# Risk factors for infant mortality in rural and urban Nigeria: evidence from the national household survey

***Authors' information***:

[*]Emmanuel Olorunleke Adewuyi[1, 2]
BPharm, P/Grad Dip (Public Health), MPH
e.adewuyi@postgrad.curtin.edu.au

Yun Zhao[1]
BSc, P/Grad Dip (Math), MSc, PhD
Y.Zhao@exchange.curtin.edu.au

Reeta Lamichhane[1]
Bachelor in Nursing (BN), MPH
rcsindhu@gmail.com

[1] Department of Epidemiology and Biostatistics
School of Public Health, Faculty of Health Sciences,
Curtin University, Bentley Campus, 6102, Perth, WA, Australia.

[2] Federal Ministry of Defense, 2 Division Hospital, Adekunle Fajuyi Cantonment, Ojoo Area, Ibadan, Nigeria.

* Correspondence: Emmanuel Adewuyi, Federal Ministry of Defense, 2 Division Hospital, Adekunle Fajuyi Cantonment, Ibadan, Oyo State, Nigeria.
Email: e.adewuyi@postgrad.curtin.edu.au

**Word count**: 2 959 (excluding abstract, reference list and Tables)

## Abstract

***Aims:*** This study investigates the rural-urban differences in infant mortality rates (IMR) and the associated risk factors in Nigeria.

***Methods:*** The dataset from the 2013 Nigeria demographic and health survey (NDHS), disaggregated by rural-urban residence was analyzed using complex samples statistics. A multivariable logistic regression analysis was computed to explore the adjusted relationship and identify risk factors for infant mortality.

***Results:*** In rural and urban Nigeria, IMR were 70 and 49 deaths per 1000 live births, respectively. Risk factors in rural residence were past maternal marital union (Adjusted OR [AOR]: 1.625, P = 0.020); small birth size (AOR: 1.550, P < 0.001); birth interval <24 months (AOR: 2.057, P < 0.001); residence in North-East (AOR: 1.346, P = 0.038), and North-West (AOR: 1.653, P < 0.001) regions and caesarean delivery (AOR: 2.922, P = 0.001). Risk factors in urban residence were poor wealth index (AOR: 2.292, P < 0.001); small birth size (AOR: 2.276, P < 0.001); male gender (AOR: 1.416, P = 0.022); birth interval <24 months (AOR: 1.605, P= 0.002); maternal obesity (AOR: 1.641, P = 0.008); and caesarean delivery (AOR: 1.947, P = 0.032).

***Conclusions:*** Infants in rural residence had higher rates of mortality than their urban counterparts and disparities in risk factors exist between the residences.

***Keywords:*** Determinants, infant mortality, maternal obesity, mode of delivery, Nigeria, risk factors, rural-urban disparities in Nigeria.

## Background

Through the millennium development goals (MDG), a significant reduction in infant mortality rate (IMR) has been recorded, worldwide [1]. To demonstrate the impressive progress made through such a global initiative, reports indicate that infant mortality fell from an estimated 8.9 million in 1990 to approximately 4.5 million in 2015 [1]. In all, 62 countries, including 12 in the low-income category, realized MDG 4: two-third reduction in under-five mortality (U5M) rate by 2015 [1]. This substantial progress was made possible through the implementation of innovative, evidence-based and context-specific programs. For instance, the scale-up of cost-effective interventions like vaccination, HIV control, obstetric care, nutritional support, and integrated management of diseases like diarrhea and pneumonia have proven effective in many countries – Malawi, Ethiopia and so on [1-3].

Like many countries around the world, Nigeria has implemented a number of programs including the Midwives Service Scheme, and the Ward Health System, all aimed at improving child survival chances in the country [4]. These interventions notwithstanding, the country maintains one of the highest numbers of under-five and infant mortalities in the world [1]. Unarguably, IMR has reduced substantially over the years in Nigeria – from 126 deaths per 1000 live births in 1990, to 69 deaths per 1000 live births in 2015, representing about 45% decreased mortality [1]. However, with over 53% contribution to the rate of U5M, the burden of infant mortality remains considerably high in Nigeria [5, 6]. Going by the current rate of 69/1000 live births, one in every fifteen children in Nigeria dies before completing one year of existence [4]. It is no surprise, therefore, that the country did not realize MDG 4 by the set deadline of 2015

With the recent commencement of the sustainable development goals (SDG), there is a critical need for an accelerated reduction in the rate of infant and, hence, U5M in Nigeria. SDG 3.2, with an ambitious aim of consolidating on the gains of MDG 4, seeks to achieve a global U5M rate as low as 25 deaths per 1000 live births by the year 2030 [1]. To be on track for this target, Nigeria requires a two to three-fold increased reduction in U5M rate [1], and one of the priority focus should be on improving infant survival. The need for a speedy reduction of IMR in Nigeria is equally critical given that infant mortality is often used to judge the level of socioeconomic development of a nation [4]. Although the necessity for a greater attention on neonatal mortality is being canvassed, globally [7-9]; a holistic approach that accords infant and other childhood survival a commensurate priority is key to a speedy realization of this goal.

Reducing IMR, and realizing SDG 3.2 in Nigeria, as in any other country, requires a greater prioritization of the most disadvantaged populations through an unwavering commitment to equity in intervention coverage [1]. In light of this premise, there is a growing consensus on using high quality disaggregated data in identifying and eliminating disparities in child survival [1, 10]. Disaggregating childhood mortality studies along rural-urban residence, for instance, may help in capturing the most disadvantaged groups alongside the associated risk factors which otherwise could be lost to the use of a 'one-size-fits-all approach' of pooled datasets. In support of this position, a recent Nigerian study reported a lack of 'access to electricity' as a significant risk factor for neonatal mortality only in urban residence [9]; whereas the same factor did not make any statistical difference in the rural [9] and in the overall residence [8]. Brazil, which has already achieved SDG 3.2 represents a striking example of using evidence-based data disaggregation approach in closing childhood survival equity gaps [1].

Regrettably, the use of disaggregated data in infant mortality studies is limited in Nigeria. Hence, gaps in knowledge exist on the rates and risk factors for infant mortality in rural and urban Nigeria. By exploring the latest available evidence, this study aims to bridge the gaps. To the best of knowledge, this is the first study to investigate the determinants of infant mortality in rural and urban Nigeria using a disaggregated dataset that is nationally representative. Given the current economic challenges in Nigeria, this study may help in priority setting and in designing target-specific interventions aimed at addressing infant mortality in the country.

## Aims

To investigate IMR and the associated risk factors in Nigeria with a special focus on the differences between the rural and urban residence.

## Methods

### *Data sources*

The data analyzed in this study was from the 2013 edition of the Nigerian demographic and health survey (NDHS), a public domain data that are freely available online with permission from ICF International. The survey which was cross-sectional in design is nationally representative of the Nigerian population. The survey was implemented by the Nigerian population commission with support from many development partners including technical assistance from ICF International, USA [4]. The major objective of the survey was the provision of an up-to-date information on nutritional status of children and women, family planning awareness, maternal and childhood mortalities, among other factors [4]. There have been four previous editions of NDHS: 1990, 1999, 2003 and 2008, before the 2013 which is the latest and most current in the series.

The 2013 NDHS applied a three-stage stratified cluster sampling technique for sample selection. There was a total of 904 clusters in the design for the survey – 532 in rural areas and 372 in urban residence [4]. Men and women were eligible for interview if they were aged 15 to 49 years, willing and had resided in the selected households for at least one night before the survey [4]. Structured questionnaires adapted from the Measure Demographic and Health Survey program were the instruments for data collection. The questionnaires were of three types – households', women's and men's – developed initially in English language but later translated into the three major Nigerian languages (Hausa, Igbo, and Yoruba). The questionnaires were thereafter pretested and used for the survey by the trained interviewers [4].

Out of 40 680 representative households selected for the survey, 38 904 were occupied as at fieldwork time (22 834 in rural residence and 16 070 in urban residence). Of the households found to be occupied, a total of 38 522 , consisting of 22 663 in rural areas and 15 859 in urban areas was interviewed successfully, representing a 99% households' response rate – 99.3% in rural residence and 98.7% in urban residence [4]. A comprehensive information on the sampling techniques and the setting for the survey has previously being published [4]. Information on births and deaths of children within five years preceding the 2013 NDHS was analyzed in this study. Mortality data were self-reported and analyses were restricted to the available information on singleton live births. Multiple births may produce misleading results as they are associated with increased risk of infant mortality [11], hence, they were excluded in analyses.

***Study variables***

The main outcome variable for this study was infant mortality, defined as the probability of dying before the first birthday [4], and expressed as the number of deaths per 1000 live births. Children who died before completing their first year of existence were compared to those who survived the

same period of time. Explanatory variables were selected based on Mosley and Chen's conceptual framework [12], slightly modified cognizant of the available information in NDHS dataset. Three categories of variables were investigated as follows: distal (socioeconomic), proximate (bio-demographic) and intermediate (health/behavioral [corresponds to Mosley and Chen's "Personal Illness Control"]). This classification agrees with practice in previous studies [8, 9, 13], and is supported by the method of data collection used in NDHS – at households and individual levels [4].

Socioeconomic variables were further classified into three – households, maternal and paternal (partner's) factors. Households socioeconomic factors comprised of wealth index, the composite indicator of socioeconomic status reported in the 2013 NDHS which was recoded from five to three categories (poor = "poorest" and "poorer", middle = "middle", rich = "richer" and "richest"). The new categorization gives a better reflection of the socioeconomic status classification in Nigeria. . Other household socioeconomic factors assessed included: cooking fuel, toilet facility, access to electricity, and drinking water source [9]. Maternal socioeconomic factors, on the other hand, were: maternal education level, literacy, and working status (occupation). Paternal education level and occupation were sub-grouped under the paternal socioeconomic factors.

Bio-demographic (proximate) factors were likewise sub-divided into demographic (maternal marital status, religion, residence, and region of residence) as well as biological factors (maternal age, body mass index [BMI], age at first birth, child's birth order, child's birth size [a proxy for birthweight], gender of child, and preceding birth interval) [9]. Last, health/behavioral (intermediate) factors were sub-divided into pre-delivery (desire for pregnancy and antenatal

care attendance), delivery (place of delivery, delivery assistance and mode of delivery) and post-delivery (breastfeeding initiation)[9].

***Statistical analysis***

To assess the unadjusted association of each variable with IMR, frequency tabulation and Chi-square ($\chi^2$) test were carried out. A simple logistic regression analysis (SLR) was conducted to examine the unadjusted likelihood of dying within one year of life, expressed as crude odds ratio (COR). In line with the recommended hierarchical approach [14], a multivariable logistic regression analysis was conducted to identify factors associated with infant mortality. This approach permits the assessment of distal variables with appropriate adjustment for proximate and intermediate variables [14] .

To be selected for multivariable model building, variables must satisfy the inclusion criterion of $P < 0.20$ in the SLR. Three sets of parsimonious models (I, II, III) were built separately for data disaggregated by rural-urban residence. Model I assessed the adjusted relationship between the outcome variable and socioeconomic factors; and, variables associated with the outcome at the 10% significance level ($P<0.1$) were retained for the next model. Model II was built for variables retained in model I and bio-demographic variables, and significant variables at 10% significance level ($P<0.1$) were similarly retained for the subsequent model. Model III combined variables retained in model II with health/behavioral variables. In model III, significant variables at 5% significance level ($P < 0.05$) were retained and reported along with their 95% confidence interval and P values. A backward elimination method was used in obtaining the parsimonious model.

Collinearity was checked using the variance inflation factors (VIF). ‘Maternal education level’ and ‘maternal literacy level’ were strongly correlated, hence, ‘maternal literacy level’ was

excluded in multivariable analyses. Also, 'antenatal attendance' was not included in multivariable models because a substantial part of its information was missing (Table 1).

Given the multi-stage cluster sampling technique used in NDHS, all statistical analyses were computed using the complex samples statistics. This statistical method adjusts for the unequal probability selection by incorporating the sample design into the survey analysis such that results are representative and bias in estimates are minimized. All data management and analyses were performed using IBM SPSS Statistics for Windows, version 21.0 (Released 2012; IBM, Armonk, NY, USA).

## Results

### *Profile of the study population, IMR and SLR*

Table 1 presents the background characteristics of the study populations (rural and urban) together with the IMR. In rural and urban residences, IMR were 70 and 49 per 1000 live births, respectively ($P < 0.001$). Generally, urban residents fared better in all the study variables. For instance, 63.70% of women in rural residence had no education compared to 22.40% in urban residence. Similarly, more women in urban residence (67%) had access to skilled delivery services than those in the rural residence (24.8%).

**Table 1: Characteristics of study variables and infant mortality rates**

| Variables | Rural | | | Urban | | |
|---|---|---|---|---|---|---|
| | n (unweighted)+ | n (%) ** | IMR | n (unweighted) | n (%) ** | IMR |
| ***Socioeconomic Variables*** | | | | | | |
| **Maternal education level** | | | | | | |
| None | 12117 | 13031 (63.70) | 74 | 2171 | 2229 (22.40) | 58 |
| Primary | 4058 | 3681 (18.00) | 68 | 2108 | 2106 (21.20) | 62 |
| Secondary/Higher | 4274 | 3737 (18.30) | 60 | 5656 | 5600 (56.40) | 41 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Maternal literacy level** | | | | | | |
| Cannot read at all | 14391 | 15112 (73.90) | 74 | 3127 | 3159 (31.80) | 64 |
| Able to read | 5826 | 5092 (24.90) | 59 | 6763 | 6736 (67.80) | 43 |
| Missing | 232 | 245 (1.20) | | 45 | 50 (0.50) | |
| **Maternal occupation** | | | | | | |
| Not working | 6459 | 6605 (32.30) | 71 | 2386 | 2414 (24.30) | 48 |
| Working | 13883 | 13783 (67.40) | 70 | 7508 | 7481 (75.30) | 50 |
| Missing | 107 | 61 (0.30) | | 41 | 40 (0.40) | |
| **Paternal education level** | | | | | | |
| None | 9654 | 10368 (50.70) | 76 | 1584 | 1639 (16.50) | 52 |
| Primary | 3933 | 3783 (18.50) | 69 | 1798 | 1798 (18.10) | 56 |
| Secondary/Higher | 6267 | 5767 (28.20) | 59 | 6279 | 6239 (62.80) | 47 |
| Missing | 595 | 511 (2.50) | | 274 | 258 (2.60) | |
| **Paternal occupation** | | | | | | |
| Not Working | 132 | 123 (0.60) | 32 | 134 | 109 (1.10) | 19 |
| Working | 19840 | 19938 (97.50) | 70 | 9508 | 9557 (96.20) | 50 |
| Missing | 477 | 389 (1.90) | | 293 | 268 (2.70) | |
| **Wealth index (SES)** | | | | | | |
| Poor | 12909 | 13537 (66.20) | 76 | 1097 | 1053 (10.60) | 82 |
| Middle | 4302 | 4110 (20.10) | 59 | 1726 | 1619 (16.30) | 48 |
| Rich | 3238 | 2802 (13.70) | 61 | 7112 | 7262 (73.10) | 45 |
| **Cooking fuel** | | | | | | |
| Solid fuels | 19133 | 19365 (94.70) | 71 | 5783 | 5524 (55.60) | 55 |
| Non-solid fuels | 1139 | 961 (4.70) | 57 | 4046 | 4332 (43.60) | 43 |
| Missing | 177 | 123 (0.60) | | 106 | 79 (0.80) | |
| **Toilet facility** | | | | | | |
| Unimproved | 12690 | 12719 (62.20) | 71 | 2724 | 2434 (24.50) | 60 |
| Improved | 7579 | 7587 (37.10) | 68 | 7103 | 7412 (74.60) | 46 |
| Missing | 180 | 143 (0.70) | | 108 | 89 (0.90) | |
| **Drinking water source** | | | | | | |
| Unimproved sources | 11034 | 11051 (54.00) | 69 | 2555 | 2431 (24.50) | 62 |
| Improved sources | 9213 | 9242 (45.20) | 70 | 7273 | 7416 (74.60) | 45 |
| Missing | 202 | 156 (0.80) | | 107 | 87 (0.90) | |
| **Electricity access** | | | | | | |
| No | 14180 | 14212 (69.50) | 71 | 1856 | 1788 (18.00) | 68 |
| Yes | 6078 | 6094 (29.80) | 68 | 7971 | 8067 (81.20) | 45 |
| Missing | 191 | 143 (0.70) | | 108 | 79 (0.80) | |
| ***Bio-demographic variables*** | | | | | | |
| **Maternal age at first childbirth** | 13837 | 14028 (68.60) | 72 | 4253 | 4332 (43.60) | 50 |
| Below 20 years (Teen) | 6612 | 6421 (31.40) | 67 | 5682 | 5603 (56.40) | 49 |
| 20 years or more (Non-teen) | | | | | | |
| **Maternal marital status** | | | | | | |
| Unmarried | 383 | 307 (1.50) | 97 | 209 | 189 (1.90) | 34 |
| Formerly married/cohabited | 524 | 491 (2.40) | 98 | 332 | 308 (3.10) | 57 |
| Married/cohabiting | 19542 | 19651 (96.10) | 69 | 9394 | 9448 (95.10) | 50 |
| **Religion** | | | | | | |
| Traditionalist/other | 221 | 225 (1.10) | 63 | 75 | 50 (0.50) | 39 |
| Islam | 13156 | 14110 (69.00) | 73 | 4622 | 4878 (49.10) | 45 |
| Christianity | 6968 | 5971 (29.20) | 64 | 5190 | 4948 (49.80) | 54 |
| Missing | 104 | 123 (0.60) | | 48 | 50 (0.50) | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Residence** | | | | | | |
| Rural | 20449 | 19810 (65.20) | $70^{++}$ | - | - | - |
| Urban | - | - | - | 9935 | 10574 (34.80) | $49^{++}$ |
| **Maternal age** | | | | | | |
| < 20 years | 1258 | 1329 (6.50) | 87 | 247 | 248 (2.50) | 105 |
| 36 or more years | 3742 | 3619 (17.70) | 72 | 2010 | 1977 (19.90) | 63 |
| 20 - 35 years | 15449 | 15500 (75.80) | 68 | 7678 | 7710 (77.60) | 44 |
| **Birth order** | | | | | | |
| 1 | 3755 | 3763 (18.40) | 83 | 2282 | 2265 (22.80) | 56 |
| 2-3 | 6247 | 6360 (31.10) | 62 | 3530 | 3507 (35.30) | 41 |
| ≥4 | 10447 | 10327 (50.50) | 71 | 4123 | 4163 (41.90) | 53 |
| **Size of child at birth** | | | | | | |
| Small | 3186 | 3272 (16.00) | 92 | 1101 | 1143 (11.50) | 80 |
| Average | 8187 | 8098 (39.60) | 65 | 4091 | 4173 (42.00) | 46 |
| Large | 8642 | 8670 (42.40) | 60 | 4590 | 4461 (44.90) | 36 |
| Missing | 434 | 409 (2.00) | | 153 | 159 (2.60) | |
| **Gender of child** | | | | | | |
| Male | 10341 | 10284 (50.30) | 75 | 5073 | 5030 (50.60) | 54 |
| Female | 10108 | 10165 (49.70) | 66 | 4862 | 4905 (49.40) | 44 |
| **Preceding birth interval** | | | | | | |
| < 24 months | 3901 | 3906 (19.10) | 109 | 1724 | 1768 (17.80) | 74 |
| ≥ 24 months | 12793 | 12781 (62.50) | 54 | 5929 | 5901 (59.40) | 40 |
| Missing | 3755 | 3763 (18.40) | | 2282 | 2265 (22.80) | |
| **Maternal BMI** | | | | | | |
| Obese | 1106 | 1084 (5.30) | 76 | 1273 | 1272 (12.80) | 64 |
| Overweight | 2950 | 2740 (13.40) | 70 | 2520 | 2494 (25.10) | 49 |
| Underweight | 2036 | 1984 (9.70) | 74 | 571 | 566 (5.70) | 26 |
| Normal weight | 14357 | 14641 (71.60) | 69 | 5571 | 5603 (56.40) | 49 |
| **Region of residence** | | | | | | |
| North-Central | 3118 | 3292 (16.10) | 53 | 1326 | 864 (8.70) | 49 |
| North-East | 5034 | 4192 (20.50) | 72 | 1325 | 1242 (12.50) | 45 |
| North-West | 7718 | 9059 (44.30) | 81 | 1888 | 2394 (24.10) | 45 |
| South-East | 941 | 838 (4.10) | 73 | 1743 | 1739 (17.50) | 73 |
| South-South | 2495 | 1881 (9.20) | 58 | 1104 | 904 (9.10) | 47 |
| South-West | 1143 | 1186 (5.80) | 53 | 2549 | 2782 (28.00) | 41 |
| ***Health/behavioral variables*** | | | | | | |
| **Mode of delivery** | | | | | | |
| Caesarean | 207 | 204 (1.00) | 124 | 384 | 358 (3.60) | 84 |
| Non-caesarean | 20122 | 20142 (98.50) | 69 | 9366 | 9,379 (94.40) | 49 |
| Missing | 120 | 123 (0.60) | | 185 | 199 (2.00) | |
| **Breastfeeding initiation** | | | | | | |
| Beyond first one hour | 13111 | 13292 (65.00) | 61 | 5400 | 5454 (54.90) | 39 |
| Within first one hour | 6430 | 6216 (30.40) | 57 | 4110 | 4034 (40.60) | 35 |
| Missing | 908 | 961 (4.70) | | 425 | 437 (4.40) | |
| **Desire for pregnancy** | | | | | | |
| Then | 18599 | 18793 (91.90) | 68 | 8790 | 8822 (88.90) | 47 |
| No more | 289 | 245 (1.20) | 67 | 236 | 229 (2.30) | 49 |
| Later | 1334 | 1186 (5.80) | 62 | 825 | 795 (8.00) | 34 |
| Missing | 227 | 245 (1.20) | | 84 | 89 (0.90) | |
| **Place of delivery** | | | | | | |
| Home | 15523 | 15807 (77.30) | 68 | 3552 | 3755 (37.80) | 54 |
| Private Facility | 1202 | 1186 (5.80) | 69 | 2531 | 2613 (26.30) | 40 |
| Public Facility | 3468 | 3170 (15.50) | 64 | 3767 | 3477 (35.00) | 44 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Missing | 256 | 266 (1.30) | | 85 | 89 (0.90) | |
| **Delivery assistance** | | | | | | |
| Skilled | 5383 | 5071 (24.80) | 67 | 6803 | 6656 (67.00) | 42 |
| No assistance | 3177 | 3538 (17.30) | 73 | 561 | 656 (6.60) | 50 |
| TBA/combined | 11568 | 11513 (56.30) | 66 | 2477 | 2543 (25.60) | 57 |
| Missing | 321 | 348 (1.70) | | 94 | 89 (0.90) | |
| **Antenatal care attendance** | | | | | | |
| No | 5847 | 6237 (30.50) | 52 | 709 | 725 (7.30) | 52 |
| Yes | 7065 | 6728 (32.90) | 47 | 5648 | 5633 (56.70) | 32 |
| Missing | 7537 | 7484 (36.60) | | 3578 | 3577 (36.00) | |

** = Weighted for the sampling probability with the use of complex sample statistics. + = without complex samples statistics. n = rural or urban sample size. IMR = infant mortality rate per 1000 live births. IMR was not calculated for missing values. BMI: body mass index. TBA: traditional birth attendants. SES: socioeconomic status. ++: IMR in rural and urban residence were compared using the un-disaggregated data to obtain P-Value (Pearson $X^2$ test) of ($P < 0.001$) for the purpose of testing for a significant difference.

Table 2 presents the result of the unadjusted relationship between outcome and explanatory variables. In the SLR, several factors were found to be associated with infant mortality both in rural and urban residence. Also, using the SLR, the likelihood of infant mortality (based on the overall 2013 NDHS data) was 1.45 times higher in rural compared to urban residence ($P < 0.001$) [result not shown on Table].

**Table 2: Results of the unadjusted relationship between infant mortality and explanatory variables**

| **Variables** | **Rural** | | | **Urban** | | |
|---|---|---|---|---|---|---|
| | **COR** | **95% CI** | **P-Value** | **COR** | **95% CI** | **P-Value** |
| ***Socioeconomic variables*** | | | | | | |
| **Maternal education level** | - | - | 0.038* | - | - | 0.002* |
| None | 1.260 | 1.049 - 1.512 | 0.013* | 1.428 | 1.058 - 1.928 | 0.020* |
| Primary | 1.141 | 0.894 - 1.457 | 0.289 | 1.540 | 1.182 - 2.007 | 0.001* |
| Secondary/Higher (ref) | 1.000 | - | - | 1.000 | - | - |
| **Maternal literacy level** | - | - | 0.003* | - | - | < 0.001* |
| Cannot read at all | 1.280 | 1.086 - 1.509 | 0.003* | 1.549 | 1.222 - 1.965 | < 0.001* |
| Able to read (ref) | 1.000 | - | - | 1.000 | - | - |
| **Maternal occupation** | - | - | 0.925 | - | - | 0.697 |
| Not working | 1.006 | 0.880 - 1.152 | 0.925 | 0.951 | 0.740 - 1.223 | 0.697 |
| Working (ref) | 1.000 | - | - | 1.000 | - | - |
| **Paternal education level** | - | - | 0.007* | - | - | 0.534 |
| None | 1.296 | 1.103 - 1.523 | 0.002* | 1.106 | 0.785 - 1.558 | 0.564 |
| Primary | 1.170 | 0.948 - 1.444 | 0.144 | 1.208 | 0.865 - 1.685 | 0.267 |
| Secondary/Higher (ref) | 1.000 | - | - | 1.000 | - | - |
| **Paternal occupation** | - | - | 0.139 | - | - | 0.086 |
| Not Working | 0.440 | 0.148 - 1.307 | 0.139 | 0.371 | 0.119 - 1.152 | 0.086 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Working (ref) | 1.000 | - | - | 1.000 | - | - |
| **Wealth index** | - | - | 0.005* | - | - | < 0.001* |
| Poor | 1.257 | 0.996 - 1.585 | 0.054 | 1.909 | 1.433 - 2.544 | < 0.001* |
| Middle | 0.958 | 0.737 - 1.245 | 0.748 | 1.083 | 0.771 - 1.521 | 0.646 |
| Rich (ref) | 1.000 | - | - | 1.000 | - | - |
| **Cooking fuel** | - | - | 0.152 | - | - | 0.023* |
| Solid fuels | 1.254 | 0.920 - 1.711 | 0.152 | 1.294 | 1.037 - 1.615 | 0.023* |
| Non-solid fuels (ref) | 1.000 | - | - | 1.000 | - | - |
| **Toilet facility** | - | - | 0.582 | - | - | 0.031* |
| Unimproved | 1.038 | 0.909 - 1.185 | 0.582 | 1.344 | 1.027 1.759 | 0.031* |
| Improved (ref) | 1.000 | - | - | 1.000 | - | - |
| **Drinking water source** | - | - | 0.890 | - | - | 0.009* |
| Unimproved sources | 0.989 | 0.840 - 1.163 | 0.890 | 1.392 | 1.088 - 1.782 | 0.009* |
| Improved sources (ref) | 1.000 | - | - | 1.000 | - | - |
| **Electricity access** | - | - | 0.682 | - | - | 0.002* |
| No | 1.038 | 0.869 - 1.239 | 0.682 | 1.537 | 1.167 - 2.025 | 0.002* |
| Yes (ref) | 1.000 | - | - | 1.000 | - | - |
| ***Bio-demographic variables*** | | | | | | |
| **Maternal age at first child birth** | - | - | 0.381 | - | - | 0.825 |
| Below 20 years [teen] | 1.066 | 0.924 - 1.229 | 0.381 | 1.027 | 0.808 - 1.305 | 0.825 |
| 20 years or more [non-teen] (ref) | 1.000 | - | - | 1.000 | - | - |
| **Maternal marital status** | - | - | 0.027* | - | - | 0.589 |
| Unmarried | 1.448 | 0.935 2.243 | 0.097 | 0.680 | 0.292 - 1.585 | 0.372 |
| Formerly married/co-habited | 1.458 | 1.026 2.073 | 0.035* | 1.165 | 0.627 - 2.164 | 0.629 |
| Married/co-habiting (ref) | 1.000 | - | - | 1.000 | - | - |
| **Religion** | - | - | 0.245 | - | - | 0.337 |
| Traditionalist/other | 0.968 | 0.573 - 1.636 | 0.904 | 0.724 | 0.272 - 1.929 | 0.518 |
| Islam | 1.140 | 0.965 - 1.346 | 0.123 | 0.833 | 0.648 - 1.070 | 0.153 |
| Christianity (ref) | 1.000 | - | - | 1.000 | - | - |
| **Maternal age** | - | - | 0.083 | - | - | < 0.001* |
| < 20 years | 1.303 | 1.028 - 1.652 | 0.029* | 2.542 | 1.630 - 3.965 | < 0.001* |
| 36 or more years | 1.061 | 0.896 - 1.257 | 0.492 | 1.440 | 1.095 - 1.893 | 0.009* |
| 20 - 35 years (ref) | 1.000 | - | | 1.000 | - | - |
| **Birth order** | - | - | 0.003* | - | - | 0.066 |
| 1 | 1.194 | 1.017 - 1.402 | 0.031* | 1.064 | 0.813 1.392 | 0.651 |
| 2-3 | 0.868 | 0.742 - 1.014 | 0.074 | 0.762 | 0.581 1.000 | 0.050 |
| ≥4 (ref) | 1.000 | - | - | 1.000 | - | - |
| **Size of child at birth** | - | - | < 0.001* | - | - | < 0.001* |
| Small | 1.593 | 1.329 - 1.910 | < 0.001* | 2.344 | 1.756 - 3.127 | < 0.001* |
| Average | 1.093 | 0.939 - 1.272 | 0.250 | 1.288 | 0.991 - 1.674 | 0.059 |
| Large (ref) | 1.000 | - | - | 1.000 | - | - |
| **Gender of child** | - | - | 0.038* | - | - | 0.063 |
| Male | 1.141 | 1.007 - 1.292 | 0.038* | 1.242 | 0.988 - 1.561 | 0.063 |
| Female (ref) | 1.000 | - | - | 1.000 | - | - |
| **Preceding birth interval** | - | - | < 0.001* | - | - | < 0.001* |
| < 24 | 2.133 | 1.866 - 2.439 | < 0.001* | 1.935 | 1.462 - 2.561 | < 0.001* |
| ≥ 24 (ref) | 1.000 | - | - | 1.000 | - | - |
| **Maternal BMI** | - | - | 0.902 | - | - | 0.073 |
| Obese | 1.102 | 0.725 - 1.675 | 0.649 | 1.339 | 0.982 1.825 | 0.065 |
| Overweight | 1.018 | 0.830 - 1.248 | 0.864 | 1.009 | 0.779 1.306 | 0.946 |
| Underweight | 1.073 | 0.868 - 1.325 | 0.515 | 0.521 | 0.263 1.033 | 0.062 |
| Normal weight (ref) | 1.000 | - | - | 1.000 | - | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Region of residence** | - | - | 0.001* | - | - | 0.022* |
| South-West | 1.009 | 0.588 – 1.733 | 0.974 | 0.846 | 0.532 – 1.345 | 0.479 |
| North-East | 1.389 | 1.085 – 1.778 | 0.009* | 0.930 | 0.552 – 1.566 | 0.784 |
| North-West | 1.580 | 1.247 – 2.002 | <0.001* | 0.931 | 0.594 – 1.458 | 0.753 |
| South-East | 1.428 | 0.969 – 2.103 | 0.072 | 1.532 | 1.013 – 2.317 | 0.043* |
| South-South | 1.121 | 0.848 – 1.481 | 0.423 | 0.962 | 0.593 – 1.561 | 0.875 |
| North-Central (ref) | 1.000 | - | - | 1.000 | - | - |
| ***Health/behavioral variables*** | | | | | | |
| **Mode of delivery** | - | - | 0.009* | - | - | 0.011* |
| Caesarean | 1.907 | 1.174 - 3.095 | 0.009* | 1.792 | 1.145 - 2.805 | 0.011* |
| Non-caesarean (ref) | 1.000 | - | - | 1.000 | - | - |
| **Breastfeeding initiation** | - | - | 0.425 | - | - | 0.359 |
| Beyond first one hour | 1.071 | 0.904 - 1.269 | 0.425 | 1.122 | 0.877 - 1.434 | 0.359 |
| Within first one hour (ref) | 1.000 | - | - | 1.000 | - | - |
| **Desire for pregnancy** | - | - | 0.760 | - | - | 0.225 |
| Then | 1.108 | 0.844 - 1.454 | 0.460 | 1.429 | 0.950 - 2.149 | 0.087 |
| No more | 1.082 | 0.588 - 1.992 | 0.800 | 1.465 | 0.680 - 3.156 | 0.329 |
| Later (ref) | 1.000 | - | - | 1.000 | - | - |
| **Place of delivery** | - | - | 0.702 | - | - | 0.128 |
| Home | 1.079 | 0.895 - 1.301 | 0.424 | 1.235 | 0.935 - 1.630 | 0.137 |
| Private Facility | 1.099 | 0.795 - 1.519 | 0.568 | 0.908 | 0.671 - 1.231 | 0.535 |
| Public Facility (ref) | 1.000 | - | - | 1.000 | - | - |
| **Delivery assistance** | - | - | 0.491 | - | - | 0.088 |
| Skilled | 1.016 | 0.855 - 1.209 | 0.853 | 0.734 | 0.558 - 0.967 | 0.028 |
| No assistance | 1.112 | 0.931 - 1.327 | 0.241 | 0.875 | 0.549 - 1.395 | 0.574 |
| TBA/combined (ref) | 1.000 | - | - | 1.000 | - | - |
| **Antenatal care attendance** | - | - | 0.202 | - | - | 0.015* |
| No | 1.124 | 0.939 - 1.346 | 0.202 | 1.662 | 1.103 - 2.503 | 0.015* |
| Yes (ref) | 1.000 | - | - | 1.000 | - | - |

*Statistically significant at 5% significance level. COR: crude odds ratio. CI: confidence interval. ref: reference value

### *Risk factors for infant mortality in rural and urban residence*

Based on the results of the multivariable models disaggregated by rural-urban residence (Table 3), no socioeconomic factor was statistically significant as a risk factor for infant mortality in rural Nigeria. However, two bio-demographic factors, maternal marital status and region of residence, were significantly associated with infant mortality in the (rural) residence only. Rural infants whose mothers were formerly but no longer married had 62.5% increased risk of mortality compared to those whose mothers were married or cohabiting (Table 3). Also, infants whose mothers resided in the North-East and North-West regions had 34.6% and 65.3%

increased risk of mortality, respectively, compared to their counterparts in the North-Central region of the country.

In urban residence, wealth index, a proxy for socioeconomic status, was significantly associated with infant mortality. Based on this result, poor households had 2.29 times increased risk of infant mortality compared to households in the rich wealth index. Further, maternal obesity was associated with 64.1% increased infant mortality risk while 'maternal underweight' was protective, reducing infant mortality risk by 63.9% (Table 3) only in urban residence. Also, male infants in urban residence were nearly 42% more at risk of mortality than their female counterparts.

Regardless of residence type (rural or urban), three factors – small birth size, preceding birth interval < 24 months and caesarean delivery – attained statistical significance as risk factors for infant mortality. Compared to those perceived as having large birth size, infants reported as having small birth size had 1.55 times and nearly 2.3 times increased mortality risk in rural and urban residences, respectively. Similarly, preceding birth interval < 24 months was associated with about two folds increased risk of infant mortality in rural residence and about 60% increased risk of mortality in urban residence. Last, infants delivered through a caesarean section had increased likelihood of mortality compared to those with a non-caesarean delivery, whether in rural or urban residence (Table 3).

**Table 3: Factors associated with infant mortality in rural and urban Nigeria**

| Variables | Rural | | | Urban | | |
|---|---|---|---|---|---|---|
| | AOR | 95% CI | P-Value | AOR | 95% CI | P-Value |
| **Wealth index (SES)** | - | - | - | - | - | < 0.001* |
| Poor | | | | 2.292 | 1.589 – 3.308 | < 0.001* |
| Middle | - | - | - | 1.202 | 0.839 – 1.722 | 0.316 |
| Rich (ref) | - | - | - | 1.000 | - | - |
| **Maternal marital status** | - | - | 0.029* | - | - | - |
| Unmarried | 1.853 | 0.759 - 4.523 | 0.175 | | | |
| Formerly married/cohabited | 1.625 | 1.079 - 2.447 | 0.020* | - | - | - |
| Married/cohabiting (ref) | 1.000 | - | - | - | - | - |
| **Size of child at birth** | - | - | < 0.001* | - | - | < 0.001* |
| Small | 1.550 | 1.266 - 1.898 | < 0.001* | 2.276 | 1.585 - 3.270 | < 0.001* |
| Average | 1.044 | 0.873 - 1.247 | 0.638 | 1.314 | 0.979 - 1.764 | 0.069 |
| Large (ref) | 1.000 | - | - | 1.000 | - | - |
| **Gender of child** | - | - | - | - | - | 0.022* |
| Male | | | | 1.416 | 1.052 - 1.907 | 0.022* |
| Female (ref) | - | - | - | 1.000 | - | - |
| **Preceding birth interval (Months)** | - | - | < 0.001* | - | - | 0.002* |
| < 24 | 2.057 | 1.784 - 2.371 | < 0.001* | 1.605 | 1.191 - 2.161 | 0.002* |
| ≥ 24 (ref) | 1.000 | - | - | 1.000 | - | - |
| **Region of residence** | - | - | 0.001* | - | - | - |
| South-West | 1.109 | 0.568 - 2.169 | 0.761 | | | |
| North-East | 1.346 | 1.017 - 1.783 | 0.038* | - | - | - |
| North-West | 1.653 | 1.271 - 2.148 | < 0.001* | | | |
| South-East | 1.337 | 0.811 - 2.202 | 0.254 | - | - | - |
| South-South | 1.005 | 0.703 - 1.437 | 0.977 | | | |
| North-Central (ref) | 1.000 | - | - | - | - | - |
| **Maternal BMI** | - | - | - | - | - | 0.032* |
| Obese | | | | 1.641 | 1.139 - 2.365 | 0.008* |
| Overweight | - | - | - | 1.081 | 0.784 - 1.490 | 0.634 |
| Underweight | | | | 0.361 | 0.135 - 0.963 | 0.042* |
| Normal weight (ref) | - | - | - | 1.000 | - | - |
| **Mode of delivery** | - | - | 0.001* | - | - | 0.032* |
| Caesarean | 2.922 | 1.569 - 5.443 | 0.001* | 1.947 | 1.059 - 3.581 | 0.032* |
| Non-caesarean (ref) | 1.000 | - | - | 1.000 | - | - |

*Statistically significant at 5% significance level. AOR: adjusted odds ratio. CI: confidence interval. ref: reference value

## Discussion

From the results of the multivariable analyses, three factors – small birth size, preceding birth interval < 24 months and caesarean mode of delivery – were significantly associated with infant mortality, irrespective of rural-urban residence. Other risk factors differ considerably with residence type. These included poor wealth index, maternal obesity and male gender in urban

residence, as well as maternal marital status and the region of residence in rural residence. These findings support the importance of disaggregated studies/data for identifying population-specific differences in the rates and determinants of infant mortality.

In urban residence, infants from poor households were more at risk of mortality than their counterparts in the middle wealth index category, showing that low socioeconomic status was a significant risk for infant mortality in urban Nigeria. This survival disadvantage in poor urban households is comparable to the high infant mortality rates in rural residence (Tables 1). While, contrary to expectation, wealth index did not attain statistical significance as a predictor of infant mortality in rural residence, the results of IMR (Table 1) indicate that infants living in urban areas (IMR = 49 deaths per 1000 live births) generally had lower rate of mortality than their rural counterparts (IMR = 70 deaths per 1000 live births, $P < 0.001$). This finding agrees with trends in studies showing that disparities exist in childhood mortalities across socioeconomic and geographic devides [8, 15], in this instance, rural-urban, with greater risks for rural infants. The finding may be blamed on several factors including inequities in intervention coverage between rural and urban residence as well as between poor and rich households [6, 15, 16]. Similar to those in poor households, infants born in rural areas are often disadvantaged by socioeconomic factors – access to safe drinking water, improved toilet facility, electricity, among others factors [1, 4]. This is particularly likely in Nigeria given the high poverty and rural-urban migration (a possible perception of better living conditions in urban areas) level in the country [17]. Also, compared to urban Nigeria, access to healthcare services is poorer in many rural communities, consequent upon ill-equipped facilities, traditional practices/beliefs, distance barriers, and inadequately skilled workers [4, 17, 18]

Interestingly, the effects of all socioeconomic factors disappeared in rural residence following adjustment for other factors/confounders (Table 3). The result is similar to the finding of a study on neonatal mortality where the impacts of all socioeconomic factors were lost in rural Nigeria following adjustment for other factors [9]. This may be due to the masking effect of 'maternal marital status' and the 'region of residence' which were overwhelmingly significant in rural residence (Table 3). It is equally possible that the disparities in the region of residence found in rural Nigeria had accounted for the impact of some of the factors, especially, those in the socioeconomic category. The statistical significance of some of the factors in the SLR (without adjustment) [Table 2] which was lost in the multivariable analysis (with adjustment) may be an evidence in support of this premise.

Infants in rural residence whose mothers were married, or cohabiting were found to have a lower risk of mortality compared to those whose mothers were formerly married. This finding is consistent with the result of a study in rural Ghana indicating that marital union was protective against childhood mortality [18]. The emotional and financial support that marital relationship affords in a developing country like Nigeria may explain the present result [8, 18]. The fact that infants whose mothers were previously but no longer married – divorcees, widows, and the separated – had the greater risk of mortality lends credence to this argument. Women in the named categories would be expected to experience greater psychological and/or financial difficulties than their colleagues in a stable marriage, and this may contribute in some ways to making their infants more vulnerable. This is more so as marriage is universally perceived as a social and economic security in Nigeria [4].

Similar to the findings in other studies, infants with small birth size (a substitute for low birthweight) had higher risks of mortality in this study [8, 16, 19], regardless of the residence

type. Genetic factors, malnutrition in pregnancy, as well as obstetric factors have largely been blamed for this result [9, 20]. Intra-uterine fetal monitoring and nutrition support services in pregnancy are possible interventions for this finding [9, 20]. Also, preceding birth interval < 24 months was a striking risk factor in all residences (Table 3). This finding agrees with other studies and may be explained by the exhaustion of maternal biological resources (theory of maternal depletion syndrome) as well as possible competition among siblings for attention and resources [5, 8, 19]. The impact of short birth interval (< 24 months) on infant mortality as found in this study, however, differs between the residences with greater risks in rural Nigeria. This possibly reflects lesser knowledge and poorer use of family planning services among rural women in Nigeria. With evidence showing an overall contraceptive prevalence of 16% – nine percent in rural areas and 23 percent in urban residence – family planning services are poorly utilized in Nigeria [4]. Interventions focusing on improved use of family planning services, therefore, may prove useful in speeding up the reduction of IMR in the country. The higher mortality risk found among male infants is equally consistent with previous studies [5, 8, 13]. This has been linked with the delayed maturation of fetal lungs in male newborns predisposing them to a greater likelihood of respiratory tract infections [5, 8, 13].

Further, maternal BMI was significantly associated with infant mortality in urban residence, and while obesity assumed statistical significance as a risk factor, maternal underweight was protective. This protective role does not agree with the popular opinion in the literature [21], however, a mixed effect of this variable has been reported in respect of neonatal outcomes [22, 23]. In any case, there is evidence that maternal obesity increases the risk of pregnancy-related complications such as stillbirth, preeclampsia, gestational hypertension, preterm delivery, low

birthweight, cesarean section, congenital abnormalities and so on [24, 25]. These may contribute to the increased risks of infant mortality among obese mothers.

The finding that residence in the North-West and the North-East regions of Nigeria increased the risks of infant mortality in rural residence may be connected in some ways with the on-going insurgency in parts of the named regions [26]. This is particularly likely in the North-East considering that survey did not hold in six clusters of the region (four in Borno and two in Yobe state) due to security reason [4]. In light of this report, infant mortality may have been underestimated in the North-East region; and this limitation needs to be considered when interpreting the results of this study. Other contributory factors would be the impact of low level of socioeconomic development, education, breastfeeding, and utilization of health services in northern Nigeria [4, 27, 28]; especially, in the rural residence of the North-East region which for years has been the epicenter of insurgency [26].

Last, caesarean delivery was associated with increased risk of infant mortality both in rural and urban residences. This result is consistent with previous studies reporting an association between cesarean delivery and infant mortality [5, 29] . In the Nigerian context, emergency caesarean section in women with life-threatening complications, possibly evidenced by the low uptake of the obstetric intervention (Table 1), have been linked with this finding [5, 9, 30]. The low uptake of cesarean section in the country may be due to misconceptions about the mode of delivery among Nigerian women [5, 30]. However, as suggested by Adewuyi & Zhao [9] in respect of neonatal mortality, the high cost of the obstetric intervention in the country could be a contributory factor. While cesarean delivery is known to be lifesaving, particularly, in complicated pregnancies, its possible contribution to late breastfeeding initiation, shortening of

gestation duration, and the practice of emergency caesarean section (due to late presentation), among other factors could limit or reverse its beneficial effects on infants' survival [29].

**Strengths and limitations**

One remarkable strength of this study is the large sample size and the national representativeness of the dataset used; hence, data disaggregation does not undermine generalizability of estimates. High response rate, low missing data, rural-urban disaggregation, and application of complex samples statistics in all analyses are some of the other strengths. A few limitations, however, need to be considered when the results of this study are being interpreted. First, the cross-sectional design does not allow estimation of causality. Second, obstetric complications, antenatal attendance, postnatal care, and small for gestational age were not assessed/not included in the multivariable models due to either substantially missing information or their non-availability in the NDHS dataset. Third, underestimation of infant mortality is possible given that only surviving women participated in NDHS. Fourth, underestimation of infant mortality may also occur due to recall bias since estimates were based on retrospective birth histories. Last, there was heaping of mortalities at $12^{th}$ month of age in the 2013 NDHS; and this may result in a slight underestimation of infant mortality [4].

**Conclusions and recommendations**

IMRs were 70 and 49 deaths per 1000 live births in rural and urban residence, respectively. This reveals the existence of disparities in the rate of infant mortality in rural and urban Nigeria; and indicates that rural infants were more at risk of mortality. Similar disparities in risk factors for infant mortality were observed in the two residences. Hence, interventions aimed at speeding up the reduction of IMR in Nigeria would need to prioritize findings in this study. First, rural

infants, generally, and, infants in the rural North-East and North-West regions, in particular, should be accorded a priority attention. Given the possible effects of insurgency, low education, breastfeeding and socioeconomic levels, on infant mortality risks in the two named regions, multidimensional/sectorial approaches that address these and similar factors should be adopted.

Second, improved utilization of family planning services (for enhanced child spacing) need to be pursued as part of a holistic approach to speeding up the reduction of IMR both in rural and urban Nigeria. Being a known cost-effective means of promoting child spacing (through lactational amenorrhea), early initiation and exclusive breastfeeding practices should be further promoted in the country. Closely related is the imperative of safer and affordable cesarean deliveries both in rural and urban residences. Possible misconceptions on caesarean section need to be addressed just as it is important to promote better access to emergency obstetric care services. Third, this study further recommends, as a matter of priority in urban Nigeria, the need for policies/programs on poverty and maternal obesity reduction which may form components of long-term approaches to reducing IMR. Infant mortality associated with small birth size, as found in urban areas may equally benefit from target-specific interventions that prioritize the provision of intra-uterine feta monitoring and nutrition support services. Last, this study reveals that the risk of infant mortality was significantly higher among rural mothers who were previously but no longer married/cohabiting. Future intervention efforts would need to put this finding in perspective, for instance, by focusing on education in matters of sexual behaviors and by promoting family oriented/supportive programs/services in rural Nigeria.

**Acknowledgements**

The authors gratefully appreciate ICF International, USA, for providing the NDHS dataset for this study.

**Funding:** None

**Conflict of interest:** None

**Ethical approval:** This study is a secondary analysis of NDHS dataset, as such, no ethical approval is required. Permission to use the dataset was obtained from ICF International Inc., USA.

# References


1. UNICEF, *Committing to Child Survival: A Promise Renewed, Progress Report 2014. 2014.* New York, USA: UNICEF, 2015.

2. Kuruvilla, S., et al., *Success factors for reducing maternal and child mortality.* Bulletin of the World Health Organization, 2014. **92**(7): p. 533-544.

3. Molyneux, M. and E. Molyneux, *Reaching Millennium Development Goal 4.* The Lancet Global Health, 2016. **4**(3): p. e146-e147.

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

5. Ezeh, O.K., et al., *Risk factors for postneonatal, infant, child and under-5 mortality in Nigeria: a pooled cross-sectional analysis.* BMJ open, 2015. **5**(3): p. e006779.

6. Susuman, A.S., et al., *High infant mortality rate, high total fertility rate and very low female literacy in selected African countries.* Scandinavian journal of public health, 2016. **44**(1): p. 2-5.

7. Wardlaw, T., et al., *UNICEF Report: enormous progress in child survival but greater focus on newborns urgently needed.* Reproductive health, 2014. **11**(1): p. 82.

8. Adewuyi, E.O., Y. Zhao, and R. Lamichhane, *Socioeconomic, bio-demographic and health/behavioral determinants of neonatal mortality in Nigeria: a multilevel analysis of 2013 demographic and health survey.* Int J Contemp Pediatr, 2016. **3**(2).

9. Adewuyi, E.O. and Y. Zhao, *Determinants of neonatal mortality in rural and urban Nigeria: evidence from a population-based national survey.* Pediatrics International, 2016: doi: 10.1111/ped.13086.

10. Hosseinpoor, A.R., et al., *Equity-oriented monitoring in the context of universal health coverage.* PLoS Med, 2014. **11**(9): p. e1001727.

11. Miyahara, R., et al., *The large contribution of twins to neonatal and post-neonatal mortality in The Gambia, a 5-year prospective study.* BMC pediatrics, 2016. **16**(1): p. 1.

12. Mosley, W.H. and L.C. Chen, *An analytical framework for the study of child survival in developing countries.* Population and development review, 1984: p. 25-45.

13. Mustafa, H.E. and C. Odimegwu, *Socioeconomic determinants of infant mortality in Kenya: analysis of Kenya DHS 2003.* J Humanit Soc Sci, 2008. **2**: p. 1934-722.

14. Victora, C.G., et al., *The role of conceptual frameworks in epidemiological analysis: a hierarchical approach.* International journal of epidemiology, 1997. **26**(1): p. 224-227.

15. Arntzen, A. and A.M.N. Andersen, *Social determinants for infant mortality in the Nordic countries, 1980-2001.* Scandinavian journal of public health, 2004. **32**(5): p. 381-389.

16. Khadka, K.B., et al., *The socio-economic determinants of infant mortality in Nepal: analysis of Nepal Demographic Health Survey, 2011.* BMC pediatrics, 2015. **15**(1): p. 1.

17. Abbass, I.M., *Trends of rural-urban migration in Nigeria.* European Scientific Journal, 2012. **8**(3).

18. Kanmiki, E.W., et al., *Socio-economic and demographic determinants of under-five mortality in rural northern Ghana.* BMC international health and human rights, 2014. **14**(1): p. 1.

19. Lamichhane, R., et al., *Factors associated with infant mortality in Nepal: a comparative analysis of Nepal demographic and health surveys (NDHS) 2006 and 2011.* BMC Public Health, 2017. **17**(1): p. 53.

20. Lawn, J.E., et al., *4 million neonatal deaths: when? Where? Why?* The Lancet, 2005. **365**(9462): p. 891-900.

21. Aune, D., et al., *Maternal body mass index and the risk of fetal death, stillbirth, and infant death: a systematic review and meta-analysis.* Jama, 2014. **311**(15): p. 1536-1546.

22. Blomberg, M., *Maternal Obesity, Mode of Delivery, and Neonatal Outcome.* Obstetrics & Gynecology, 2013. **122**(1): p. 50-55.

23. Cresswell, J.A., et al., *Effect of maternal obesity on neonatal death in sub-Saharan Africa: multivariable analysis of 27 national datasets.* The Lancet. **380**(9850): p. 1325-1330.

24. Siega-Riz, A.M., A.M. Siega-Riz, and B. Laraia, *The implications of maternal overweight and obesity on the course of pregnancy and birth outcomes.* Matern Child Health J, 2006. **10**(5 Suppl): p. S153-6.

25. Chen, A., et al., *Maternal obesity and the risk of infant death in the United States.* Epidemiology (Cambridge, Mass.), 2009. **20**(1): p. 74.

26. Eme, O.I. and J. Ibietan, *The cost of Boko Haram activities in Nigeria.* Arabian Journal of Business and Management Review (OMAN Chapter), 2012. **2**(2): p. 10.

27. Doctor, H.V., et al., *Northern Nigeria maternal, newborn and child health programme: selected analyses from population-based baseline survey.* The Open Demography Journal, 2011. **4**(11-12): p. 11.

28. Adewuyi, E.O. and K. Adefemi, *Breastfeeding in Nigeria: a systematic review.* Int J Community Med Public Health, 2016. **3**(2): p. 385-396.

29. Shah, A., et al., *Cesarean delivery outcomes from the WHO global survey on maternal and perinatal health in Africa.* International Journal of Gynecology & Obstetrics, 2009. **107**(3): p. 191-197.

30. Sunday-Adeoye, I. and C. Kalu, *Pregnant Nigerian women's view of cesarean section.* Nigerian journal of clinical practice, 2011. **14**(3): p. 276-279.