & Birth interval too close	43	0.1
Mother too old & Birth order too high	3,780	11.9
Birth interval too close & Birth order too high	2,746	8.6
Mother too old & Birth interval too close & Birth order too high	701	2.2
Total	**31,828**	**100.0**

3.2. Patterns of Infant Mortality in Nigeria by Risk Characteristics

Table 2 showed the distribution of infant mortality according to the risk attributes of the study population. Overall, as expected, the result as presented in the table and Figures 2-4 indicate that the rate of mortality was highest among infants born with high-risk attributes, especially with multiple high-risk, compared to others. Consideration of the pattern of mortality across specific components of the single high-risk categories reveals that mortality rate was highest for infants born by too young mothers (55 per 1,000) and lowest for those born to too old mothers (25 per 1,000) relative to those not in high-risk group. However, in the multiple high-risk category, the rate of dying during infancy was highest among children born to too young mothers in close succession to previous birth (96 per 1,000) and lowest for high birth order infants born to too old mothers (40 per 1,000) compared to those not in high-risk group.

Table 2: Patterns of Infant Mortality in Nigeria by Risk Status Characteristics, NDHS 2013

Characteristics	No. of Infant Death	IMR (per 1000)
Child's Risk Status		
Not High-Risk	**187**	**26**
Unavoidable Risk	**129**	**29**
Any High-Risk	**826**	**41**
Single High-Risk:	**419**	**33**
Mother too young	113	55
Mother too old	9	25
Birth interval too close	73	33
Birth order too high	224	28
Multiple High-Risk:	**407**	**54**
Mother too young & Birth interval too close	19	96
Mother too old & Birth interval too close	-	-
Mother too old & Birth order too high	150	40
Birth interval too close & Birth order too high	179	65
Mother too old, Birth interval too close & Birth order too high	59	84
Total	**1,141**	

3.3. Association between Infant Mortality and Biodemographic Characteristics

Table 3 reveals significant association between child's risk status and infant mortality, with a continuous increase in the proportions of infant deaths as the magnitude of the child's risk status at birth increases; thus, 4.4% of children with not high risk status died during infancy in contrast to 5.3 and 6.6% of infants in unavoidable risk and high-risk birth status categories respectively. Of those with any high-risk status at birth, 5.4 and 8.3% of infant deaths occurred among those having single and multiple high-risk status correspondingly ($p<0.05$).

However, more specific consideration of the infant deaths proportions by component risk status groups indicates that greater proportion of death amongst the children of too young mothers (less than 18 years) relative to others in both the single and multiple risk status groups ($p<0.05$). For instance, slightly less than 1 in 10 (9.2%) of children whose mothers were too young at the time of their birth died before their first birthday which is more than double the proportion of deaths among those born by too old mothers (4.1%) and those of high birth order (i.e. "risky birth order" children) (4.5%). Also, 5.7% of those born too close to preceding child (i.e. "risky birth interval" children) died before age 1.

Table 3: Bivariate Association between Biodemographic Characteristics and Infant Mortality, NDHS 2013

Characteristics	Survival Status		P-value (χ^2)
	% Alive	% Dead	
Child's Risk Status at Birth			**0.00 (174.00)**
Not High-Risk (rc)	**95.6**	**4.4**	
Unavoidable Risk	**94.7**	**5.3**	
Any High-Risk:	**93.4**	**6.6**	
Single High-Risk:	**94.6**	**5.4**	
Mother too young	90.8	9.2	
Mother too old	95.9	4.1	
Birth interval too close	94.3	5.7	
Birth order too high	95.5	4.5	
Multiple High-Risk:	**91.7**	**8.3**	
Mother too young & Birth interval too close	86.0	14.0	
Mother too old & Birth interval too close	100.0	0.0	
Mother too old & Birth order too high	94.0	6.0	
Birth interval too close & Birth order too high	89.6	10.4	
Mother too old, Birth interval too close & Birth order too high	87.6	12.4	

Furthermore, in the multiple risk status group components, the result show that the greatest proportion of infant deaths were recorded among risky birth interval children born by too young mothers (14.0%) followed by risky birth order children born by too old mothers within risky birth interval. Furthermore, not less than one-tenths (10.4%) of risky birth interval/birth order children and 6.0% of risky birth order children born by older mothers and none of risky birth interval children born by older mothers died before reaching age 1.

3.4. Effects of the Child's Risk Characteristics on Infant Mortality in Nigeria

Figure 1: Survival Chart illustrating risks of mortality before the first birthday for last children born alive to women prior to the survey who were fully exposed to risk of dying during infancy, NDHS 2013

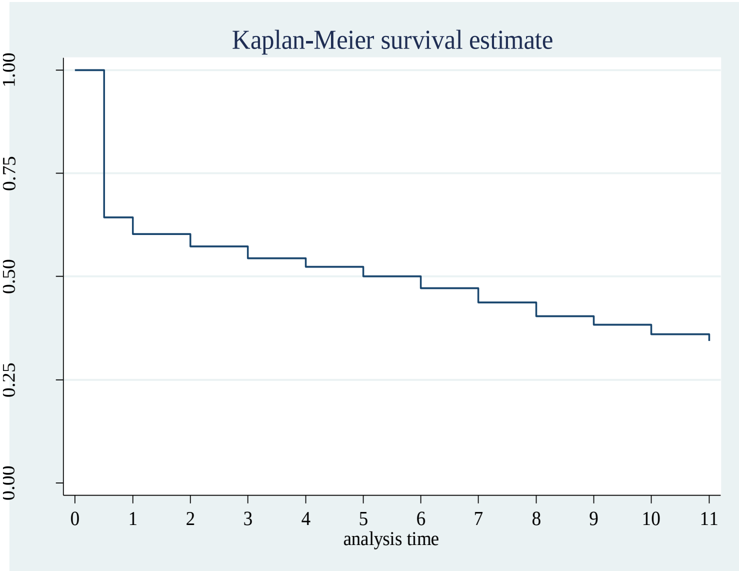
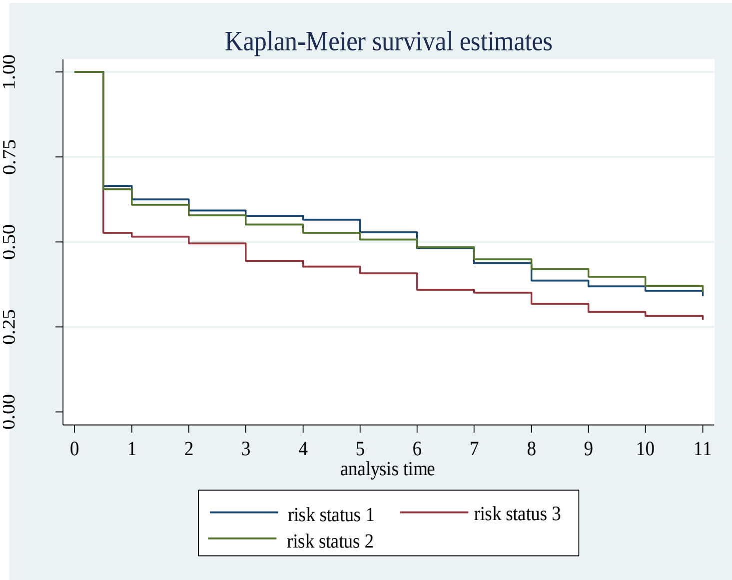
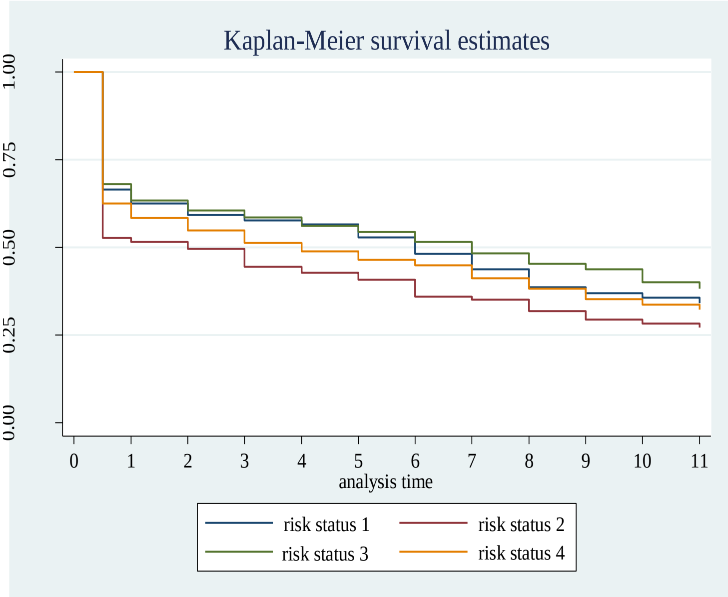


Figure 2: Survival Chart portraying risks of mortality before the first birthday for last children born alive to women prior to the survey who were fully exposed to risk of dying during infancy by risk status at birth across high-risk overall aggregated categories NDHS 2013



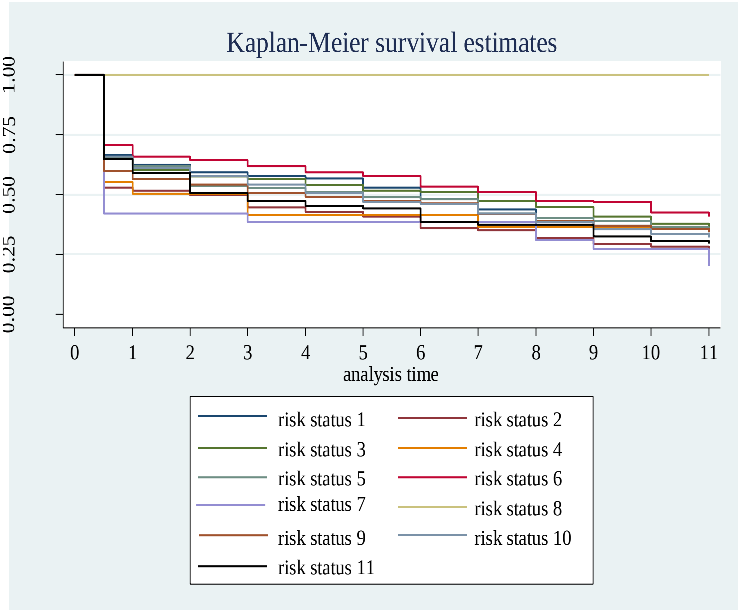
risk status: 1= Not high-risk; 2= Unavoidable risk; 3= Any high-risk

Figure 3: Survival Chart depicting risks of mortality before the first birthday for last children born alive to women prior to the survey who were fully exposed to risk of dying during infancy by risk status at birth across high-risk sub-aggregated categories, NDHS 2013



risk status: 1= Not high-risk; 2= Unavoidable risk; 3= Single high-risk; 4= Multiple high-risk

Figure 4: Survival Chart portraying risks of mortality before the first birthday for last children born alive to women prior to the survey who were fully exposed to risk of dying during infancy by risk status at birth across high-risk component categories NDHS 2013



risk status: 1= Not High-Risk; 2= Unavoidable Risk; 3= Mother too young; 4= Mother too old; 5= Birth interval too close; 6= Birth order too high; 7= Mother too young & Birth interval too close; 8= Mother too old & Birth interval too close; 9= Mother too old & Birth order too high; 10= Birth interval too close & Birth order too high; 11= Mother too old & Birth interval too close & Birth order too high.

In Table 4, both the unadjusted and adjusted hazard ratios indicating relationships between the selected biodemographic characteristics and infant mortality were examined. By and large, result of the survival time during infancy depicted in Figure 1 gave an indication that the risk of mortality was considerably greater during neonatal period; in which majority of the first year deaths were recorded. Equally, as evident from the table and Figures 2-4, there exist strong links between the main explanatory characteristics, child's risk status at birth, and the outcome, infant mortality. Overall, children having high-risk attributes at birth exhibited significantly consistent higher risks of dying during infancy relative to those having reference birth characteristics as indicated by the hazards lines revealed in the figures as well as both the unadjusted and the adjusted models contained in the table (Model I, UHR=1.49; Model II, AHR=1.58; Model III, AHR=1.55). Moreover, the significantly higher risk of infant deaths exposed to by children with high-risk birth status was driven, to a large extent, by consistently significant elevated risk of dying in infancy among children of multiple high-risk birth status; and to minute extent by some significant contributions from children with mother-too-young risk status in the single high-risk category.

More specifically, the analyses, considering the risks across components of the risk status groups, revealed mixed evidences with respect to the (nature of) influences of respective high-risk attributes relative to the reference. Regarding the single high-risk status component groups, children in "mother too young" and "birth order too high" risk status categories exhibited consistently higher hazards of dying in infancy relative to their peers in not high-risk status category. Besides, except in the full model where all factors were controlled for, the result indicated that only infants having "mother too young" risk status had significantly higher hazards of dying in infancy; with hazard being between 2.07 (Model I, UHR) and 1.35 (Model III, AHR) greater than exposed to by their peers in reference status group. Similar but generally insignificant pattern emerged for those in closely spaced risk status group. In contrast, the mortality hazard ratios associated with being born to too old mother and of being high-order child increased with continuous control for other predictors.

Table 4: Unadjusted (UHR) and Adjusted (AHR) Hazard Ratios and 95% Confidence Intervals (C.I.) of the Relationship between Child's Risk Status at Birth and Infant Mortality, NDHS 2013

	Model I		**Model II***		**Model III****	
	UHR (95% C.I.)		**AHR (95% C.I.)**		**AHR (95% C.I.)**	
Child's Risk Status						
Not High-Risk	**1.00**		**1.00**		**1.00**	
Unavoidable Risk	**1.23**	**(0.93-1.61)**	**1.28**	**(0.96-1.71)**	**1.47**	**(0.94-2.30)**
Any High-Risk:	**1.49****	**(1.24-1.79)**	**1.58****	**(1.31-1.92)**	**1.55****	**(1.14-2.10)**
Single High-Risk:	**1.23**	**(1.00-1.52)**	**1.28***	**(1.03-1.59)**	**1.27**	**(0.92-1.75)**
Mother too young	2.07**	(1.58-2.72)	1.66**	(1.25-2.22)	1.35	(0.82-2.24)
Mother too old	0.93	(0.47-1.84)	1.04	(0.53-2.02)	1.21	(0.47-3.09)
Birth interval too close	1.30	(0.92-1.84)	1.21	(0.84-1.75)	0.83	(0.45-1.54)
Birth order too high	1.02	(0.81-1.28)	1.17	(0.91-1.50)	1.41	(0.98-2.04)
Multiple High-Risk[a]:	**1.90****	**(1.56-2.30)**	**2.25****	**(1.83-2.77)**	**2.18****	**(1.53-3.11)**
Mother too young & Birth interval too close	3.25**	(1.85-5.71)	2.90**	(1.63-5.17)		nc
Mother too old & Birth order too high	1.35*	(1.06-1.73)	1.65**	(1.27-2.15)	2.18**	(1.45-3.27)
Birth interval too close & Birth order too high	2.36**	(1.89-2.94)	2.66**	(2.11-3.37)	2.36**	(1.54-3.60)
Mother too old, Birth interval too close & Birth order too high	2.82**	(2.02-3.96)	3.03**	(2.13-4.30)	3.37**	(1.99-5.71)

nc: no convergence due to small sample size
[a] category "Mother too old & Birth interval too close" was excluded due to no recorded infant death
* stratified over child's birth size and birth multiplicity status due to lack of proportionality in risk ratios
** stratified over birth delivery assistant provider and source of household drinking water due to lack of proportionality in risk ratios

As shown in the Table 4, a close examination of infant mortality risks across the relevant multiple high-risk status component groups suggest that having any multiple high-risk characteristics at birth exposed children to consistently significant greater risks of infant mortality relative to having other risk attributes; especially in the adjusted models. However, the hazards, despite being consistently higher, were either attenuated or further aggravated by accounting for a set of other factors. For instance, while the risks of death were continuously attenuated (Model I, UHR=3.25; Model II, AHR=2.90) for the infants born to too young mothers shortly after the previous birth by controlling jointly for the effects of predictors. Contrarily, the continuous adjustments accentuated the hazards, constantly, for too high-order children borne by too old mothers (Model I, UHR=1.35; Model III, AHR=2.16) and for high order infants born to too old mothers shortly after the previous birth standing between 182 (Model I) and 235% (Model III) higher risks of dying compared to those in reference group. Concerning the too closely spaced high-order children, whereas controlling for the effects of biodemographic and proximal determinants increased their risk of dying (Model I, UHR=2.36; Model II, AHR=2.68), jointly controlling for the influences of all the selected characteristics reduced their mortality risk by 32% point (Model III, AHR=2.36).

3.5. Estimates of the Extent of Infant Mortality in Nigeria Accounted for by Child's Risk Status at Birth

The third specific objective of this study was conceived to quantify the proportion of infant deaths attributable, specifically, to being of high-risk status at the time of birth. Employing the population attributable fraction post-estimation technique, the results in Table 5 indicate an attributable 9% reduction in infant mortality risk to characteristic not high-risk status at the time of birth. Contrarily, unavoidable risk status at birth, as shown in the table, was demonstrated to have been responsible for about 1% of the total infant mortality. Likewise and more importantly, approximately 19% of infant mortality captured in this analysis was accounted for by high-risk birth status. Put differently, about 1 in 5 of infant mortality in Nigeria can be attributed to births with high-risk status.

Table 5: The Population Attributable Fraction (PAF) of Infant Mortality Associated with Child's Risk Status at Birth, NDHS 2013

Child's Risk Status at Birth	PAF	95% Conf. Interval
Not high-risk	-0.09	(-0.14 - -0.03)
Unavoidable risk	0.01	(-0.33 - 0.05)
Any high-risk	0.19	(0.03 - 0.33)

4.0. Discussion

The results from the descriptive analysis suggest wide variation in the pattern of infant mortality by child's risk status at birth covariate. The descriptive analysis revealed higher rate of mortality among infants whose births were characterized by multiple high-risk but also those born to young mothers. More importantly, a special analytical lens was focused on ascertaining the net contribution of child's risk status at birth to mortality during infancy. As has been underscored, the child's risk status at birth characteristic is a composite characteristic derived from three biodemographic attributes comprising the maternal age at the birth of a child, preceding birth interval and child's birth order.

Over all, this study demonstrates substantial infant mortality differential in Nigeria with respect to the variable of focus: child's risk status at birth predicted significant variations in infant mortality, net of other predictors. Considering the child's risk status at birth, there were mixed outcomes with respect to consistency in the nature, strength and significance of the hazards of infant mortality across the risk status classification due to the influence of other correlates. In general, unavoidable risk status at birth was consistently associated with higher but statistically insignificant infant death vulnerability compared to the reference birth risk status. Conversely, apart from accounting for about one-fifth of infant mortality, high-risk birth status conferred significantly higher risk of dying in infancy on a child even when other factors were controlled for. This was largely attributable to significant mortality risk contribution from the multiple high-risk infants who exhibited statistically high tendency of dying prior to age 12 month relative to the reference not high-risk infants. Comparable findings had been reported in a recent pooled analysis by Rutstein and Winter (2014), whose results, in addition, indicate consistently significant greater mortality risk for "unavoidable risk" group of children.

A consideration of the risks of infant deaths along specific high-risk birth dimensions revealed that having single high-risk birth status characterized by too old mother's age, too close birth interval and too high birth order, respectively, predicted no statistically significant higher hazards of mortality during infancy relative to having reference risk status at birth with and without factorial adjustment. These findings, however, provide a mix of evidence compared to that found by Rutstein and Winter (2014), as to the nature and extent of influence across the mentioned risk groups when other characteristics were completely adjusted for. For instance, whereas too young maternal age at birth and being a high-order child were respectively found to predict higher but statistically marginal risks of infant mortality in this study, Rutstein and Winter reported lower but also statistically insignificant risks for the same risk groups. Also, while Rutstein and Winter found significantly elevated mortality risk for closely spaced children, the result of this study suggest that this risk attribute insignificantly lowers infant mortality risk. On the other hand and in conformity with what was demonstrated by Rutstein and Winter, multiple high-risk status was found to expose a child to increased mortality hazards during the reference period regardless of the category and extent of adjustment. The hazards were substantially higher among high order infants with too close birth interval born to too old mothers.

Literature is replete with consistent reports of statistically momentous adverse birth, health and mortality consequences of childbearing outside optimal reproductive ages (Dwivedi et al., 2013; Santos et al., 2012; DaVanzo et al., 2008; Hosseinpoor et al., 2006; Kishor & Parasuraman, 1998; Hobcraft et al., 1985), short birth interval (Adedini et al., 2014; Kozuki et al., 2013; Dube et al., 2013; Chowdury et al., 2013; Rutstein, 2008; Hosseinpoor et al., 2006; Conde-Agudelo et al., 2006; Mutunga, 2004; Stephansson et al., 2003; Mturi & Curtis, 1995; Cleland & Sathar, 1984) and primi/grand-parity (Mutunga, 2004; Becher et al., 2004; Rahman & Sarkar, 2009; Syamala, 2004; Amey, 2002; Rutstein, 1988; Hobcraft et al., 1985). Moreover, the influences of birth interval and birth order characteristics on infant mortality had been found to be far stronger and clearer to fathom when both are jointly measured than when individually considered (Kozuki et al., 2013a; Dube et al., 2013; Kembo & Van Ginneken, 2009; Mustafa, 2008; Agha, 2000).

Teenage motherhood is characterized by absolute naivety or limited knowledge regarding infant care, physical/physiological immaturity, maternal-foetal nutritional competition, increased risk of obstetric complications, adverse perinatal and birth outcomes and mortality in infancy (Kozuki et al., 2013; Gibbs, Wendt, Peters, & Hogue, 2012; Santhya, 2011; Kramer & Lancaster, 2010; Trivedi & Pasrija, 2007; Chen et al., 2007; Conde-Agudelo, Belizan, & Lammers, 2005; Hobcraft et al., 1985). Further, teenage mothers tend to exhibit less likelihood of health services utilization, often owing to limitations imposed by adverse social and economic circumstances (Geronimus & Korenman, 1993) such as low level of education, unemployment, poverty, unwanted pregnancy, single motherhood/unstable marital unions and associated stigma.

Older mothers, on the other hand, in addition to increased likelihood of nutritional and healthcare utilization inadequacies, often suffer greater bio-medical disadvantages that accompany cumulative childbirth experiences. Advanced maternal age is strongly correlated with increased risk of pregnancy-related disease conditions such as anaemia, pre-eclampsia, gestational diabetes and hypertension and greater incidence of congenital malformations, obstetric complications, preterm birth and poor perinatal outcomes (Yogev et al., 2010; Cleary-Goldman et al., 2005; Nault et al., 1990, cited by Amey, 2002; AGI, 2002; Magadi et al., 2000; Hobcraft et al., 1985).

Also, short birth intervals is strongly associated with increased risk of adverse birth and perinatal outcomes such as preterm birth, low birth weight, small-for-gestational age, as well as undernourishment; hence, increased risk of dying during childhood, especially in infancy (Kozuki et al., 2013; Rutstein, 2008; Conde-Agudelo et al., 2006; AGI, 2002). Likewise, regarding birth order, being of first and later order births are highly correlated with adverse outcomes as for inappropriate reproductive intervals, being births that occur mostly outside the optimal reproductive ages (Kozuki et al., 2013; Conde-Agudelo et al., 2012; Santhya, 2011; AGI, 2002; Amey, 2002; Magadi et al., 2000; Hobcraft et al., 1985).

Scholars have underscored a range of biological and non-biological hypotheses in their search for mechanisms linking reproductive factors to adverse birth outcomes and childhood mortality. Maternal physiological/nutritional depletion, folic deficiency, sub-optimal lactation, sibling resource competition, household's resource constraint and vertical transmission of infection hypotheses have been advanced as possible mechanisms through which sub-optimal fertility behaviour may adversely affect health and survival of children (Conde-Agudelo et al., 2012; Rutstein, 2005; DaVanzo et al., 2004; Boerma & Bicego, 1992; Hobcraft et al., 1985).

According to Conde-Agudelo et al. (2012) the maternal nutritional depletion mechanism is based on the assertion that physiological and biological demands associated with closely spaced pregnancies and births, and overlap in periods of lactation and gestation deplete mother's nutritional reserves essential for optimal perinatal and child health and survival outcomes. In addition, interference of breastfeeding–pregnancy overlap with both quality (immunity properties) and quantity (production) of breast milk may lead to sub-optimal breastfeeding and, perhaps, inappropriate infant feeding practices. There is, yet, dearth of empirical evidence in support of these postulations: whereas, a number of investigators have reported weak association between adverse outcomes and the postulated mechanisms, others have found no association. There is evidence, for instance, of weak or no indication of maternal depletion regarding the effect sub-optimal birth interval on adverse birth, health and survival outcomes (Kozuki et al., 2013; Conde-Agudelo et al., 2012).

5.0. Conclusions

The findings from this study highlight some important pictures of child health and survival circumstances in Nigeria. In addition, the risk approach adopted in this study provides a further insight into the understanding of mechanisms through which maternal fertility behaviour dynamics can propel infant mortality rates in Nigeria. This study, indeed, offers ample evidence for supporting the notion that having high-risk characteristics at birth, especially combining multiple risks attributes, portends greater mortality risks for children during infancy.

High-risk birth status is a significant contributing factor to high infant mortality statistics in Nigeria with an indication that approximately one-fifth of the current level of infant mortality in Nigeria would have been averted if no child had been borne with high-risk attributes. These findings tend to reinforce the nexus between high-risk fertility behaviour and maternal-foetal nutritional competition as well as maternal nutritional depletion syndrome hypotheses and their effects on newborn's survival.

Hence, policies and programmes aimed at reducing the persistent high rate of childhood mortality in Nigeria should give adequate and urgent attention to deliberate design and implementation of interventions that would engender significant reduction in the persistently high proportion of high-risk births among Nigerian women. Also, concerted efforts should be made to put in place measures that would prevent avoidable deaths among specific most-at-risk children populations.

Furthermore, increased risk of dying in infancy was found to be associated with high-risk birth status which derived from maternal high-risk fertility behaviour as regards maternal age at childbearing, length of preceding birth interval and order of birth. Consequently, infant mortality rate will continue to be on the high side if underlying factors that encourage and sustain the child birth practices at too extreme maternal ages, in too frequent succession and progression from low to very high parity are not urgently addressed.

- It is recommended that government as well as international/inter-governmental and non-governmental organizations should urgently initiate and implement behavioural change communication (BCC) programmes targeting high-risk fertility behaviours that expose children to high risk of poor health and survival chances.
- Closely linked to the foregoing is the need for government to further strengthen, scale up and sustain family planning programmes in the country to facilitate safe and responsible childbearing with respect to birth spacing and limiting.
- Furthermore, with the majority of infants found to have died as neonates, the current Integrated Maternal, Neonatal and Child Health (IMNCH) strategy adopted by the Federal Ministry of Health in 2007 which seeks achieving a reduction of about 72 percent of neo-natal deaths in line with the MDGs must be further strengthened and vigorously implemented to relive the country of heavy childhood mortality burden.

6.0. Strengths and Limitations of the Study

This thesis has some methodological strength that is worth highlighting. First, the study employed a nationally representative 2013 NDHS data, which was appropriately adjusted for sampling design effects and sampling variability. The use of DHS data allow for generalization of findings across settings due to spatial and temporal consistency of data collection methodology and instruments. Second, the aggregated risk approach adopted could be considered as a unique strength of this study. Previous studies on infant mortality in Nigeria did not exhaust various possible combinations of fertility variables dynamics. Those studies did not consider the possibility of a child having more than two risky characteristics which could increase his/her tendency of dying during infancy significantly.

Third, this study allowed for complete eleven month exposure period before censoring subjects who were still alive at the time of the survey to adequately account for infant mortality experience among the children's population. Addressing these methodological deficiencies, thus, represents unique strength of this investigation. Moreover, the Cox proportional hazard model was employed to address the intrinsic deficiencies in other statistical techniques that are commonly used in survival/mortality studies. This the model achieves by simultaneously accounting for exposure, time-to-event and censoring characteristics inherent in survival analysis as well as factors influencing the outcome of interest. Lastly and more importantly, unlike many studies using Cox regression technique we test potential proportional hazards assumption violation in our analysis and adjusted for this by stratifying on the time-dependent predictors in each of the model fit accordingly.

However, there are some limitations that call for cautions in the interpretation and generalization of the results of this study. First is the cross-sectional nature of the data used in this study. The analysis from this data can only provide, to a large extent, evidence of statistical relationships between the outcome and estimator characteristics. Second, mortality studies especially in developing countries are, by and large, faced with several data limitations. For instance, since variables used were bias-prone self report of events, data quality can be affected by under-reporting or outright omission of deaths as well as misreporting of age at death. This may be due to (i) memory lapse/recall bias due to retrospective nature of data collection procedure or time lag between occurrence of events and time of interview (ii) culture that discourages reference to the dead, or the fact that child's death is considered a sad event the memory which respondents may not want to recall (iii) high level of illiteracy among respondents, and (iv) lack of vital registration system from which reliable mortality information can be gathered. Third, it should also be noted, apropos the 2013 NDHS, that interviews were not conducted in eight clusters comprising four in Borno, two in Yobe, one in Nasarawa, and one in Plateau states respectively, due to the security situation in the North East and North West zones of the country. Thus, result of this study may not reflect recent infant mortality circumstances in these excluded clusters.

7.0. Ethical Clearance

As was previously stated, this study employed the 2013 NDHS public domain birth-recode data set. Hence, ethical approval to utilize the data for analysis in this study was formally obtained from the Ethics Committee of ICF International, Calverton, USA.

References

Adedini, S. A., Odimegwu, C., Imasiku, E. N., Ononokpono, D. N., & Ibisomi, L. (2014). Regional variations in infant and child mortality in Nigeria: a multilevel analysis. *Journal of Biosocial Science*, 1 - 23. doi:10.1017/S0021932013000734

Adetunji, J. A. (1995). Infant Mortality and Mother's Education in Ondo State, Nigeria. *Social Science and Medicine, 40*(2), 253-263.

Allison, P. D. (2005). *Survival analysis using SAS: A practical guide.* Cary, NC: SAS.

Amey, F. K. (2002). Polygyny and Child Survival in West Africa. *Social Biology, 49*(1-2), 74-89.

Becher, H., Muller, O., Jahn, A., Gbangou, A., Kynast-Wolf, G., & Kouyate, B. (2004). Risk factors of infant and child mortality in rural Burkina Faso. *Bulletin of the World Health Organization, 82,* 265-273.

Black, R. E., Morris, S. S., & Bryce, J. (2003). Where and why are 10 million children dying every year? *Lancet, 361*, 2226–2234.

Boerma, J., & Bicego, G. T. (1992). Preceding Birth Intervals and Child Survival: Searching for Pathways of Influence. *Studies in Family Planning, 23*(4), 243-256.

Chen, X. K., Wen, S. W., Fleming, N., Demissie, K., Rhoads, G. G., & Walker, M. (2007). Teenage pregnancy and adverse birth outcomes: a large population based retrospective cohort study. *International Journal of Epidemiology, 36*(2), 368-373.

Chowdury, A. H., Hossain, M. E., Khan, M. M., & Hoq, M. N. (2013). Cox's Proportional Hazard Model Analysis of Child Survival in Bangladesh. *Asian Journal of Social Sciences & Humanities, 2*(2), 608-618.

Cleary-Goldman, J; Malone, F. D.; Vidaver, J.; Ball, R. H.; Nyberg, D. A.; Comstock, C. H.; Saade, G. R.; Eddleman, K. A.; Klugman, S.; Dugoff, L; et al. (2005). Impact of maternal age on obstetric outcome. *Obstetrics and Gynecology, 105*(5 Pt 1), 983-990.

Cleland, J. G., & Sathar, Z. A. (1984). The effect of birth spacing on childhood mortality in Pakistan. *Population Studies, 38,* 401-418.

Cleland, J. G., & van Ginneken, J. K. (1988). Maternal Education and Child Survival in Developing Countries: The Search for Pathways of Influence. *Social Science & Medicine, 27*, 1357–68.

Conde-Agudelo, A., Belizan, J. M., & Lammers, C. (2005). Maternal-perinatal morbidity and mortality associated with adolescent pregnancy in Latin America: Cross-sectional study. *American Journal of Obstetrics and Gynecology, 192*(2), 342-349.

Conde-Agudelo, A., Rosas-Bermúdez, A., & Kafury-Goeta, A. C. (2006). Birth spacing and risk of adverse perinatal outcomes: a meta-analysis. *JAMA, 295*(15), 1809-1823.

Conde-Agudelo, A., Rosas-Bermúdez, A., & Kafury-Goeta, A. C. (2007). Effects of birth spacing on maternal health: A systematic review. *American Journal of Obstetrics and Gynecology, 196*(4), 297-308.

Conde-Agudelo, A., Rosas-Bermudez, A., Castaño, F., & Norton, M. H. (2012). Effects of Birth Spacing on Maternal, Perinatal, Infant, and Child Health: A Systematic Review of Causal Mechanisms. *Studies in Family Planning, 43*(2), 93–114.

Cox, D. (1972). Regression models and life-tables. *Journal of the Royal Statistical Society Series B (Methodological), 32*(4), 187-220. Retrieved from http://www.jstor.org/stable/2985181

Cox, D. R. (1970). *The analysis of binary data.* London: Methuen, Chapman & Hall.

DaVanzo, J., Hale, L., Razzaque, A., & Rahman, M. (2008). The effects of pregnancy spacing on infant and child mortality in Matlab, Bangladesh: How they vary by the type of pregnancy outcome that began the interval. *Population Studies, 62*(2), 131-154.

DaVanzo, J., Razzaque, A., Rahman, M., Hale, L., Ahmed, K., Ali Khan, M., . . . Gausia, K. (2004). The effects of birth spacing on infant and child mortality, pregnancy outcomes, and maternal mortality in Matlab, Bangladesh. *RAND Working Paper*.

Dube, L., Taha, M., & Asefa, H. (2013). Determinants of Infant Mortality in Community of Gilgel Gibe Field Research Center, Southwest Ethiopia: a matched case control study. *BMC Public Health, 13*(401). Retrieved from http://www.biomedcentral.com/1471-2458/13/401

Dwivedi, S. N., Begum, S., Dwivedi, A. K., & Pandey, A. (2013). Determinants of infant mortality in rural India: A three-level model. *Health, 5*(11), 1742-1749. Retrieved from http://dx.doi.org/10.4236/health.2013.511235

Federal Republic of Nigeria [Nigeria]. (2013). *Nigeria Millennium Development Goals 2013 Report.* Abuja, Nigeria: Government of the Federal Republic of Nigeria.

Geronimus, A., & Korenman, S. (1993). The socio-economic costs of teenage childbearing: evidence and interpretation. *Demography, 30*(2), 281-290.

Gibbs, C. M., Wendt, A., Peters, S., & Hogue, C. J. (2012). The impact of early age at first childbirth on maternal and infant health. *Paediatric and Perinatal Epidemiology, 26*((Suppl 1)), 259-284.

Hobcraft, J. N., McDonald, J. W., & Rutstein, S. O. (1985). Demographic Determinants of Infant Early Child Mortality: A Comparative Analysis. *Population Studies, 39*, 363-385.

Hosseinpoor, A. R., Doorslaer, E. V., Speybroeck, N., Nagavhi, M., Mohammad, K., Majdzadeh, R., . . . Vega, J. (2006). Decomposing socioeconomic inequality in infant mortality in Iran. *International Journal of Epidemiology, 35*, 1211-1219. doi:10.1093/ije/dy1164

Jaadla, H., & Klesment, M. (2014). Infant Mortality in the Lutheran Population of Tartu at the End of the Nineteeth Century. *Ajalooline Ajakiri, 2/3*(148/149), 139–172. Retrieved from http://dx.doi.org/10.12697/AA.2014.2-3.01

Kembo, J., & Van Ginneken, J. (2009). Determinants of infant and child mortality in Zimbabwe: Results of multivariate hazard analysis. *Demographic Research, 21*(13), 367-384.

Kishor, S. (1993). May God give sons to all: Gender and child mortality in India. *American Sociological Review, 58*(2), 247–65.

Kishor, S., & Parasuraman, S. (1998). Mother's Employment and Infant and Child Mortality in India. *National Family Health Survey Subject Reports, No. 8*.

Kleinbaum, D. G., & Klein, M. (2005). *Survival analysis: a self-learning text* . Springer.

Kozuki, N., Lee, A. C. C., Silveira, M. F., Victora, C. G.; Adair, L, Humphrey, J.,... Child Health Epidemiology Reference Group Small-for-Gestational-Age-Preterm Birth Working Group. (2013). The associations of birth intervals with small-forgestational- age, preterm, and neonatal and infant mortality: a meta-analysis. *BMC Public Health, 13*(Suppl 3), S3. doi:10.1186/1471-2458-13-S3-S3

Kozuki, N., Sonneveldt, E., & Walker, N. (2013). Residual confounding explains the association between high parity and child mortality. *BMC Public Health, 13*(Suppl 13), S5.

Kozuki, Naoko; Lee, Anne C. C.; Silveira, Mariangela F.; Sania, Ayesha; Vogel, Joshua P.; Adair, Linda;... Child Health Epidemiology Reference Group (CHERG) Small-for-Gestational-Age-Preterm Birth Working Group. (2013). The associations of parity and maternal age with small-for-gestational-age, preterm, and neonatal and infant mortality: a meta-analysis. *BMC Public Health, 13*(Suppl 3), S2. doi:10.1186/1471-2458-13-S3-S2

MacDorman, M. F., & Mathews, T. J. (2009, September–October). The Challenge of Infant Mortality: Have We Reached a Plateau. *Public Health Reports, 124*, 670-681.

Magadi, M., Madise, N., & Rodrigues, R. (2000). Frequency and timing of antenatal care in Kenya: Explaining the variations between women of different communities. *Social Science and Medicine, 51*(4), 551-561.

Mturi, A. J., & Curtis, L. S. (1995). The determinants of infant and child mortality in Tanzania. *Health policy plan, 10*, 384-94.

Mustafa, H. E., & Odimegwu, C. (2008). Socio-economic Determinants of Infant Mortality in Kenya: Analysis of Kenya DHS 2003. *Journal of Humanities and Social Sciences, 2*(2), 1-16.

Mutunga, C. J. (2004). Environmental Determinants of Child Mortality in Kenya.

National Population Commission & ICF International. (2014). *Nigeria Demographic and Health Survey 2013.* Abuja, Nigeria, and Rockville, Maryland, USA: NPC and ICF International.

National Population Commission (NPC), Nigeria. (2004). *National Policy on Population for Sustainable Development* . Abuja, Niggeria.

Newson, R. B. (2013). Attributable and unattributable risks and fractions and other scenario comparisons. *The Stata Journal, 13*(4), 672–698.

OECD/WHO. (2014). Infant mortality. In *Health at a Glance: Asia/Pacific 2014: Measuring Progress towards Universal Health Coverage.* OECD Publishing. Retrieved from http://dx.doi.org/10.1787/health_glance_ap-2014-6-en

Rahman, K. M., & Sarkar, P. (2009). Determinants of Infant and Child Mortality in Bangladesh. *Pak. J. Soc. Sci., 6*(3), 175-180.

Rustein, S. O. (2008). *Further Evidence Effects of Preceding Birth Intervals on Neonatal, Infant and Under-Five-Years Mortality and Nutritional Status in Developing Countries: Evidence from the Demographic and Health Surveys.* DHS Working Papers, No. 41. Claverton, MD, USA: Macro International Inc.

Rutstein, S. O. (1988). *Infant and child mortality: Levels, trends and demographic differentials.* No. 24. Voorburg, Netherland: International Statistical Institute.

Rutstein, S. O. (2000). Factors associated with trends in infant and child mortality in developing countries during the 1990s. *Bulletin of World Health Organization, 78*(10).

Rutstein, S. O. (2005). Effects of preceding birth intervals on neonatal, infant and under-five-years mortality and nutritional status in developing countries: Evidence from the demographic and health surveys. *International Journal of Gynecology and Obstetrics, 89*, S7-S24.

Rutstein, S., & Rojas, G. (2006). *Guide to DHS Statistics Demographic and Health Surveys.* Claverton, Maryland: ORC Macro.

Rutstein, S., & Winter, R. (2014). *The Effects of Fertility Behavior on Child Survival and Child Nutritional Status: Evidence from the Demographic and Health Surveys, 2006 to 2012.* Rockville, Maryland, USA: ICF International.

Santhya, K. G. (2011). Early marriage and sexual reproductive health vulnerabilities of young women: a synthesis of recent evidence from developing countries. *Curr Opin Obstet Gynecol, 23*, 334-9.

Santos, H. G., Andrade, S. M., Silva, A. M., Carvalho, W. O., & Mesas, A. E. (2012). Risk factors for infant mortality in a municipality in southern Brazil: a comparison of two cohorts using hierarchical analysis. *Cad. Saúde Pública, 28*(10), 1915-1926.

Sartorius, B. K., & Sartorius, K. (2014). Global infant mortality trends and attributable determinants – an ecological study using data from 192 countries for the period 1990–2011. *Population Health Metrics, 12*(29). Retrieved from http://www.pophealthmetrics.com/content/12/1/29

Stephansson, O., Dickman, P. W., & Cnattingius, S. (2003). The influence of interpregnancy interval on the subsequent risk of stillbirth and early neonatal death. *Obstetrics Gynaecology, 102*(1), 101-108.

Storeygard, A., Balk, D., Levy, M., & Deane, G. (2008). The Global Distribution of Infant Mortality: A Subnational Spatial View. *Popul Space Place, 14*(3), 209–229. doi:10.1002/psp.484

Stover, J., & Ross, J. (2013). Changes in the distribution of high-risk births associated with changes in contraceptive prevalence. *BMC Public Health, 13*((Suppl 3)), S4. doi:10.1186/1471-2458-13-S3-S4

Sustainable Development Solutions Network. (2014). *Indicators of Sustainable Development Goals: A report by the Leadership Council of the Sustainable Development Solutions Network.* Working draft, 22 May, 2014. Paris, France and New York, USA: Author.

Syamala, T. S. (2004). Relationship between Socio-Demographic Factors and Child Survival. *J Hum Ecol, 16*(2), 141-145.

The Alan Guttmacher Institute. (2002). *Family Planning and Infant Mortality.* Issues in Brief, 2002 Series.

Uddin, J., & Hossain, Z. (2008). Predictor of Infant Mortality in a Developing Country. *Asian Journal of Epidemiology, 1*(1), 1-16.

United Nations. (2014). *Levels and Trends in Child Mortality: Report 2014.* United Nations.

United Nations Children's Fund. (2014). *Annual Report 2013.* Division of Communication. New York, NY 10017, USA: UNICEF. Retrieved from www.unicef.org

United Nations Development Programme. (2014). *Sustaining Human Progress: Reducing Vulnerabilities and Building Resillience.* Human Development Report 2014.

Wang, H., Liddell, C. A., Coates, M. M., Mooney, M. D., Levitz, C. E., Schumacher, A. E., . . . Murray, C. J. (2014). Global, regional, and national levels of neonatal, infant, and under-5 mortality during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet, 384*(9947), 957–979. doi:10.1016/S0140-6736(14)60497-9

Yogev, Y., Melamed, N., Bardin, R., Tenenbaum-Gavish, K., Ben-Shitrit, G., & Ben- Haroush, A. (2010). Pregnancy outcome at extremely advanced maternal age. *Am J Obstet Gynecol, 203*(6), 558e.1-558-e.7.