3-1-2017

Determinants of neonatal mortality in rural and urban Nigeria: Evidence from a population-based national survey

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10.1111/ped.13086
This is an Author's Accepted Manuscript of: Adewuyi, E. O., & Zhao, Y. (2017). Determinants of neonatal mortality in rural and urban Nigeria: Evidence from a population-based national survey. *Pediatrics International, 59*(2), 190-200.
https://doi.org/10.1111/ped.13086

TITLE PAGE

Type of article: Original article

Title of article: Determinants of neonatal mortality in rural and urban Nigeria: evidence from a population-based national survey

Short title: Neonatal mortality in rural and urban Nigeria

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Total number of pages: 32
Word count: 3981 [excluding acknowledgment, disclosure, reference list (page 19 - 21) and Tables (page 23 – 32)].

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Abstract

Background:

Significant reduction in the global burden of neonatal mortality was achieved through the millennium development goals. However, in Nigeria, only a marginal reduction was realized. This study assesses the rural-urban differences in neonatal mortality rates and the associated risk factors in Nigeria.

Methods:

Dataset from the 2013 Nigeria demographic and health survey, disaggregated by rural-urban residence (n = 20449 and 9935, respectively) was explored using univariate, bivariate, and multivariable analyses. Complex samples analysis was applied in adjusting for the unequal selection probabilities due to the multi-stage cluster sampling method used in the 2013 NDHS. The adjusted relationship between the outcome and predictor variables was assessed using a multi-level logistic regression analysis.

Results:

NMR for rural and urban populations were 36 and 28 deaths per 1000 live births, respectively. Risk factors in urban residence were lack of electricity access (adjusted odd ratio [AOR]: 1.555, 95% confidence interval [CI]: 1.089 – 2.220), small birth size (AOR: 3.048, 95%CI: 2.047 – 4.537), and male gender (AOR: 1.666, 95%CI: 1.215 – 2.284). Risk factors in rural residence were small birth size (AOR: 2.118, 95%CI: 1.600 – 2.804), and birth interval less than two years (AOR: 2.149, 95%CI: 1.760 – 2.624). Cesarean mode of delivery was a risk factor both in rural (AOR: 5.038, 95%CI: 2.617 – 9.700) and urban Nigeria (AOR: 2.632, 95%CI: 1.543 – 4.489).

Conclusion:

Determinants of neonatal mortality were different in rural and urban Nigeria, and rural neonates had greater risk of mortality than their urban counterparts.

Keywords:

Determinants, neonatal mortality, rural-urban Nigeria, electricity access, mode of delivery.

Introduction

The latest report from the United Nations (UN) indicates that a substantial milestone was reached in the global reduction of the rate of neonatal mortality – thanks to the millennium development goals (MDGs). [1] From 36 deaths per 1000 live births in 1990, neonatal mortality rate (NMR) decreased dramatically to 19 deaths per 1000 live births in 2015, [2] representing about 47% reduction in the global burden of neonatal mortality since 1990. Many countries around the world, including some in the low-middle income categories, realized the targets of MDG 4 – two-third reduction in child mortality rate by 2015. [2] This significant progress notwithstanding, neonatal mortality continues to be a subject of considerable public health importance. [1,2] In the year 2015 alone, about 2.8 million infants died within their first 28 days of life (neonatal period). [1] This figure translates to over 46% of global under-five mortalities, [1,2] up from 44% recorded in 2013 and 37% in 1990. [3] In all regions of the world, evidence suggests an increasing proportion of neonatal mortality in the declining under five mortality rates. [2]

Nigeria remains one of the countries in the world with a considerable burden of neonatal mortality. [4] Consistently, studies have shown that only a marginal reduction in the rate of neonatal mortality was achieved in the country since 1990. [2,5] While the global NMR stands at 19 deaths per 1000 live births; [2] a recent study indicates that Nigeria maintains a rate of 33 deaths per 1000 live births (based on the analysis of 2013 Nigeria demographic and health survey [NDHS] dataset). [6] Unlike countries such as Malawi, Uganda, Tanzania, Niger, Liberia, Ethiopia, and so on, Nigeria did not meet the targets of MDG 4. [2]

Now, in the post-2015 era, and with the change of baton from MDGs to SDGs (sustainable development goals), there is the urgent need for an accelerated reduction in the rate of neonatal mortality in Nigeria. [2,7] This need is critical considering that SDGs has more ambitious targets for child survival (goal 3.2) than MDGs – achieving a global NMR of 12 deaths per 1000 live births and child mortality rate of 25 deaths per 1000 live births by 2030. [2,7,8] According to the UNICEF's estimates, Nigeria will require about two to three times increased reduction in the rate of child/neonatal mortality to be on track for these targets. [2]

One practical approach to reducing child/neonatal mortality is the use of evidence based on disaggregated studies/data. [2,9,10] Moving beyond evidence based only on national average of neonatal mortality, for example, to those based on the differences between rural and urban residences (following data disaggregation), could contribute to lowering inequities. [2] As demonstrated in Brazil, this method enhances the tracking and subsequently contribute to closing the gaps in neonatal mortality among the vulnerable populations. [2] Regrettably, the use of disaggregated data in perinatal studies is limited in Nigeria. [2,4]

So far, a few studies have examined the determinants of neonatal mortality in Nigeria [4,6,11] however, those were limited in that they were not disaggregated along rural-urban residence. Hence, much remains to be understood on the different factors contributing to the incidence of neonatal mortality in rural and urban Nigeria. By exploring a broad range of variables previously reported as risk factors for neonatal mortality, the current study aims to investigate differences in neonatal mortality rates and the associated risk factors (determinants) in rural and urban Nigeria, thereby, bridging the existing gaps in knowledge. To the best of knowledge, this is the first study to analyze a comprehensive array of factors associated with neonatal mortality in Nigeria using a nationally representative dataset disaggregated by rural-urban residence.

Owing to its comprehensive approach to variable selection, data disaggregation by population type (rural and urban), and rigorous statistical modelling with adjustment for sampling weighing probabilities, findings in this study have a significant implication for policies in Nigeria and by extension, the west African sub-region. Current economic realities in Nigeria as in many developing countries support the need for a judicious disbursement of resources. Cognizant of these realities, this study identifies the vulnerable populations to which interventions should be targeted, and the risk factors that should be prioritized in designing programs aimed at reducing the rate of neonatal mortality in rural and urban Nigeria.

Methods

Data source

The data analyzed in this study was sourced from NDHS, 2013 edition. NDHS is a cross-sectional survey that is nationally representative of the Nigerian population, and the data are publicly and freely available online. The survey was implemented by the Nigerian National Population Commission (NPC) with support from many development partners, including the United States Agency for International Development (USAID), the United Kingdom Department for International Development (DFID), and the United Nations Populations Fund (UNFPA). [12] Technical support for the survey was provided by the ICF Macro International Corporation, through the MEASURE DHS program. [12] Specifically, the survey aims to provide quality and up-to-date data on marriage, maternal and childhood mortalities, awareness and use of family planning methods, nutritional status of women and children, and so on, in Nigeria. [12]

The 2013 edition of NDHS is the latest in the series of its kind. There have been four previous editions – 1990, 1999, 2003, and 2008. [12] The 2013 NDHS employed a stratified three-stage cluster sampling techniques in the selection of samples. [12] Clusters were the primary sample units (PSU) and the survey design consisted of 904 clusters – 532 in rural areas and 372 in urban areas. [12] A representative sample of 40,680 households consisting of 23,940 rural households and 16,740 urban households was selected for the survey (with a response rate of 99%). [12] Men and women aged 15 – 49 years, present in each of the selected households, at least, one night prior to the survey were eligible to be interviewed. [12]

Questionnaires were the instrument for data collection, and three types – household's, woman's and man's questionnaires – were utilized. [12] The questionnaires were developed originally in English but subsequently translated into the three major Nigerian languages – Hausa, Igbo, and Yoruba – before they were pretested and finalized for the survey. [12] A comprehensive and detailed description of the setting, data sources and sampling design for the 2013 NDHS have previously been published. [12]

The data analyzed in this study were those of singleton live births for the period of five years preceding the survey. Multiple births are associated with increased risk of infant mortality and liable to produce misleading results, hence, they were not included in this study. [13] Also, only information available for each of the variables investigated were included and missing data were excluded in analyses.

Variables

The outcome variable for this study was neonatal mortality which was defined as death within the first 28 days of an infant's life. [14] Neonatal Mortality Rates (NMR) were calculated and expressed as the number of neonatal deaths per 1000 live births. In addition, the survival status of neonates was coded as 1 = 'died' for newborns who died within their first 28 days of life, and 0 = 'survived' for those who survived beyond 28 days. This coding created a binary variable to be used in the regression analyses of this study.

The independent variables were selected based on the objective of this study and their importance for neonatal survival as previously reported in the literature. The variables were grouped into three – socioeconomic, bio-demographic and health/behavioral (Table 1) – as defined and categorized in Table 1. Socioeconomic variables included in this study were maternal education level, maternal literacy level, maternal occupation, paternal education level, paternal occupation, wealth index, decision-making on health care need, toilet facility, source of drinking water, electricity access and cooking fuel.

Bio-demographic variables, namely, maternal age at first childbirth, maternal marital status, residence, region of residence, ethnicity, religion, birth order, size of child at birth, gender of child, gender of household head, preceding birth interval, maternal age and maternal body mass index, were equally included in this study. Health/behavioural variables used in this study included iron intake, breastfeeding initiation, antenatal attendance, delivery assistance, place of delivery, mode of delivery, malaria prophylaxis with IPT_p, and tetanus injection during pregnancy.

Two health/behavioral variables – postnatal care and desire for pregnancy – were not included because over 80% of their information were missing. Also, a few risk factors were not considered, including maternal chronic diseases, obstetrical complications and, gestational age because information for those were not collected in NDHS. Also, birth size was assessed as a prozy for birthweight because in developing countries like Nigeria, a large proportion of children are often delivered with no record of birthweight. [15] For such deliveries, the best estimate of birthweight is usually the perception of mothers on birth size. While this method could be error-prone, there is evidence that its estimates are usually closely related to the mean birthweight of babies. [16]

Table 1 (A, B, C): Definition and categorization of variables used in the analyses [6]

A. Socioeconomic variables

Variables	Definition and categorization
Maternal education level	The highest educational level of mothers (no education, primary, secondary, higher education).
Maternal literacy level	This variable defines the level of maternal literacy (cannot read at all, can read parts of/whole sentences).
Maternal occupation	Maternal occupation (not working, working).
Paternal education level	Paternal [husband/partner] education level (no education, primary, secondary, higher education).
Paternal occupation	Paternal occupation (not working, working).
Wealth index	Wealth (poor, middle, rich)
Decision-making on health care need	The person who usually decides on own or women's health care needs (respondent alone, respondent and husband/partner, husband/partner alone).
Toilet facility	Recoded according to the UNICEF/WHO classification [34] (unimproved, improved).
Source of drinking water	Recoded according to the UNICEF/WHO classification [34] (unimproved, improved sources).
Electricity access	Access to electricity (no, yes).
Cooking fuel	Cooking fuel was recoded in line with the 'energy ladder' concept (solid fuel, non-solid fuel) [35].

B. Bio-demographic variables

Maternal age at first birth	Maternal age at first child birth was recoded (< 20 years, ≥ 20 years).
Maternal marital status	Marital staus of mothers (never in union, divorced/separated/no longer living together, married/living with a partner).

Residence	Type of residence was classified (rural, urban).
Region of residence	Categorized according to the geopolitical zones in Nigeria (North-Central, North-East, North-West, South-East, South-South, South-West).
Ethnicity	Recoded into four [the three major ethnic groups and 'others' – all the other ethnic groups put together] (Hausa, Igbo, Yoruba, 'Others').
Religion	Recoded into the three main religions in Nigeria (Christianity, Islam, Traditionalist).
Birth order	Birth order (1, 2-3, and $\geq$ 4)
Size of child at birth	The perception of mothers as to the size of their babies at birth (small, average, Large).
Gender of child	The sex of child (male, female).
Gender of household head	The sex of the head of household (male, and female).
Preceding birth interval	Preceding birth interval (< 24 months, $\geq$ 24 months).
Maternal Body Mass Index (BMI)	Recoded using the WHO International classification [36] (underweight = BMI < 18.5 kg/m^2, normal = BMI 18.5 – 24.9 kg/m^2, overweight = BMI 25 – 29.9 kg/m^2, Obese = BMI $\geq$ 30 kg/m^2).
Maternal age (years)	Age of mothers at the time of the survey (< 20 years, 20 – 35 years, $\geq$ 36 years).

C. Health/behavioral variables

Iron intake	Iron intake during pregnancy (yes, no).
Breastfeeding initiation	The time breastfeeding was commenced following child delivery (Immediately/within the first hour of birth, beyond the first hour of birth).
Antenatal attendance	Antenatal attendance (no, yes).
Delivery assistance	The person who render assistance during delivery (skilled [doctors, nurses, and midwives], combined [health professionals and traditional birth attendants], no assistance).
Place of delivery	Places where mothers gave birth to their babies (home, government, and private facility).
Mode of delivery	How babies were delivered (caesarean delivery, non-caesarean [vaginal] delivery).
Malaria Prophylaxis with IPT_p	Intermittent preventive treatment of malaria in pregnancy (IPT_p) describes whether or not mothers received malaria prophylactics (sulfadoxine/pyrimethamine) during pregnancy. The variable was recoded as: no, yes.
Tetanus injection during pregnancy	Recoded as no, yes.

Statistical analysis

Three levels of analysis – univariate, bivariate and multivariable – were carried out. The univariate analysis assessed the differentials in neonatal mortality rate (NMR) attributed to each independent variable described in Table 1, using a chi square test. Secondly, bivariate analysis was performed using a simple logistic regression analysis to assess the unadjusted (crude) relationship (presented as crude odds ratio [COR]) between each independent variable and the survival status of neonates. Lastly, multivariable logistic regression analysis was carried out to explore the adjusted relationship between independent variables and neonatal mortality, controlling for other variables and confounders, and the outcome was expressed as adjusted odds ratio (AOR). Selection of variables for the multivariable logistic regression model building followed the recommendation by Hosmer-Lemeshow [17], that is, only variables with a p-value of 0.25 or less in the univariate or the bivariate analyses were included in the multivariable regression modeling.

Three sets of Models (I, II, III) were fitted in line with the recommended hierarchical approach. [18] Model I was built for socioeconomic (distal) variables and those found to be significant at 10% level were retained for the subsequent model. Model II comprised of variables retained in Model I together with the bio-demographic (proximate) variables. Significant variables at 10% level were likewise retained for inclusion in the next model. Model III was fitted for all variables retained in Model II together with the health/behavioral (intermediate) variables. The significance level for the final model was at $p < 0.05$, and variables found to be significant at this level were reported along with their p – values and 95% confidence intervals (CI). At each level of the analysis, the backward elimination method was used in obtaining a parsimonious model.

The above procedure was followed separately for data disaggregated by rural and urban residence (the term ‘residence’ was used interchangeably with ‘areas’ and ‘population’ in this study). A complex samples analysis approach was applied in adjusting for the sampling weight due to the multistage stratified cluster sampling of NDHS. Also, only available information for each of the variables was included in the analysis. All of the data management and analysis was performed using IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp. Released 2013. Armonk, NY: IBM Corp USA).

Results

Background characteristics

Within the five years preceding the 2013 survey, there was a total of 30,384 singletons live–births and those were included in this study. Over 65% (n = 20449) of the study participants resided in rural residence while close to 35% (n = 9935) lived in the urban residence. Table 2 presents the background characteristics of the study populations alongside the result of the univariate analysis. The study population in urban areas had better outcomes in all of the socioeconomic variables analyzed in this study. For instance, 22.4% of mothers in urban areas had no education, compared to almost two-thirds of mothers (63.7%) living in rural areas.

Table 2 (A, B, C): Characteristics of study variables and neonatal mortality rates disaggregated by rural-urban residence.

A. Socioeconomic variables

Variables	Rural			Urban		
	N (%)+	NMR++	P¶-Value	N (%)+	NMR++	P¶-Value
Maternal education level						
No education	13026 (63.70)	36.00	0.689	2225 (22.40)	30.00	0.143
Primary	3681 (18.00)	39.00		2106 (21.20)	36.00	
Secondary	3333 (16.30)	33.00		4342 (43.70)	24.00	
Higher	409 (2.00)	30.00		1262 (12.70)	23.00	
Maternal literacy level						
Cannot read at all	15122(74.80)	37.00	0.272	3156(31.90)	33.00	0.083
Can read parts or whole sentences	5095(25.20)	33.00		6734(68.10)	25.00	
Maternal occupation						
Not working	6591 (32.40)	38.00	0.338	2414 (24.40)	30.00	0.564
Working	13751 (67.60)	35.00		7480 (75.60)	27.00	
Paternal education level						
No education	10344 (52.10)	37.00	0.132	1633 (16.90)	25.00	0.619
Primary	3772 (19.00)	34.00		1797 (18.60)	31.00	
Secondary	4328 (21.80)	37.00		4106 (42.50)	24.00	
Higher	1410 (7.10)	22.00		2116 (21.90)	30.00	
Paternal occupation						
Not Working	120 (0.60)	18.00	0.292	106 (1.10)	12.00	0.233
Working	19852(99.40)	36.00		9536(98.90)	28.00	

+ Weighted for the sampling probability. ++ Neonatal mortality per 1000 live births. N = sample size. ¶Pearson Chi-Square test (χ^2).

Variables	Rural			Urban		
	N (%)+	NMR++	P¶-Value	N (%)+	NMR++	P¶-Value
Wealth index (SES)						
Poor	13537 (66.20)	37.00	0.418	1053 (10.60)	36.00	0.307
Middle	4110 (20.10)	31.00		1619 (16.30)	25.00	
Rich	2802 (13.70)	38.00		7262 (73.10)	27.00	
Decision-making on health care need						
Respondent alone	584 (3.00)	29.00	0.651	786(8.40)	26.00	0.546
Respondent and husband/partner	4729 (24.30)	34.00		3946 (42.20)	25.00	
Husband/partner alone	14168 (72.80)	36.00		4623 (49.40)	29.00	
Cooking fuel						
Solid fuels	19316(95.30)	35.00	0.449	5507(56.00)	27.00	0.969
Non-solid fuels	956(4.70)	41.00		4322(44.00)	27.00	
Toilet facility						
Unimproved	12698(62.60)	35.00	0.850	2433(24.80)	30.00	0.464
Improved	7571(37.40)	36.00		7395(75.20)	27.00	
Drinking water source						
Improved sources	9212 (45.50)	34.00	0.278	7400 (75.30)	32.00	0.219
Unimproved sources	11035 (54.50)	37.00		2428 (24.70)	26.00	
Electricity access						
No	14181 (70.00)	36.00	0.986	1779 (18.10)	36.00	0.036*
Yes	6077 (30.00)	36.00		8048 (81.90)	25.00	

*Statistically significant at 5% significance level. + Weighted for the sampling probability. ++ Neonatal mortality per 1000 live births. N = sample size. ¶Pearson Chi-Square test (χ^2).

B. Bio-demographic variables

Variables	Rural			Urban		
	N (%)+	NMR++	P¶-Value	N (%)+	NMR++	P¶-Value
Maternal age at first childbirth						
Below 20 years	14023 (68.60)	35.00	0.683	4332 (43.60)	26.00	0.386
20 years or more	6426 (31.40)	37.00		5603 (56.40)	29.00	
Maternal marital status						
Never in union	304(1.50)	45.00	0.001*	186(1.90)	34.00	0.579
Divorced/separated/no more living together	304(1.50)	78.00		166(1.70)	42.00	
Married/living with partner	19639(97.00)	35.00		9433(96.40)	27.00	
Ethnicity						
Hausa	8364 (40.90)	41.00	0.045*	2494 (25.10)	27.00	0.702
Igbo	961 (4.70)	38.00		2315 (23.30)	32.00	
Yoruba	777 (3.80)	46.00		2394 (24.10)	26.00	
Other[c]	10347 (50.60)	30.00		2732 (27.50)	26.00	
Religion						
Christianity	5988 (29.40)	36.00	0.738	4951 (50.10)	28.00	0.788
Islam	14118 (69.40)	36.00		4881 (49.40)	27.00	
Traditionalist	227 (1.10)	25.00		55 (0.60)	39.00	
Region of residence						
North-Central	3292 (16.10)	27.00	0.269	864 (8.70)	28.00	0.860
North-East	4192 (20.50)	36.00		1242 (12.50)	24.00	
North-West	9059 (44.30)	40.00		2394 (24.10)	27.00	
South-East	838 (4.10)	39.00		1739 (17.50)	33.00	
South-South	1881 (9.20)	29.00		904 (9.10)	27.00	
South West	1186 (5.80)	39.00		2782 (28.00)	27.00	

*Statistically significant at 5% significance level. + Weighted for the sampling probability. ++ Neonatal mortality per 1000 live births. N = sample size. ¶Pearson Chi-Square test (χ^2). [c] Combination of other ethnic groups (In Nigeria, there are hundreds of ethnic groups, however, in this analysis, the three most popular were chosen, and others put together).

Variables	Rural			Urban		
	N (%)+	NMR++	P¶-Value	N (%)+	NMR++	P¶-Value
Birth order						
1	3763 (18.40)	49.00	0.001*	2265 (22.80)	39.00	0.006*
2-3	6360 (31.10)	32.00		3507 (35.30)	22.00	
≥4	10327 (50.50)	33.00		4163 (41.90)	26.00	
Size of child at birth						
Large	8666 (43.30)	30.00	<0.001*	4461 (45.60)	17.00	<0.001*
Average	8086 (40.40)	30.00		4177 (42.70)	27.00	
Small	3262 (16.30)	55.00		1144 (11.70)	51.00	
Gender of child						
Male	10286 (50.30)	40.00	0.004*	5027 (50.60)	32.00	0.012*
Female	10163 (49.70)	31.00		4908 (49.40)	23.00	
Gender of household head						
Male	18856(92.20)	36.00	0.783	8635(86.90)	27.00	0.320
Female	1593(7.80)	34.00		1300(13.10)	33.00	
Preceding birth interval (Months)						
< 24	3906 (23.40)	55.00	<0.001*	1768 (23.10)	37.00	0.001*
≥ 24	12788 (76.60)	26.00		5885 (76.90)	20.00	
Maternal BMI						
Underweight	1989 (09.70)	35.00	0.151	568 (5.70)	09.00	0.125
Normal	14632 (71.60)	35.00		5603 (56.40)	27.00	
Overweight	2747 (13.40)	35.00		2494 (25.10)	28.00	
Obese	1081 (5.30)	54.00		1270 (12.80)	37.00	
Maternal age (years)						
< 20	1324 (6.50)	48.00	0.098	252 (2.50)	64.00	0.005*
20- 35	15497 (75.80)	34.00		7707 (77.60)	26.00	
36 and more	3627 (17.70)	38.00		1975 (19.90)	31.00	

*Statistically significant at 5% significance level. + Weighted for the sampling probability. ++ Neonatal mortality per 1000 live births. N = sample size. ¶Pearson Chi-Square test (χ^2).

C. Health/behavioral variables

Variables	Rural			Urban		
	N (%)$^{+}$	NMR^{++}	P¶-Value	N (%)$^{+}$	NMR^{++}	P¶-Value
Iron intake						
No	6246 (47.80)	26.00	0.780	993 (15.10)	26.00	0.336
Yes	6821 (52.20)	27.00		5582 (84.90)	21.00	
Breastfeeding Initiation						
Immediately/within first hour	6227 (31.80)	25.00	0.601	4048 (42.50)	16.00	0.950
Beyond first hour	13354 (68.20)	27.00		5476 (57.50)	16.00	
Place of delivery						
Home	15811 (78.30)	33.00	0.200	3753 (38.10)	27.00	0.928
Government facility	3170 (15.70)	38.00		3477 (35.30)	25.00	
Private facility	1191 (5.90)	43.00		2610 (26.50)	26.00	
Delivery assistance						
Skilled	5076 (25.20)	42.00	0.029*	6651 (67.60)	25.00	0.238
TBA/Combined	11519 (57.20)	31.00		2538 (25.80)	31.00	
No assistance	3532 (17.50)	33.00		652 (6.60)	20.00	
Mode of delivery						
Not Caesarean Section	20126 (99.00)	35.00	<0.001*	9389 (96.30)	26.00	<0.001*
Caesarean Section	203 (1.00)	105.00		361 (3.70)	61.00	
Antenatal attendance						
No	6211 (48.10)	27.00	0.832	718 (11.30)	37.00	0.021*
Yes	6701 (51.90)	26.00		5639 (88.70)	21.00	
Malaria prophylaxis with IPTs						
No	9989 (77.60)	28.00	0.038*	4254 (65.40)	22.00	0.943
Yes	2891 (22.40)	20.00		2251 (34.60)	22.00	
Tetanus injection in pregnancy						
No	6948 (53.30)	26.00	0.732	1138 (17.40)	23.00	0.725
Yes	6096 (46.70)	27.00		5410 (82.60)	21.00	

*Statistically significant at 5% significance level. $^{+}$ Weighted for the sampling probability. $^{++}$ Neonatal mortality per 1000 live births. N = sample size. ¶Pearson Chi-Square test (χ^2).

NMR in rural and urban Nigeria

The neonatal mortality rates for rural and urban populations were 36 deaths per 1000 live births and 28 deaths per 1000 live births, respectively. In urban residence, households with access to electricity had lower NMR (25 deaths per 1000 live births) compared to those that had no access to electricity (36 deaths per 1000 live births, $p = 0.036$).

Among the bio-demographic factors, birth order, birth size, gender of child, and preceding birth interval were all found to be significantly associated with NMR, regardless of rural-urban residence. Neonates with small birth size (rural: 55/1000 live births; urban: 51/1000 live births) had significantly higher NMR compared to those with larger birth size (rural: 30/1000 live births, $p<0.001$; and urban: 17/1000 live births, $p<0.001$). Maternal marital status and ethnicity were additional bio-demographic factors found to be statistically significant only in rural residence. According to the result, NMR was more than 50% higher among divorced/separated mothers compared to their married colleagues.

Both in rural and urban populations, mode of delivery (health/behavioral variable) was significantly associated with NMR while skilled delivery assistance was significantly associated with neonatal mortality only in rural residence. Notably, antenatal attendance, which did not make any difference in rural residence was associated with lower NMR in urban areas. Also, there was significantly lower NMR among rural neonates whose mothers had received prophylactic treatment for malaria (IPT_p) [20/1000 live births] compared to their colleagues whose mothers had received no such treatment (28/1000 live births, $p = 0.038$). In urban areas, prophylaxis for malaria did not make any significant difference in NMR. Table 3 presents the results of unadjusted association between neonatal mortality and factors assessed in the present study by rural and urban residence in Nigeria.

Table 3 (A, B, C): Results of bivariate analysis for the unadjusted relationship between neonatal mortality and explanatory variables disaggregated by rural-urban residence

A. Socioeconomic variables

Variables	Rural			Urban		
	COR	**95% CI**	**P-Value**	**COR**	**95% CI**	**P-Value**
Maternal education level	**-**	**-**	**0.784**	**-**	**-**	**0.153**
No education	1.205	0.661 – 2.195	0.543	1.318	0.744 – 2.338	0.344
Primary education	1.323	0.676 – 2.589	0.413	1.585	0.939 – 2.677	0.085
Secondary education	1.118	0.616 – 2.027	0.714	1.042	0.622 – 1.746	0.876
Higher (ref)	1.000	-	-	1.000	-	-
Maternal literacy level	**-**	-	**0.272**	**-**	**-**	**0.083**
Cannot read at all	1.130	0.909 – 1.404	0.272	1.354	0.961 – 1.909	0.083
Can read parts/whole sentences (ref)	1.000	-	-	1.000	**-**	-
Maternal occupation	**-**	**-**	**0.338**	**-**	**-**	**0.564**
Not working	1.096	0.909 – 1.321	0338	1.105	0.787 – 1.550	0.564
Working (ref)	1.000	-		1.000	-	-
Paternal education level	**-**	**-**	**0.058**	**-**	**-**	**0.536**
No education	1.682	1.157 – 2.445	0.006*	0.839	0.485 – 1.450	0.529
Primary	1.547	1.044 – 2.291	0.030*	1.032	0.627 – 1.697	0.903
Secondary	1.655	1.087 – 2.517	0.019*	0.807	0.513 – 1.271	0.354
Higher (ref)	1.000	-	-	1.000	-	-
Paternal occupation	-	-	**0.301**	-	-	**0.246**
Not working	0.508	0.140 – 1.837	0.301	0.440	0.110 – 1.763	0.246
Working (ref)	1.000	-	-	1.000	-	-
Wealth index (Socioeconomic status)	-	-	**0.324**	-	-	**0.321**
Poor	0.973	0.716 – 1.322	0.861	1.365	0.881 – 2.117	0.164
Middle	0.828	0.602 – 1.140	0.247	0.923	0.607 – 1.404	0.707
Rich (ref)	1.000	-	-	1.000	-	-
Decision-making on health care need	-	-	**0.621**	-	-	**0.555**
Respondent alone	0.942	0.493 – 1.308	0.378	0.882	0.492 – 1.581	0.672
Respondent and husband/partner	0.803	0.744 – 1.193	0.620	0.836	0.604 – 1.157	0.280
Husband/partner alone (ref)	1.000	-	-	1.000	-	-
Toilet facility	-	-	**0.850**	-	-	**0.464**
Unimproved	0.981	0.803 – 1.193	0.850	1.125	0.820 – 1.1545	0.464
Improved (ref)	1.000	-	-	1.000	-	-
Electricity access	-	-	**0.986**	-	-	**0.037***
No	0.998	0.788 – 1.263	0.986	1.433	1.023 – 2.007	0.037*
Yes (ref)	1.000	-	-	1.000	-	-
Cooking fuel	-	-	**0.449**	-	-	**0.969**
Solid fuels	0.863	0.590 – 1.264	0.449	0.994	0.732 – 1.350	0.969
Non-solid fuels (ref)	1.000	-	-	1.000	-	-
Drinking water source	-	-	**0.278**	-	-	**0.219**
Improved sources (ref)	1.000	-	-	1.000	-	-

Unimproved sources	0.893	0.728 – 1.096	0.278	1.220	0.888 – 1.675	0.219

B. Bio-demographic variables

Variables	**Rural**			**Urban**		
	COR	**95% CI**	**P-Value**	**COR**	**95% CI**	**P-Value**
Maternal age at first childbirth	**-**	**-**	**0.683**	**-**	**-**	**0.386**
Below 20 years	0.958	0.780 – 1.176	0.683	0.874	0.643 – 1.186	0.386
20 years or more (ref)	1.000	-	-	1.000	-	-
Maternal marital status	-	-	**0.002***	**-**	**-**	**0.627**
Never in union	1.292	0.761 – 2.193	0.342	1.266	0.544 – 2.946	0.584
Divorced/separated/no longer living together	2.335	1.420 – 3.839	0.001*	1.548	0.540 – 4.436	0.416
Married/living with partner (ref)	1.000	-	-	1.000	-	-
Region	**-**	**-**	**0.151**	**-**	**-**	**0.879**
North-Central	0.679	0.330 – 1.396	0.292	1.040	0.646 – 1.674	0.871
North-East	0.923	0.464 – 1.837	0.818	0.917	0.539 – 1.561	0.750
North-West	1.016	0.516 – 2.002	0.962	1.006	0.655 – 1.544	0.979
South-East	1.015	0.460 – 2.243	0.970	1.249	0.819 – 1.904	0.301
South-South	0.743	0.359 – 1.539	0.424	1.021	0.600 – 1.737	0.938
South-West (ref)	1.000	**-**	-	1.000	-	-
Ethnicity	-	-	**0.013***	**-**	**-**	**0.682**
Hausa	1.392	1.130 – 1.715	0.002*	1.047	0.668 – 1.640	0.842
Igbo	1.282	0.832 – 1.976	0.260	1.251	0.828 – 1.890	0.288
Yoruba	1.569	0.806 – 3.056	0.185	1.033	0.679 – 1.573	0.879
Other (ref)	1.000	-	-	1.000	-	-
Religion	-	-	**0.652**	**-**	-	**0.721**
Christianity	1.459	0.603 – 3.533	0.401	0.691	0.260 – 1.838	0.458
Islam	1.470	0.643 – 3.358	0.361	0.675	0.258 – 1.764	0.422
Traditionalist (ref)	1.000	-	-	1.000	-	-
Birth order	**-**	**-**	**<0.001***	**-**	**-**	**0.007***
1	1.504	1.057 – 2.106	<0.001*	1.492	1.057 – 2.106	0.023*
2-3	0.980	0.565 – 1.173	0.846	0.814	0.565 – 1.173	0.270
≥ 4 (ref)	1.000	-	-	1.000	-	-
Size of child at birth	**-**	**-**	**<0.001***	**-**	**-**	**<0.001***
Small	1.899	1.471 – 2.452	<0.001*	3.151	2.147 – 4.624	<0.001*
Average	1.014	0.819 – 1.255	0.899	1.605	1.160 – 2.221	0.004*
Large (ref)	1.000	-	-	1.000	-	-
Gender of child	**-**	**-**	**0.004***	**-**	**-**	**0.013***
Male	1.298	1.089 – 1.547	0.004*	1.444	1.082 – 1.925	0.013*
Female (ref)	1.000	-	-	1.000	-	-
Gender of household head	**-**	**-**	**0.783**	**-**	**-**	**0.321**
Male	1.043	0.775 – 1.403	0.783	0.807	0.528 – 1.233	0.321
Female (ref)	1.000	-	-	1.000	-	-
Preceding birth interval (months)	**-**	**-**	**<0.001***	**-**	**-**	**0.001***
<24	2.182	1.806 – 2.637	<0.001*	1.861	1.299 – 2.665	0.001*
≥ 24 (ref)	1.000	-	-	1.000	-	-
Maternal body mass index (BMI)	**-**	**-**	**0.370**	**-**	**-**	**0.161**
Obese	1.605	0.951 – 2.710	0.077	1.367	0.879 – 2.126	0.165
Overweight	1.028	0.793 – 1.332	0.836	1.023	0.686 – 1.526	0.910

Underweight	1.005	0.761 – 1.326	0.974	0.336	0.097 – 1.158	0.084
Normal weight (ref)	1.000	-	-	1.000	-	-
Maternal age (years)	**-**	**-**	**0.063**			**0.001***
< 20	1.434	1.053 – 1.953	0.022*	2.592	1.562 – 4.301	< 0.001*
20- 35 (ref)	1.000	-	-	1.000	-	-
36 and more	1.119	0.858 – 1.459	0.407	1.212	0.834 – 1.761	0.313

C. Health/behavioral variables

Variables	**Rural**			**Urban**		
	COR	**95% CI**	**P-Value**	**COR**	**95% CI**	**P-Value**
Iron intake	**-**	**-**	**0.780**	**-**	**-**	**0.337**
No	0.967	0.766 – 1.222	0.780	1.271	0.779 – 2.073	0.337
Yes (ref)	1.000	-	-	1.000	-	-
Breastfeeding initiation	**-**	**-**	**0.601**	**-**	**-**	**0.950**
Within first hour	0.935	0.726 – 1.204	0.601	1.011	710 – 1.441	0.950
Beyond first hour (ref)	1.000	-	-	1.000	-	-
Place of delivery	**-**	**-**	**0.211**	**-**	**-**	**0.931**
Home	0.762	0.524 – 1.108	0.155	1.039	0.710 – 1.515	0.845
Government health facility	0.896	0.589 – 1.361	0.606	0.971	0.673 – 1.401	0.876
Private health facility (ref)	1.000	-	-	1.000	-	-
Mode of delivery	**-**	**-**	**<0.001***	**-**	**-**	**<0.001***
Caesarean Section	3.255	1.912 – 5.542	<0.001*	2.397	1.523 – 3.771	<0.001*
Non-Caesarean Section (ref)	1.000	-	-	1.000	-	-
Delivery assistance	**-**	**-**	**0.048***	**-**	**-**	**0.239**
Skilled	1.367	1.066 – 1.752	0.014*	0.789	0.562 – 1.106	0.168
No assistance	1.076	0.829 – 1.395	0.583	0.644	0.341 – 1.217	0.176
TBA/combined (ref)	1.000	-	-	1.000	-	-
Antenatal attendance	**-**	**-**	**0.832**	**-**	**-**	**0.022***
No	1.025	0.815 – 1.289	0.832	1.797	1.087 – 2.970	0.022*
Yes (ref)	1.000	-	-	1.000	-	-
Malaria prophylaxis in pregnancy	**-**	**-**	**0.039***	**-**	**-**	**0.943**
No	1.398	1.018 – 1.920	0.039*	1.018	0.626 – 1.656	0.943
Yes (ref)	1.000	-	-	1.000	-	-
Tetanus injection in	**-**	**-**	**0.732**	**-**	**-**	**0.725**
pregnancy	0.961	0.768 – 1.204	0.732	1.094	0.663 – 1.807	0.725
No	1.000	-	-	1.000	-	-
Yes (ref)						

*Statistically significant at 5% level, COR: crude odd ratio, CI: confidence interval.

Factors associated with neonatal mortality in rural and urban Nigeria

The results of our multivariable analyses show that no socioeconomic variable attained statistical significance as a predictor of neonatal mortality in rural residence. However, three factors (two bio-demographic and one health/behavioral) were significantly associated with neonatal mortality in rural residence. The factors include size of child at birth, preceding birth interval, and mode of delivery (Table 4). A preceding birth interval of less than two years was associated with over two times increased risk of neonatal mortality (AOR = 2.149, 95%CI: 1.760 – 2.624, p < 0.001). Similarly, the likelihood of mortality was over five times higher for neonates delivered by caesarean section compared to those that had a non-ceasarean delivery (AOR = 5.038, 95%CI: 2.617 – 9.700, p < 0.001).

Table 4: Results of multivariable analysis for factors associated with neonatal mortality in rural and urban Nigeria

Variables	Rural			Urban		
	AOR	95% CI	P-Value	AOR	95% CI	P-Value
Electricity access	**-**	**-**	**-**	**-**	**-**	**0.015***
No				1.555	1.089 – 2.220	0.015*
Yes (ref)				1.000	-	-
Size of child at birth	**-**	**-**	**< 0.001***	**-**	**-**	**< 0.001***
Small	2.118	1.600 – 2.804	< 0.001*	3.048	2.047 – 4.537	< 0.001*
Average	1.067	0.830 – 1.373	0.611	1.699	1.221 – 2.364	0.002*
Large (ref)	1.000	-	-	1.000	-	-
Birth interval (months)	**-**	**-**	**< 0.001***	**-**	**-**	**-**
< 24	2.149	1.760 – 2.624	< 0.001*			
≥ 24 (ref)	1.000	-	-			
Gender of child	**-**	**-**	**-**	**-**	**-**	**0.002***
Male				1.666	1.215 – 2.284	0.002*
Female (ref)				1.000	-	-
Mode of delivery	**-**	**-**	**< 0.001***	**-**	**-**	**< 0.001***
Caesarean section	5.038	2.617 – 9.700	< 0.001*	2.632	1.543 – 4.489	< 0.001*
Not caesarean section (ref)	1.000	-	-	1.000	-	-

*Statistically significant at 5% level, AOR: adjusted odd ratio, CI: confidence interval.

In urban residence, four factors (one socioeconomic, two bio-demographic and one health/behavioral) were found to be significantly associated with neonatal mortality. Access to electricity, being born with a large body size, being of a female gender and being delivered by non-caesarean section (normal delivery) were protective against neonatal mortality (Table 4).

Compared to households where there was access to electricity, mortality was over 55% higher for neonates belonging to households where electricity access was lacking (AOR = 1.555, 95%CI: 1.089 –2.220, $p = 0.015$).

Also, neonates with a small body size had increased odds of mortality compared to those with a larger body size. According to this finding, the smaller the birth size, the greater the risk of dying – a kind of a dose-response relationship. In addition, male neonates were about 1.7 times more at risk of mortality than female neonates (AOR = 1.699, 95%CI: 1.215 – 2.284, $p = 0.002$). Lastly, neonates that were delivered by caesarean section had about 2.6 times the odds of mortality than those that had a normal delivery (AOR = 2.632, 95%CI: 1.543 – 4.489, $p < 0.001$).

Discussion

Based on the results of our multivariable analysis, no socioeconomic factor was predictive of neonatal mortality in rural residence. However, bio-demographic factors – small birth size, and birth interval less than two years – were associated with increased likelihood of neonatal mortality. In urban residence, lack of access to electricity (socioeconomic factor), small birth size and male gender (bio-demographic factors) were significantly associated with higher incidence of neonatal mortality. Caesarean mode of delivery (health/behavioral factor) was a risk factor both in rural and urban areas.

The index of socioeconomic status (wealth quintile) was not statistically significant in any of the populations (rural or urban). However, the finding that mortality was significantly higher in rural neonates (NMR = 36 deaths per 1000 live births) compared to urban neonates (NMR = 28 deaths per 1000 live births) possibly reflects socioeconomic disparity. This urban advantage agrees with the general trend in the literature. [19,20] For example, a previous UNICEF analysis has shown that birth in the rural areas is a significant risk factor for neonatal mortality. [14] Geographic isolation, socioeconomic disadvantage, and lack/shortage of health care services/providers are likely explanations for this difference [21]. As the case in many developing countries, health facilities are either poorly equipped, inadequately staffed or both in rural Nigeria. [5] Also, the majority of individuals deemed as 'skilled' in rural healthcare facilities may be lacking in core competencies. These coupled with factors such as the cost of care, poverty, distance barrier to facilities and traditional beliefs/practices may contribute to a higher incidence of neonatal mortality in rural residence.

Similar to the findings of previous studies, [4,6,11] neonates with small birth size were at a greater risk of mortaltiy in this study, regardless of the population type (rural and urban). Small birth size (a proxy for low birthweight) is closely related to preterm delivery [4] and its occurrence may be due to genetic predisposition, maternal morbidity, and, so on. Also, nutrition and obstetric factors have been implicated in the occurrence of low birthweight. [22] These are possible entry points for intervention efforts, for example, by monitoring intra-uterine fetal growth and providing nutritional support services for all pregnant women.

The electricity advantage found in this study agrees with the results of other studies, [23-25] and pathways through which electricity access may benefit health, and, thus, child/neonatal outcomes have been identified in the literature. First is in respect of using electric power as a source of lighting, cooking, and heating. These uses of electricity (as opposed to using solid fuels) may contribute to reducing the incidence of respiratory tract infections, [25] and, thus, child/neonatal mortality. Second, access to electricity promotes hygienic practices such as laundrying, boiling water and refrigerating foods. These practices in turn may reduce the incidence of infectious diseases, and, hence, the rates of neonatal mortality. [26]

It is worth mentioning that the protective role of electricity access reported in this study was in urban residence only. In rural residence, the use of electricity did not make any statistically significant difference. This finding supports the contention of Wang [25], that the health impact of increased electricity access will more likely be stronger or noticeable in urban compared to rural residence. To begin with, the high population density which characterizes many urban centres favors the spread of infectious diseases. [25] This fact means a greater appreciation of power supply for hygienic practices – use of washing machine, refrigerator, electric cooker, etc., which are better employed in urban areas. [25] Neonates in urban households with electricity access, therefore, may enjoy a healthier living condition and greater chances of survival than their counterparts in households with no electricity access. [26,27] This position may be relevant in explaining the results obtained in this study.

As in many African countries, low access to electricity supply has been a critical challenge for decades in Nigeria. [28] According to a recent study, only 48% of the Nigerian population have access to electricity supply. [6] In the present study, nearly 82% of households in urban residence enjoyed electricity access compared to only 30% in rural areas (Table 2). Thus, urban households had much greater electricity access than rural households. As strongly suppported by Wang's position, [25] this increased electricity access in urban Nigeria may contribute in making the variable a significant predictor of neonatal mortality in the residence.

Consistent with other studies, [11,29] this study found that male neonates (in urban residence) had greater odds of mortality than their female counterparts. Biological variability between male and female newborns is a logical explanation for this result. [4,6,11] The finding that mortality was higher among neonates with birth interval less than two years may be due to 'maternal depletion syndrome' and competition among siblings for resources and attention, resulting in poorer care for newborns and consequently in increased neonatal mortality rate. [30]

This study further indicates that caesarean mode of delivery was is a significant risk factor both in rural and urban residence. The reason for this finding is not entirely clear as caesarean section (a vital obstetric intervention) is expected to be a safer mode of delivery. [31] However, Table 2 clearly shows that caesarean delivery was not a popular choice in Nigeria – 3.7% in urban residence and only 1% in rural residence. Most instances of the intervention were reportedly performed under emergency situations in women with life-threatening complications. [11] Emergency caesarean delivery is a known risk for neonatal mortality. [11] The low uptake of caesarean section may be blamed on misconceptions and apprehension about the mode of delivery as suggested by Ezeh, Agho, Dibley, Hall, Page [11]; however, the high cost of the obstetric intervention in Nigeria is a possible contributory factor.

Although studies have emphasized the importance of early breastfeeding initiation to neonatal survival. [32,33] in this study, the variable did not attain statistical significance in any of the analyses (univariate, bivariate and multivariable) and populations (rural and urban).

Strengths and limitations

This study leverage on some significant strengths. First, the dataset used – 2013 NDHS – is nationally representative of the Nigerian population. Therefore, findings are generalizable and reflect the most current situations in the country. Second, a complex samples analysis approach was applied in adjusting for the sampling weight; hence, estimates and their 95% CIs are reasonably accurate and reliable. Third, missing data are relatively small and should have no significant influence on the findings of this study. Lastly, determinants of neonatal mortality were examined for rural and urban residences. Hence, this study provides a balanced evidence for addressing neonatal mortality in Nigeria. Apparently, this is the first study to assess NMR and associated risk factors in rural and urban Nigeria using NDHS dataset.

Some limitations, however, need to be taken into consideration when interpreting the results of this study. First, neonatal mortality is closely related to maternal mortality. Hence, underestimation of NMR is a possibility since only surviving women participated in NDHS. Second, the majority of neonatal mortality occurs on day zero, it is possible that some of those were stillbirths misreported as neonatal mortality. [4] Such misreporting might result in a slight increase in NMR. [4] Third, possible risk factors for neonatal mortality such as gestational age, maternal morbidity, postnatal care, obstetric complications and desire for pregnancy were not investigated in this study because information for those were either substantially missing or not collected in the NDHS. Lastly, study design in NDHS is cross-sectional and so limited in estimating the causal relationship between the outcome and the explanatory variables.

Conclusion

NMR for rural and urban populations were 36 and 28 deaths per 1000 live births, respectively, and rural neonates were more at risk of mortality than their urban counterparts. Intervention efforts would need to prioritize safer and affordable caesarean delivery, both in rural and urban residences. Enhanced access to family planning services may further benefit child spacing and, thus, neonatal survival in rural residence. Monitoring of intra-uterine fetal growth and provision of appropriate nutrition support services for all pregnant women are other implementable interventions both in rural and urban residences. Such interventions should complement the existing nutrition supplementation (iron and folic acid intake) being provided through the antenatal care. This study suggests the need for improved access to electricity in urban residence. However, uninterrupted power supply in both rural and urban Nigeria is highly desirable.

This study has reported that cesarean mode of delivery was a highly significant risk factor for neonatal mortality in rural and urban Nigeria. It may be hypothesized that women who had undergone cesarean delivery would be less likely to initiate breastfeeding within the recommended one-hour post-delivery time; and that this may have contributed to increased mortality among their neonates. Future studies in Nigeria will need to investigate this hypothesis further. Also, future researches are needed to explore the causal relationship between factors examined in this study and neonatal mortality in rural and urban Nigeria

Acknowledgements

We gratefully appreciate Measure DHS, ORC Macro, Calverton, MD, USA, for providing the NDHS data for this study.

Disclosure

Funding: None
Conflict of interest: The authors declared that they have no conflict of interest
Ethical approval: Ethical approval for this study was obtained from the institutional Research Ethics Committee. Permission to use NDHS dataset was obtained from Measure DHS International Inc., USA.

Authors’ contributions

EOA and YZ were involved in the conception and design of this study. EOA carried out the data analysis and drafted the original manuscript; YZ gave advice on interpretation of results, revised and edited the manuscript. All authors read and approved the final manuscript.

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