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Levels, Trends and Determinants of Infant Mortality in Nigeria: An Analysis using the Logistic Regression Model

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Abstract

This paper presents a statistical analysis of the levels, trends and determinants of infant mortality in Nigeria using the logistic regression model. Infant mortality data for each of the five years preceding the 2003, 2008, 2013 and 2018 Nigeria Demographic Health Survey (NDHS) was retrieved and used for the analysis. Findings from the study revealed that infant mortality rates decline have stagnated in the five year period prior to the 2018 survey with an Annual Rate of Reduction (ARR) of 0% relative to an initial ARR of 5.7% between 2003 and 2008. The ARR of 2.039% over the 15 year period spanning 2003 to 2018 suggests that the rate of infant mortality reduction is slow. This study also showed that maternal characteristics such as age and educational levels as well as cultural practises like use of clean water and toilet facilities were statistically significant determinants of infant mortality in Nigeria with *P-values* < 0.05 across each of the survey years.

1. Introduction

The call to end preventable childhood death was one of the glaring targets of the Millennium Development Goals (MDG). Tasked with the mandate of reducing global childhood death by two-thirds before the year 2015, many countries in Asia and Africa failed to meet the target and subsequently, the Sustainable Development Goals (SDG) were rolled out signifying a recommitment to the health of mother and child during the different stages of childhood development [21]. On a global level, the world has

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continued to press in the right direction and many countries in Europe and America have made steady progress over the years with respect to childhood mortality reduction [4]. Despite the global record of improved childhood survival and reduced average mortality rate as seen by the rise in the Annual Rate of Reduction (ARR) from 1.9% in the year 2000 to 3.5% in 2015 [12], [13], [8], childhood mortality at all levels are still unacceptably high and significantly distributed unevenly among the different regions, continents and countries with countries such as India, Bangladesh and Nigeria to mention a few in Asia and Africa still recording ridiculously high and unacceptable rates of neonatal, post neonatal, infant, under-five and childhood death [6], [2], [9]. The different stages of childhood mortality continue to respond differently to the various prevention and intervention programmes of the United Nations with the rate of reduction in under-five mortality being the most significant of all the reported reductions in childhood mortality (National Bureau of Statistics [15], [19]). Results from previous studies have shown that a significant proportion of under-five mortality occurs at the neonatal and infant stages of the child's life [11], [17], [16], [20]. In 2018, approximately 5.3 million children across the globe lost their lives mainly due to preventable causes before their fifth birthday of which 1.5 million children accounting for 29% of under-five deaths died as infants [21].

It is therefore imperative for stakeholders in public health sector to focus attention on mortality of children occurring during the stage of infancy. Infant mortality defined as the probability of a child dying between birth and the first birthday [22] is relevant to the demographic assessment of a country's population and is an important indicator of the country's socioeconomic development and quality of life. It can also help identify children who may be at higher risk of death and lead to strategies to reduce this risk [21], [18].

In Nigeria, studies have shown that the rate of reduction in infant mortality relative to under-five mortality is poor indicating that less progress have been made in the fight against childhood mortality occurring within the first year of life [5], [1], [14], [7]. Given the percentage of under-five deaths that occurs during the first year of life, Nigeria is faced with the danger of failing to attain the SDG for childhood mortality except it implements and rigorously pursue drastic measures aimed at a substantial and corresponding decrease in infant mortality [10]. To achieve the childhood mortality target in responds to the call to end preventable deaths and give our infants a chance to live (which is a fundamental right), a good understanding of the current levels and trends as well as the significant determinants of infant mortality is necessary to monitor progress and required to help policy makers/relevant stakeholders make informed decisions on effective prevention/intervention programmes.

Having painstakingly searched through relevant articles and journals via the internet, this study, to the best of our knowledge is the first to utilize a nationally representative data from four consecutive Nigeria Demographic and Health Surveys (NDHS) for the modeling and analysis of the levels and trends of infant mortality in Nigeria for each of the five years period prior to the 2003, 2008, 2013 and 2018 surveys (20 years) and its implication for the achievement of the SDG for childhood mortality by 2030. The aim of this study is therefore to (i) carry out an analysis of the levels and trends in the age at death distribution of infants in Nigeria over a longer time frame with a view to assessing the progress in the reduction of infant mortality (ii) broaden insights into the significant determinants of infant mortality necessary to achieve the SDG for childhood mortality in Nigeria.

2. Materials and Method

2.1. Ethical consideration

This study follows the guidelines in **RE**porting of studies **C**onducted using **O**bservational **R**outinely-collected health **D**ata (RECORD) [3]. The consent of the anonymous participants of the survey was sought prior to participation. The NDHS stores information captured with a variable named CASEID rather than the respondents name; this practice makes each participant anonymous and keeps personal information of the respondents private. Additionally, Demographic Health Survey (DHS) obtained ethical approval from ORC Macro Institutional Review Board.

2.2. Study area

This paper is focused on Nigeria. Nigeria which is the most populous country in Africa is divided into 36 states and a Federal Capital Territory (FCT), grouped into six geopolitical zones; North Central, North-East, North-West, South-East, South-South, and South-West.

2.3. Data source and sampling

This study utilized data obtained from the Nigeria Demographic and Health Survey (NDHS) for 2003, 2008, 2013 and 2018 for its analysis. The surveys which were implemented by the National Population Commission (NPC) in collaboration with the National Malaria Elimination Programme (NMEP) of the Federal Ministry of Health, Nigeria, is nationally representative and collects demographic and health related information for women between the ages of 15 – 49 (reproductive age) through face to face interviews. It employed a probabilistic, stratified multistage sampling technique to select the respondents. A three stage sampling that begins with the selection of Local Government Areas (LGAs) is followed by the selection of Enumeration Areas (EA) which are the Primary Sampling Units (PSU) also referred to as clusters. The systematic selection of households within the selected EAs is the last stage of the sampling. The number of selected households per EA is variable but ranges from 30 to 40 households/women per rural cluster and from 25 to 30 households/women per urban cluster.

Amongst others, the survey collects birth history and other information on all births to each of the interviewed women; therefore, the "child recode data" was used in this study because it contained all follow-up information on all children born to the interviewed women within the five years period preceding each survey year.

2.4. Data analysis

In the five years preceding the 2003 NDHS, **6029** children were given birth to from among the 7620 eligible female respondents. In the subsequent NDHS for 2008, 2013 and 2018, **28647**, **31482** and **33924** children were given birth from among the 33385, 38948 and 41,821 eligible female respondents respectively. All analysis in this study was based on the survivorship of the **100082** children within the first year of their lives.

2.5. Variables

Outcome variable: The outcome variable for this study is infant mortality. Question on whether the child was alive or dead, with the responses 1 = yes (Dead) or 0 = no (Alive) represent the dependent variable in the dataset.

Table 1: Definition of the outcome variables.

Dependent variable *(outcome variable)*	**Answer category**	**Code**
Infant mortality	No	0
	Yes	1

The Explanatory variables: The explanatory (independent) variables included in this study are: Mother's Age = MoA, Mother's Region = Reg, Place of residence = PoR, Mother's Education = MoE, Source of Drinking Water =SoDw, Toilet Type = ToT, Mother's Religion = MoR, Cooking Fuel = CoF, Mode of Delivery = MoD, Breast

Feeding = BrF, Place of Delivery = PoD, Size of Child at Birth = ScB, Number of Antenatal Visits =NaV and Gender = Gen.

Table 2: Definition of the explanatory variables.

S/N	Independent variable	Coding
1	Mother's Age = MoA	(15-19) = 0, (20-29) = 1, (30-39) = 2, (40-49) = 3
2	Mother's Region = Reg	North central=1, North East=2, North West=3, South East=4, South South=5, South West=6
3	Place of residence = PoR	Urban =1, Rural=2
4	Mother's Education = MoE	No Education=0, Primary=1, Secondary=2, Higher = 3
5	Source of Drinking Water =SoDw	improved source=1, Non improved source =2
6	Toilet Type = ToT	Improved sanitation = 1, non-improved sanitation=2
7	Mother's Religion = MoR	Christian = 1, Islam = 2, Traditionalist = 3
8	Cooking Fuel = CoF	Kerosene/Electricity/Gas=1, Wood/charcoal/coal=2
9	Mode of Delivery = MoD	Caesarean Section = 1, Normal Delivery = 2
10	Breast Feeding = BrF	Not Breast Fed = 0, Breast Fed = 1
11	Place of Delivery = PoD	Home=0, Hospital=1, Others=3
12	Size of Child at Birth = ScB	Large = 1, Average = 2, Small = 3
13	Number of Antenatal Visits =NaV	None = 0, Below 5 = 1, Above 5 = 2
14	Gender = Gen	Male = 1, Female = 2

Using the child recode data that contains all follow up information on the full birth history of the children born to the eligible interviewed women and the age at death for those whose child/children had died prior to each of the surveys, we computed the conditional life-table age distribution of infant deaths by assigning death and exposure time across each calendar year on a monthly basis using life table techniques embedded in SPSS software version 22 and adjusted our age mortality profiles to match all deaths that occurred from 0 to 11 months.

Justification for the use of Binary Logistic Regression

Logistic regression makes use of one or more predictor variables that may be either continuous or categorical data. Unlike ordinary linear regression, however, logistic regression is used for predicting binary outcomes of the dependent variable (treating the dependent variable as the outcome of a Bernoulli trial) rather than a continuous outcome. The binary logistic regression was therefore used in this study in order to examine and predict the likelihood or probability of a child dying at infancy in Nigeria. The regression model enabled the estimation of risk of death relative to the various determinants of interest. In the model, the outcome variable was dichotomized to take the value of "1" if the event occurs (i.e., death of a child), and "0" if the event does not occur (i.e., child survives).

Other forms of regression models cannot be used for such variables because the predicted value needs to be constrained between 0 and 1, which is not possible in other forms of regression. It also violates the assumption that the variable is normally (single peak) distributed, since a (1, 0) variable by definition has a binomial distribution (double peak). Logistic regression model is used to solve this problem by determining the "odds ratio" or simply 'odds' of an event occurring (i.e., taking a value of 1) against its non-occurrence (i.e., taking a value of 0).

2.6. Binomial distribution and logistic regression model

Let π be the probability of success (i.e. child died as an infant) for a Bernoulli trial having two possible outcomes (success and failure) and allow Y symbolize the number of successes from the n trials (n is the total number of children born to the women who participated in the survey). Then Y is binomially distributed with index n and parameter π and this is indicated by $Y \sim B(n, \pi)$.

The distribution of y for the random variable Y can be expressed as:

$$P(y) = \binom{n}{y} \pi^y (1-\pi)^{n-y} \qquad y = 0,1,2,\dots,n \tag{1}$$

Y has the expectation $E(Y) = \mu = n\pi$ and standard deviation $\sigma = \sqrt{n\pi(1-\pi)}$.

Now, consider the general logistic regression model with multiple independent variables. Let the k predictors for a binary response Y be represented by $(X_1, X_2, X_3, \dots, X_k)$, let $\pi(x)$ represent the probability that $Y = 1$ for success with probability $\pi(x) = P(Y = 1/X_1, X_2, X_3, \dots, X_k)$ and $1 - \pi(x)$ represent the probability that $Y = 0$ for failure with probability$1 - \pi(x) = P(Y = 0/X_1, X_2, X_3, \dots, X_k)$, then

$$logit(\pi(x)) = log\frac{P(Y = 1/X_1, X_2, X_3, \dots, X_k)}{P(Y = 0/X_1, X_2, X_3, \dots, X_k)} \quad (2)$$

$$log\left(\frac{\pi(x)}{1 - \pi(x)}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_k + \mu \quad (3)$$

$$log\left(\frac{\pi(x)}{1 - \pi(x)}\right) = \beta_0 + \sum_{j=1}^{k} \beta_j x_j + \mu \quad (4)$$

which gives

$$\pi(x) = P(Y = 1/X_1, X_2, X_3, \dots, X_k) = \frac{e^{\beta_0 + \sum_{j=1}^{k} \beta_j x_j + \mu}}{1 + e^{\beta_0 + \sum_{j=1}^{k} \beta_j x_j + \mu}}. \quad (5)$$

The logit of the logistic regression model to test the significant effect of the independent variables on the outcome variable (infant mortality) for this study is given as

$$\lambda = \beta_0 + \beta_1 \text{MoA} + \beta_2 \text{Reg} + \beta_3 \text{PoR}, + \beta_4 \text{MoE} + \beta_5 \text{SoDw} + \beta_6 \text{ToT} + \beta_7 \text{MoR} + \\ + \beta_8 \text{CoF} + \beta_9 \text{MoD} + \beta_{10} \text{BrF} + \beta_{11} \text{PoD} + \beta_{12} \text{ScB} + \beta_{13} \text{NaV} + \beta_{14} \text{Gen} + \mu \quad (6)$$

and the logistic regression model is given as

$$Y_{inf} = \frac{\exp\,(\beta_0 + \beta_1 MoA + \beta_2 Reg + \beta_3 PoR + \beta_4 MoE + \beta_5 SoDw + \beta_6 ToT + \beta_7 MoR + \beta_8 CoF + \beta_9 MoD + \beta_{10} BrF + \beta_{11} PoD + \beta_{12} ScB + \beta_{13} NaV + \beta_{14} Gen + \mu)}{1 + \exp\,(\beta_0 + \beta_1 MoA + \beta_2 Reg + \beta_3 PoR + \beta_4 MoE + \beta_5 SoDw + \beta_6 ToT + \beta_7 MoR + \beta_8 CoF + \beta_9 MoD + \beta_{10} BrF + \beta_{11} PoD + \beta_{12} ScB + \beta_{13} NaV + \beta_{14} Gen + \mu)} \quad (7)$$

and

$$y_{inf} = \begin{cases} 1 & \text{child died as an infant} \\ 0 & \text{child is alive.} \end{cases}$$

Y is the outcome variable and it is referred to as the logistic transformation of probability of infant mortality occurring. β_0 is the intercept representing the probability of occurrence of the infant mortality in the absence of all the underlying factors. β_1,…, β_{14} are the odds ratios of infant mortality occurring. The "μ" is the error term.

2.6.1. Coefficient estimation

The method of maximum likelihood estimation is employed to approximate the $K + 1$ coefficient $\beta = (\beta_0, \beta_1, \dots, \beta_k)$ by finding the parameter that maximizes the probability of the observed data. The likelihood expression derived from the binomial distribution of the response variable is given by

$$l(\beta) = \prod_{i=1}^{k} \varphi(x_i) = \prod_{i=1}^{k} \pi(x_i)^{y_i}[1-\pi(x_i)]^{1-y_i} \tag{8}$$

$$l(\beta) = \pi(x_i)^{\sum_{i=1}^{k} y_i}[1-\pi(x_i)]^{k-\sum_{i=1}^{k} y_i}$$

$$l(\beta) = \pi(x_i)^{\sum_{i=1}^{k} y_i}[1-\pi(x_i)]^{k}[1-\pi(x_i)]^{-\sum_{i=1}^{k} y_i}$$

$$l(\beta) = \left[\frac{\pi(x_i)}{1-\pi(x_i)}\right]^{\sum_{i=1}^{k} y_i}[1-\pi(x_i)]^{k}. \tag{9}$$

But equations 4 and 5 gave the following respectively:

$$\frac{\pi(x_i)}{1-\pi(x_i)} = e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j} \text{ and } \pi(x_i) = \frac{e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}}{1+e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}}.$$

Thus,

$$l(\beta) = \left(e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}\right)^{\sum_{i=1}^{k} y_i}\left(1-\frac{e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}}{1+e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}}\right)^{k}$$

$$l(\beta) = \left(e^{\beta_0\sum_{i=1}^{k} y_i+\sum_{i=1}^{k} y_i\sum_{j=1}^{k}\beta_j x_j}\right)\left(\frac{1+e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}-e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}}{1+e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}}\right)^{k}$$

$$l(\beta) = \left(e^{\beta_0\sum_{i=1}^{k} y_i+\sum_{i=1}^{k} y_i\sum_{j=1}^{k}\beta_j x_j}\right)\left(\frac{1}{1+e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}}\right)^{k}$$

$$l(\beta) = \left(e^{\beta_0\sum_{i=1}^{k} y_i+\sum_{i=1}^{k} y_i\sum_{j=1}^{k}\beta_j x_j}\right)\left(1+e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}\right)^{-k}, \tag{10}$$

where

$\beta = (\beta_0, \beta_1, \dots, \beta_k)$ and $l(\beta)$ is the likelihood function of β.

The Maximum likelihood Estimates (MLE's) denoted by $\breve{\beta}_0, \breve{\beta}_1, \breve{\beta}_2, \dots, \breve{\beta}_k$ can be found by computing β which maximizes $l(\beta)$. This is achieved by taking the logarithm of equation (10) which is represented by $L(\beta)$ and it is called the log likelihood function:

$$L(\beta) = \log(l(\beta)) = \left(e^{\beta_0\sum_{i=1}^{k} y_i+\sum_{i=1}^{k} y_i\sum_{j=1}^{k}\beta_j x_j}\right)\left(1+e^{\beta_0+\sum_{j=1}^{k}\beta_j x_j}\right)^{-k}$$

$$L(\beta) = \log\big(l(\beta)\big) = \left(\beta_0 \sum_{i=1}^{k} y_i + \sum_{i=1}^{k} y_i \sum_{j=1}^{k} \beta_j x_j\right) - klog\left(1 + e^{\beta_0 + \sum_{j=1}^{k} \beta_j x_j}\right). \quad (11)$$

Calculating the maximum likelihood estimates requires us to find the first derivative of the log likelihood function $L(\beta)$. This is done by differentiating equation (10) with respect to β_0, leading to:

$$\frac{\partial L(\beta)}{\partial \beta_0} = \sum_{i=1}^{k} y_i - k\frac{e^{\beta_0 + \sum_{j=1}^{k} \beta_j x_j}}{1 + e^{\beta_0 + \sum_{j=1}^{k} \beta_j x_j}}$$

$$\frac{\partial L(\beta)}{\partial \beta_0} = \sum_{i=1}^{k} y_i - k\pi(x_i)$$

$$\frac{\partial L(\beta)}{\partial \beta_0} = \sum_{i=1}^{k} [y_i - k\pi(x_i)]. \quad (12)$$

Differentiating (10) with respect to β_j, we have

$$\frac{\partial L(\beta)}{\partial \beta_j} = \sum_{i=1}^{k} y_i \sum_{j=1}^{k} x_j - k \sum_{j=1}^{k} x_j \frac{e^{\beta_0 + \sum_{j=1}^{k} \beta_j x_j}}{1 + e^{\beta_0 + \sum_{j=1}^{k} \beta_j x_j}}$$

$$\frac{\partial L(\beta)}{\partial \beta_j} = \sum_{i=1}^{k} y_i \sum_{j=1}^{k} x_j - k \sum_{j=1}^{k} x_j \pi(x_i)$$

$$\frac{\partial L(\beta)}{\partial \beta_j} = \sum_{i=1}^{k} x_{ik} [y_i - \pi(x_i)]. \quad (13)$$

The required estimates $\widehat{\beta}_0$ and $\widehat{\beta}_j$ estimating β_0 and β_j are calculated by equating (12) and (13) to zero and solving for each $\widehat{\beta}_j$.

2.6.2. Model assessment using likelihood ratio test

A logistic model is a better fit to a given data if it establishes an improvement over the null model (intercept only model with no explanatory variables). The assessment of the significance of regression parameters employed the likelihood ratio test. This test uses χ^2 statistics under the null hypothesis:

$$H_0 = \beta_1 = \beta_2 = \cdots = \beta_k = 0$$

and χ^2 statistic is computed as

$$\chi^2 = (-2\,\text{LL}\ of\ null\ model) - (-2\,\text{LL}\ of\ model\ with\ variables). \qquad (14)$$

Therefore

$$G = \chi^2 = -2log\left(\frac{likelihood\ of\ null\ model}{likelihood\ of\ model\ with\ variables}\right). \qquad (15)$$

G is a chi-square distribution having k degrees of freedom where k represent the number of covariates in the logistic regression model given in (7). When the $p-value$ of the overall model fit statistic is less than 0.05, we reject H_0 at $\alpha = 0.05$, and we conclude that there is at least one predictor variables whose coefficient is not zero and as a result adds to the prediction of the outcome.

2.6.3. Statistical analysis

The analysis of the study based on the selected infant mortality variables was carried out in stages. First, the frequency distributions of the independent variables according to the background characteristics of interest were analyzed for each of the 2003, 2008, 2013 and 2018 survey years using SPSS and the results displayed in Table 3. The Chi-Square test of association was then employed to determine the significant bivariate correlation between infant mortality and the risk factors of the selected independent variables. Estimates of infant mortality rates for the five years preceding each of the 2003, 2008, 2013 and 2018 surveys were subsequently calculated and the results presented in Table 4. The Average Rate of Reduction for infant mortality rate in Nigeria was calculated and the results presented in Table 5. Finally, the significant determinants of infant mortality in Nigeria using logistic regression model was determined. The logistic regression test was conducted at 5% level of significance and the results (odds ratio and statistical significance) displayed in Table 6.

2.6.4. Computation of the annual rate of reduction (ARR)

Let IMR_X denote the Infant Mortality Rate for 2003 (X is the start year).

Let IMR_Y denote the Infant Mortality Rate for 2018 (Y is the end year).

Then, the Annual Rate of Reduction (ARR) for infant mortality is given as

$$ARR_{IM} = \frac{100(IMR_X - IMR_Y)}{IMR_X(Y-X)}. \qquad (16)$$

3. Results and Discussion

Table 3: Frequency distribution of the independent variables.

	2003	2008	2013	2018
Variables	**Frequency (%)**	**Frequency (%)**	**Frequency (%)**	**Frequency (%)**
Mother's Age				
15 - 19	385 (6.4%)	1584 (5.5%)	1531 (4.9%)	1434 (4.2%)
20 - 29	3033 (50.3%)	13787 (48.1%)	14845 (47.2%)	16096 (47.4%)
30 - 39	2025 (33.6%)	10242 (35.8%)	11859 (37.7%)	13094 (38.6%)
40 - 49	586 (9.7%)	3034 (10.6%)	3247 (10.3%)	3300 (9.7%)
Total	6029 (100%)	28647 (100%)	31482 (100%)	33924 (100%)
Mother's Region				
North Central	1015 (16.8%)	5046 (17.6%)	4614 (14.7%)	5875 (17.3%)
North East	1487 (24.7%)	6559 (22.9%)	6517 (20.7%)	7211 (21.3%)
North West	1821 (30.2%)	7947 (27.7%)	9906 (31.5%)	10305 (30.4%)
South East	524 (8.7%)	2450 (8.6%)	2816 (8.9%)	3798 (11.2%)
South South	560 (9.3%)	3327 (11.6%)	3747 (11.9)	3202 (9.4%)
South West	622 (10.3%)	3318 (11.6%)	3882 (12.3%)	3533 (10.4%)
Total	6029 (100%)	28647 (100%)	31482 (100%)	33924(100%)
Place of Residence				
Rural	3911 (64.9%)	21034 (73.4%)	21131 (67.1%)	22225 (65.5%)
Urban	2118 (35.1%)	7613 (26.6%)	10351 (32.9%)	11699 (34.5%)
Total	6029 (100%)	28647 (100%)	31482 (100%)	33924 (100%)
Mother's Education				
No Education	3033 (50.3%)	14418 (50.3%)	14762 (46.9%)	15391 (45.4%)
Primary	1473 (24.4%)	6552 (22.9%)	6432 (20.4%)	5274 (15.5%)
Secondary	1308 (21.7%)	6338 (22.1%)	8365 (26.6%)	10623 (31.3%)
Higher	215 (3.6%)	1339 (4.7%)	1923 (6.1%)	2636 (7.8%)
Total	6029 (100%)	28647 (100%)	31482 (100%)	33924 (100%)
Source of Drinking Water				
Unimproved Source	4421 (73.3%)	14703 (51.3%)	12519 (39.8%)	21382 (63.0%)
Improved Source	1608 (26.7%)	13506 (47.1%)	18308 (58.2%)	12542 (37.0%)
Total	6029 (100%)	28209 (98.5%)	30827 (97.9%)	33924 (100%)
Toilet Type				
Unimproved Toilet Sanitation	5245 (87.0%)	25357 (88.5%)	26704 (84.8%)	27374 (80.7%)
Improved Toilet Sanitation	590 (9.8%)	2955 (10.3%)	4474 (14.2%)	6550 (19.3%)
Total	5835 (96.8%)	28312 (98.8%)	31178 (99.0%)	33924 (100%)
Mother's Religion				
Christian	2307 (38.3%)	11738 (41.0%)	12654 (40.2%)	13239 (39.0%)
Islam	3598 (59.7%)	16152 (56.4%)	18354 (58.3%)	20412(60.2%)
Traditionalist	119 (2.0%)	757(2.6%)	474 (1.5%)	273 (0.8%)
Total	6024 (99.9%)	28647 (100%)	31482 (100%)	33924 (100%)
Cooking Fuel				
Wood/Charcoal/Coal	4863 (80.7%)	24550 (85.7%)	25824 (82.0%)	28763 (84.8%)
Kerosene/Electricity/Gas	1065 (17.7%)	3838 (13.4%)	5359 (17.0%)	5161 (15.2%)
Total	5928 (98.3%)	28388 (99.1%)	31183 (99.1%)	33924 (100%)
Mode of Delivery				

Caesarean Section	75 (1.2%)	468 (1.6%)	697 (2.2%)	879 (2.6%)
Normal Delivery	3654 (60.6%)	28164 (98.3%)	30590 (97.2%)	32899 (97.0)
Total	3729 (61.9%)	28632 (99.9%)	31287 (99.4%)	33778 (99.6%)
Breast Feeding				
Not Breast Fed	3488 (57.9%)	12437 (43.4%)	14290 (45.4%)	16068 (47.4%)
Breast Fed	2541 (42.1)	16210 (56.6%)	17192 (54.6%)	17856 (52.6%)
Total	6029 (100%)	28647 (100%)	31482 (100%)	33924 (100%)
Place of Delivery				
Home	3853 (63.9%)	18990 (66.3%)	19619 (62.3%)	19949 (58.8%)
Hospital	2094 (34.7%)	8958 (31.3%)	11512 (36.6%)	13488 (39.8%)
Others	25 (0.4%)	699 (2.4%)	351 (1.1%)	487 (1.4%)
Total	5972 (99.1)	28647 (100%)	31482 (100%)	33924 (100%)
Size of Child				
Large	2497 (41.4%)	13012 (45.4%)	13589 (43.2%)	11275 (33.2%)
Average	2557 (42.4%)	10732 (37.5%)	12689 (40.3%)	17551 (51.7%)
Small	975 (16.2%)	4903 (17.1%)	5204 (16.5%)	4572 (13.5%)
Total	6029 (100%)	28647 (100%)	31482 (100%)	33398 (100%)
Antenatal Visits				
None	1349 (22.4%)	7013 (24.5%)	7082 (22.5%)	17824 (52.5%)
Below 5	781 (13.0%)	3180 (11.1%)	4122 (13.1%)	8853 (26.1%)
5 and Above	1631 (27.1%)	6471 (22.6%)	8868 (28.2%)	7247 (21.4%)
Total	3761 (62.4%)	16664 (58.2%)	20072 (63.8%)	33924 (100%)
Gender				
Male	3062 (50.8%)	14604 (51.0%)	15965 (50.7%)	17257 (50.9%)
Female	2967 (49.2%)	14043 (49.0%)	15517 (49.3%)	16667 (49.1%)
Total	6029 (100%)	28647 (100%)	31482 (100%)	33924
Infant Mortality				
Infant deaths	694 (11.5%)	2349 (8.2%)	2513 (8.0%)	2705 (8.0%)
Total number of live births	6029 (100%)	28, 647(100%)	31482(100%)	33924 (100%)
Infant mortality rate	115	82	80	80

Table 3 displays the frequency distribution of the selected infant mortality variables used in this study. The total number of children born to the interviewed mothers for each of the five years preceding the 2003, 2008, 2013 and 2018 surveys are 6029, 28647, 31482, 33924 respectively. The total for some of the variables differs and are less than 100% due to missing values and no responses. The results in Table 3 indicates that the number of children born to the respondents were consistently higher for women between the ages of 20 and 29 with 50.3%, 48.1%, 47.2% and 47.4% in 2003, 2008, 2013 and 2018 respectively. The population percentage of participating children for each of the survey years was higher for children born in the Northern region than for those given birth to in the Southern region with the highest number of children given birth to in the North West and the lowest number of children born in the South East with the 2018 survey year being the only exception as the South South region recorded the lowest percentage of children born to the respondents. Also, a larger percentage of the respondents were rural dweller with a percentage of over 60% in each of the survey years residing in rural settlements. Table 3 also shows that over 45% of the children born to the interviewed mothers in each of the survey years had no formal education with only 3.6%, 4.7%, 6.1%, and 7.8% of the children born to the respondents in 2003, 2008, 2013 and 2018 having a tertiary education.

Since majority of the respondents were rural dwellers with possibly little or no access to good water, means of obtaining clean cooking fuel and modern toilet facilities, it is therefore of no surprise that a greater number of the children born to the respondents lived in households using unclean cooking fuel such as wood and charcoal with unimproved source of water and unimproved toilet sanitation for each of the survey years. A higher number of the babies were given birth to the interviewed mothers at home representing 63.9%, 66.3%, 62.3% and 58.8% in 2003, 2008, 2013 and 2018 respectively relative to the number of children born in the hospital. Also, only 13%, 11.1%, 13.1% and 26.1% of the children of the respondents given birth to in the hospital received antenatal care less than five times before their delivery.

On breast feeding, 42.1%, 56.6%, 54.6% and 52.6% of the babies born in each of the five years preceding the 2003, 2008, 2013 and 2018 surveys respectively were breast fed by their mothers. The percentage of boys given birth to in each of the survey years were consistently higher slightly with just over 50% for each of the survey yeas relative to the percentage of female babies. Overall, the total number of estimated infants' death for the five years preceding each survey is 694, 2349, 2513 and 2705 representing 11.5%, 8.2%, 8% and 8% respectively. This also signifies that infant mortality rates have stagnated in the last decade.

Table 4: Estimates of Infant Mortality rates per 1,000 live births for the five years preceding each survey.

Variables	**2003**	**2008**	**2013**	**2018**
Mother's Age				
15 - 19	135	101	111	96
20 - 29	111	79	75	78
30 - 39	110	79	83	77
40 - 49	138	93	95	92
Mother's Region				
North Central	101	73	63	71
North East	139	89	86	86

North West	125	92	98	105
South East	97	88	88	62
South South	114	82	63	52
South West	69	53	61	51
Place of Residence				
Rural	132	89	90	88
Urban	85	63	60	64
Mother's Education				
No Education	138	91	94	97
Primary	117	83	83	81
Secondary	67	70	61	62
Higher	70	38	43	50
Source of Drinking Water				
Unimproved Source	120	92	88	82
Improved Source	101	71	74	75
Toilet Type				
Unimproved Toilet Sanitation	120	85	84	85
Improved Toilet Sanitation	53	54	53	58
Mother's Religion				
Christian	97	77	70	62
Islam	123	85	87	92
Traditionalist	135	100	80	40
Cooking Fuel				
Wood/Charcoal/Coal	124	86	85	93
Kerosene /Electricity/Gas	75	55	53	49
Mode of Delivery				
Caesarean Section	93	115	104	92
Normal Delivery	76	81	79	80
Breast Feeding				
Not Breast Fed	76	122	118	112
Breast Fed	69	51	48	51
Place of Delivery				
Home	128	85	86	89
Hospital	80	68	62	67
Others	80	207	327	76
Size of Child				
Large	96	68	63	72
Average	108	78	77	73
Small	183	126	130	117
Antenatal Visits				
None	102	67	66	106
Below 5	68	52	54	52
5 and Above	55	46	45	48

Gender				
Male	121	89	86	85
Female	108	74	73	75
Total	115	82	80	80

Table 4 is a display of the estimates of infant mortality rates in Nigeria for the five year period preceding each of the 2003, 2008, 2013 and 2018 NDHS based on the selected infant mortality variables. From Table 4, the overall infant mortality rates can be seen to have reduced in subsequent years from 115/1,000 live births in 2003 through 82/1,000 live births in 2008 to 80/1,000 live births in 2013 before seemingly remaining stagnant at 80/1,000 live births for the five year period preceding 2018 survey. The estimated infant mortality rates for teenage mothers reduced from 135/1,000 live births in 2003 to 96/1,000 live births in 2018 with mothers between the ages of 20 – 39 experiencing considerably lower infant mortality rates from 2003 through 2018. Mothers who resided in urban centers experienced significantly reduced infant mortality rates compared to those who lived in rural settlements with 85/1,000 live births versus 132/1,000 live births in 2003 reducing through the years to 64/1,000 live births and 84/1,000 live births in 2018 respectively. Furthermore, the result in Table 4 suggests that female children in Nigeria experienced less mortality at infancy compared to their male counterpart with consistently lower infant mortality rates from 2003 through 2018. On breast feeding, infant mortality rates (76, 122, 118 and 112)/1,000 live births was higher for children who were not breastfed compared to those who were breastfed (69, 51, 48 and 51)/1,000 live births in 2003, 2008, 2013 and 2018 respectively. The infant mortality estimates for the size of the child at birth shows that babies who were small at birth experienced more mortality (183, 126, 130, 117) per 1,000 live births compared to babies who were large in size (96, 68, 63, 72) per 1,000 live births in 2003, 2008, 2013 and 2018 respectively. Considering the mode of delivery and number of antenatal visits, babies who were given birth to in the hospital experienced significantly lowered infant mortality rates than those who were born at home. Children who were given birth to after their mothers attended antenatal care on five or more occasions also recorded significantly less infant mortality from 2003 through 2018 relative to babies born without any doctor's appointment prior to their delivery. Also, infant mortality rates were significantly higher among children who had water from unimproved sources and used unimproved toilet types for each of the 2003, 2008, 2013 and 2018 survey years. All the infant mortality rate estimates were calculated at 95% confidence level using Pearson Chi-square (χ^2) test of association.

Table 5: Summary of Infant Mortality Rates.

	2003	2008	2013	2018
Estimated IMR	115	82	80	80
ARR	**NC**	5.7%	0.5%	0%
NDHS IMR	100	75	69	67
ARR	**NC**	5.0%	1.6%	0.6%

IMR= Infant Mortality Rate, ARR= Annual Rate of Reduction, NC=Not Computed

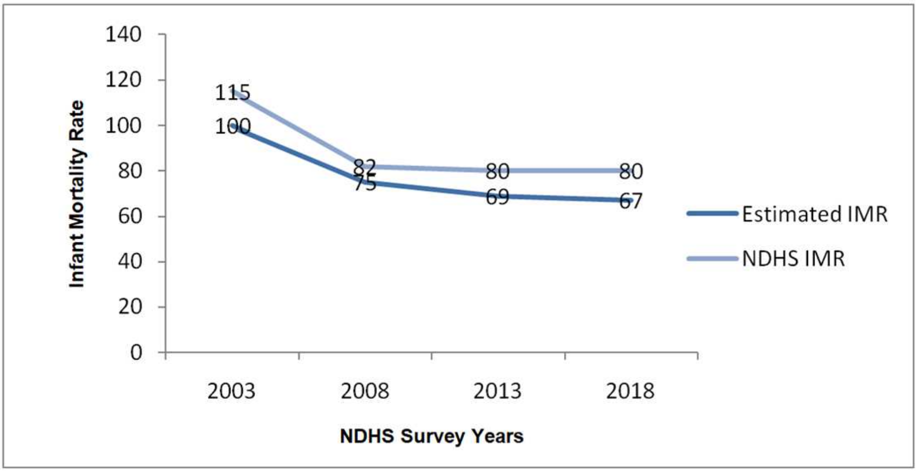

Figure 1: Infant Mortality Trend.

Table 5 presents the levels of infant mortality rate from 2003 to 2018 as well as the periodic Annual Rate of Reduction (ARR). The periodic ARR for 2003 was not computed because this study did not consider estimates of the previous NDHS survey necessary to compute the periodic ARR for 2003. From Table 5, the current estimated infant mortality rate is 80/1,000 live births for the five years preceding the 2018 survey. Compared to estimates of infant mortality rates in 2003 which stands at 115/1,000 live births; there have been a steady decline. However, this reduction in infant mortality which fell short of the target of childhood mortality goals as contained in the Millennium Development Goals (MDG) in 2015, may not be enough (if current ARR for infant mortality remains constant) to attain the target for childhood mortality as contained in the Sustainable Development Goals (SDG) given the percentage of under-five deaths that occurs at infancy. Figure 1 reveals an initial downward trend in infant mortality rate from 2003 to 2008 with an ARR of 5.7%. This high ARR could not be sustained over the years with the rate of reduction in infant mortality shrinking to 0.3% in 2013 until the ARR hits 0% for the five years preceding the 2018 survey indicative of a stunted reduction in infant mortality. If mortality rate targets are to be met, the overall infant mortality ARR from 2003 up until 2018 which is about 2.0% needs to be improved upon. On current levels and trends, a projected infant mortality rate of 52 per 1000 live births by 2030 based on the ARR between 2003 and 2018 resulting to 33% of deaths in under-five mortality in Nigeria will lead to the country falling short of the SDG for childhood mortality unless suitable interventions already put in place are rigorously pursued.

Table 6: Effects of the determinants of Infant Mortality for the five years preceding 2003-2018.

Variables	2003		2008		2013		2018	
	O.R	Sig.	O.R	Sig.	O.R	Sig.	O.R	Sig.
Mother's Age								
15 – 19 [RC]	**1.000**							
20 - 29	0.757	0.000	0.746	0.000	0.780	0.000	0.821	0.007
30 - 39	0.879	0.000	0.891	0.012	0.804	0.002	0.834	0.004
40 - 49	0.974	0.021	0.933	0.023	0.836	0.046	1.049	0.049
Mother's Region								
North Central [RC]	**1.000**							
North East	0.658	0.000	0.776	0.000	0.959	0.065	0.975	0.819
North West	0.689	0.000	0.820	0.027	0.898	0.024	0.815	0.044
South East	0.521	0.084	0.879	0.012	0.643	0.000	0.709	0.000
South South	0.462	0.007	0.608	0.000	0.561	0.000	0.458	0.000
South West	0.576	0.027	0.810	0.002	0.631	0.000	0.577	0.000
Place of Residence								
Rural [RC]	**1.000**							
Urban	0.609	0.000	0.694	0.000	0.643	0.000	0.703	0.000
Mother's Education								
No Education [RC]	**1.000**							
Primary	0.897	0.000	0.523	0.000	0.690	0.002	0.807	0.028
Secondary	0.564	0.040	0.440	0.000	0.430	0.000	0.603	0.000
Higher	0.468	0.005	0.396	0.000	0.489	0.000	0.496	0.000
Source of Drinking Water								
Unimproved Source [RC]	**1.000**							

Improved Source	0.819	0.035	0.753	0.000	0.821	0.000	0.907	0.020
Toilet Type								
Unimproved Toilet Sanitation **RC**	**1.000**							
Improved Toilet Sanitation	0.405	0.000	0.612	0.000	0.601	0.000	0.657	0.000
Mother's Religion								
Christian **RC**	**1.000**							
Islam	1.286	0.102	1.202	0.160	1.165	0.377	1.571	0.145
Traditionalist	1.349	0.071	1.077	0.569	0.916	0.610	1.409	0.004
Cooking Fuel								
Wood/Charcoal/Coal **RC**	**1.000**							
Kerosene/Electricity/Gas	0.575	0.000	0.625	0.000	0.606	0.000	0.553	0.000
Mode of Delivery								
Caesarean Section **RC**	**1.000**							
Normal Delivery	0.797	0.572	0.680	0.008	0.737	0.015	0.852	0.017
Breast Feeding								
Not Breast Fed **RC**	**1.000**							
Breast Fed	0.405	0.000	0.386	0.000	0.378	0.000	0.428	0.000
Place of Delivery								
Home **RC**	**1.000**							
Hospital	0.593	0.022	0.449	0.000	0.527	0.000	0.845	0.030
Others	0.997	0.079	0.354	0.121	0.731	0.000	1.151	0.419
Size of Child								
Large **RC**	**1.000**							
Average	0.871	0.039	0.590	0.000	0.553	0.000	0.594	0.000
Small	1.474	0.000	1.296	0.000	1.305	0.021	1.141	0.014
Antenatal Visits								
None **RC**	**1.000**							
Below 5	0.793	0.000	0.883	0.000	0.834	0.035	0.920	0.025
5 and Above	0.506	0.008	0.721	0.029	0.666	0.000	0.424	0.000
Gender								
Male **RC**	**1.000**							
Female	0.875	0.098	0.817	0.000	0.832	0.000	0.805	0.871

O.R = Odds Ratio, Sig. = Significance level, RC = Reference Category

The results of the logistic regression model used to identify the significant determinants of infant mortality for the five years preceding each of the 2003, 2008, 2013 and 2018 NDHS are presented in Table 6. There are two distinct columns for each of the survey years. The first column for each survey year displays the Odds Ratio (OR) which is the exponential of the parameter estimates from the model at 95% Confidence Interval (CI). The odds ratio defines the chances of occurrence of infant mortality with respect to the reference category for each of the infant mortality variables. The second column gives the associated *P-value* which measures the degree of statistical significance of the odds ratio. From Table 6, the odds of infant mortality for mothers between the ages of 20 – 29 (0.757, 0.746, 0.780 and 0.821) was consistently lower for each of the respective survey years than for teenage mothers with *P-value* of 0.000 indicating statistical significance. Based on the geopolitical location of mothers, the chances of infant mortality is reduced by about 54%, 39%, 44% and 54% for mothers who reside in the South South relative to mothers in the North Central zone for 2003, 2008, 2013 and 2018 respectively with *P-values* < 0.05 for each survey year making region of residence a significant determinant of infant mortality. Also, for each of the survey years, being born in urban centres reduced the risk of infant mortality by a minimum of about 30% with odds of (0.609, 0.694, 0.643, 0.703) and *P-value* = 0.000 for 2003, 2008, 2013 and 2018 respectively. Improved cultural practises such as using water from clean sources, improved toilet sanitation and use of clean cooking fuel significantly reduced the odds of infant mortality for 2003, 2008, 2013 and 2018 and were all found to be statistically significant determinant of infant mortality with *P-value* = 0.000.

On mother's education, attaining a minimum of primary education improved the chances of child survival by about 10%, 48%, 31% and 19% in 2003, 2008, 2013 and 2018 respectively with *P-values* < 0.05. As the mother's educational level increased prior to child bearing, the chances of infant mortality occurrence reduced (except for higher education in 2013) with mother's education shown to be a significant determinant of infant mortality for each of the survey years. With respect to the place of delivery, mothers who went to the hospital for the delivery of their babies had significantly reduced odds of 0.593, 0.449, 0.527 and 0.845 of experiencing childhood mortality in 2003, 2008, 2013 and 2018 respectively compared to women who delivered their babies at home. The place of delivery with a *P-value* < 0.05 is a significant determinant of infant mortality. The number of antenatal visits of mothers before the delivery of their babies was also found to be a significant determinant of infant mortality with a *P-value* < 0.05 and an improved survival chance of about 49%, 28%, 33% and 58% for mothers who visited the hospital for antenatal on five or more occasions in 2003, 2008, 2013 and 2018 respectively.

Other statistically significant infant mortality variables for each of the survey years are “Breastfeeding” and “’Size of child at birth” while infant mortality variables such as “mother’s religion”, “gender” and “mode of delivery” had *P-values* > 0.05 for at least one of the survey years implying that they were not statistically significant determinants of infant mortalities for each of the survey years.

Evaluation of the Full Model

(a) Likelihood Ratio Test

Table 7: Result of Likelihood Ratio Test.

Model	Model fit measures	Likelihood Ratio Test		
	-2Loglikelihood	Chi-Square	df	Significance
Constant Only	204.670	60.461	14	0.000
Overall model	144.209			

The model fitting measure used is -2 log-likelihood. The value of this criterion for the constant only model was 204.670 while the value of this criterion for the overall model was 144.209. Therefore, value of the likelihood ratio test was computed as follows:

$$G = 204.670 - 144.209 = 60.461.$$

The hypotheses are that:

$$H_0: \beta_1 = \beta_2 = \cdots = \beta_{14} = 0$$

$$H_1: \exists \ \beta_j \neq 0, j = 1, 2, \dots, 14.$$

The test indicted that there is at least one of the explanatory variable coefficients that is not equal to zero due to the small p-values being less than 0.05. As a result of this we reject H_0 and accept the alternative hypothesis $H_1$and so conclude that at least one of coefficient is not zero.

Receivers Operating Characteristic Curve for full Model

We use the ROC curve for the classification and predictive accuracy. It was revealed that the area under the ROC curve for the full model is 0.92.

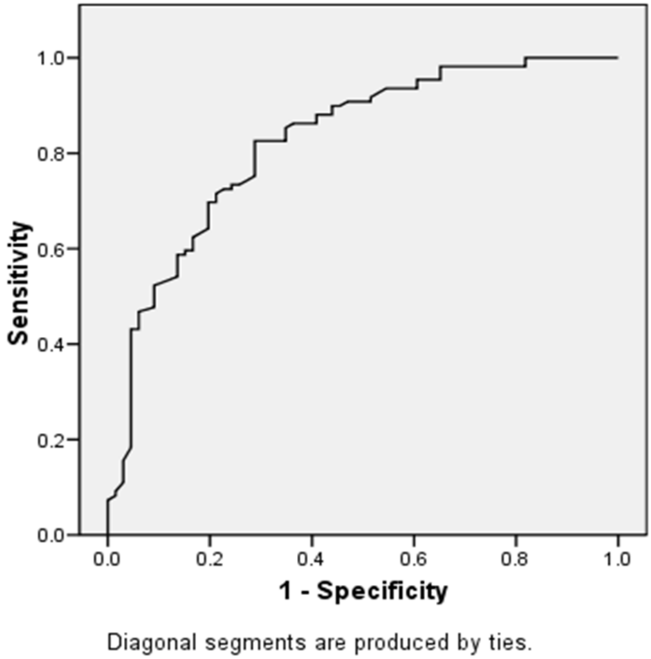

Figure 2: Receiver operating characteristic (ROC) curve for the full model.

(b) Hosmer and Lemeshow Test

Table 8: Hosmer and Lemeshow Test.

Step	Chi-Square	df	Significance
1	7.037	14	0.533

The Hosmer and Lemeshow test above showed a significance of 0.533 implying there is no statistical significance, therefore we fail to reject the null hypothesis that observed and model predicted values are the same. This outcome means the model's estimated values fit the data.

4. Conclusion

This study examined the levels, trends and determinants of infant mortality rates in Nigeria using data obtained from consecutive NDHS for 2003, 2008, 2013 and 2018. Logistic regression model was employed to identify the significant determinants of infant mortality for the five years preceding each of the survey. Findings from the study revealed that there is a decline in infant mortality rates over the years but which had stagnated in the five year period prior to the 2018 survey with an ARR of 0% relative to an initial ARR of 5.7% between 2003 and 2008. Over the course of the 15 year period between 2003 and 2018, the ARR was 2.039%. The study clearly showed that maternal characteristics such as age and educational levels as well as cultural practises like use of clean water and toilet facilities were statistically significant determinants of infant mortality in Nigeria.

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