Infant mortality and risk factors in Nigeria in 2013–2017: A population-level study

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Summary

Background Globally, over the past two decades, many countries have significantly reduced the rate of infant mortality. Yet, in Africa, Nigeria remains one of the countries with the highest infant mortality rate (IMR).

Methods We conducted a population-level study using the 2018 Nigeria Demographic Health Survey (NDHS). A total of 41,668 household data were analyzed retrospectively. The association between each exposure and infant mortality was analyzed in logistic regression models (independently adjusted by demographic and socioeconomic status variables) and confirmed by the multiple comparisons analysis.

Findings The overall IMR of 2013–2017 was 61.5 (95% CI 58.0, 65.3) per 1000 live births. In general, the North-West and North-East regions had the highest IMR, whereas the South-West, South-East and South-South regions had the lowest IMR. The regression analysis found women who delivered their babies at the age \(<18\) years old (odds ratio (OR): 1.37 [1.17, 1.62]), had religion of Islam (OR: 1.35 [1.10, 1.65]), no ANC visit (OR: 1.69 [1.21, 2.35]), \(>4\) ANC visits (OR: 1.70 [1.23, 2.34]), ANC not at home or skilled provider (0.40 [0.35, 0.46]) and the babies as the first child (OR: 1.23 [1.07, 1.42]) to be associated with higher IMR.

Interpretation Our findings imply that Nigeria is not on track to achieving the SDG target of reducing child mortality by 2030. Sustainable interventions are urgently needed to address the challenges for women of reproductive age, particularly those that are living in the rural areas and Northern regions, having limited/no access to health care/skilled providers, and delivered their first child.

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Introduction

Infant mortality (IM) is the death of an infant before his or her first birthday.\(^1\) Infant mortality rate (IMR) is a key indicator of the overall health of a society and is essential for social and economic development.\(^2\) In the National Demographic Health Survey (NDHS), IMR of each year was calculated as the number of infant deaths among the total number of alive-born children in the year.

In the past two decades, many countries have achieved significant improvements in reducing IM. According to the UN 2018 mortality report, IMR declined by 51% between 2000 and 2017.\(^3\) Despite this progress, wide disparities exist between low-income and high-income countries—76 deaths per 1000 live births and 7 deaths per 1000 live births respectively.\(^3\) Nigeria reported 72 deaths per 1000 live births among infants in 2020 with disparities across its regions and geopolitical zones.\(^4\) Nigeria has worse IMR compared...
Nigeria is one of countries with the highest infant mortality rate in Africa; however, little is known about the social determinants of the women that contribute to the high mortality rate. The 2018 Nigeria Demographic Health Survey (NDHS) surveyed a total of 41,668 households, which provides an opportunity to conduct a range of statistical analyses to understand the risk factors associated with infant mortality in the country.

Studies show that there are several determinants of IM in Nigeria. In 2010, low birth weight was reported by Samantha Slinkard et al., 2018 who reported maternal health care/skilled providers. Further research should investigate the impact of such interventions and how they can be scaled across the country to reduce the rate of infant mortality.

High infant mortality rate in Nigeria indicates that effective and sustainable interventions are still needed to reduce the challenges and burden from infant mortality for women of reproductive age. This may require the provision of targeted, customized, and localized interventions, particularly for younger women living in the Northern regions, with limited or no access to health care/skilled providers. Further research should investigate the impact of such interventions and how they can be scaled across the country to reduce the rate of infant mortality.

Methods

Nigeria demographic and health survey (NDHS) 2018 is the most up-to-date demographic and health information on the Nigerian population. It is supported by the National Population Commission (NPC) and the National Malaria Elimination Program (NMEP) of the Federal Ministry of Health, Nigeria. In the 2018 NDHS, a total of 41,668 households were surveyed retrospectively in the year of 2018 (from 14 August to 29 December) with a response rate of 99%.

The sample was selected using a stratified, two-stage cluster design: the first stage was to select enumeration areas (EAs) as the sampling units; based on each of the 1400 EAs selected, the second stage was a complete listing of households that targeted men and women aged 15–59 and 15–49, respectively, and that were selected randomly for survey.
The survey was conducted using computer-assisted personal interviewing (CAPI).²⁷

Participants, study size
In NDHS, IMR is defined as the number of deaths among the number of alive-born children at ages 0 to 11 months; the deaths include those reported at age 0 but does not include stillbirth. Given the definition of IM, we only included children born at least a year prior to the interview date; therefore, 31,775 children born between 2013 and 2017 were included. Sample weights in descriptive statistics and data analyses were applied to adjust for the over- and under-sampling. According to the DHS, the individual weight for both women and children (variable: v005) is the household weight (variable: hweight) multiplied by the inverse of the individual response rate for women in the stratum. In this manner, the weighted total number of live births are 32,003 in 2013–2017 (2013: 6489; 2014: 6825; 2015: 6752; 2016: 6434; 2017: 5503). Detailed theory and process of sampling and weighting in DHS can be found on these websites: https://dhsprogram.com/publications/publication-dhsrg1-dhs-questionnaires-and-manuals.cfm; https://dhsprogram.com/Data/Guide-to-DHS-Statistics/Early_Childhood_Mortality.htm.

Variables
The overall participants’ characteristics in 2013–2017 were analyzed prior to further analysis of the survey data. Participants’ characteristics include the region (North-Central, North-East, North-West, South-East, South-South and South-West), sex of child (male or female), mother’s age (<18, 18–35 or ≥36), rurality (urban or rural), mother’s religion (Christian, Islam or Traditionalism), ethnicity (Igbo, Hausa, Yoruba or other), wealth index (poorest, poorer, middle, richer or richest), mother’s education level (no education, primary, secondary or higher education), insurance coverage (yes or no), place of delivery (skilled provider, home or other), number of antenatal care (ANC) visit (no visit, 1 to 3, 4, ≥4), place of ANC (skilled provider/home or other), caesarean section (yes or no), first child (yes or no) and low birth weight (yes or no; defined as <2500 g). Also, the geospatial distribution of the overall IMR of all years (2013–2017) was mapped across each state of the country. In addition, a line chart was used to show the trend of IMR in Nigeria and by Nigeria’s region. To develop the map and line chart, we used software QGIS (Desktop 3.12.2 version) and RStudio 1.1.423 (RStudio, PBC, Boston, MA). Specific to the IMR in Nigeria, we used time series analysis to present the trend, addressing potential instability due to low sample size over the year. In the line chart, we also present the trend of IMRs globally and in Africa, as the comparison of IMR in Nigeria. The global and African aggregated data of the mortality rate under one year old were directly obtained from the Global Health Data Exchange of the Global Burden of Disease (GBD) Study (open-access resource to the public: http://ghdx.healthdata.org).²⁶

Ethics statement
The study is a secondary analysis based on an approved and established program—the Demographic and Health Survey (DHS). We obtained approval to use the data from the DHS repository, including for this publication. All data were obtained from the 2018 Nigeria Demographic and Health Survey. With no identifiable information of respondents, additional ethical approval was not required for the data access. More information about the ethics approval process for DHS can be found here: https://dhsprogram.com/Methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm.

Statistical analysis
We investigated the risk factors of IM for all the combined years and for each single year separately. The exposure is each of the 15 characteristics described above; the outcome is infant mortality (yes or no for each observation). The association between each exposure and IM was analyzed in each of the logistic regression models, independently adjusted by demographic variables including year (only used for all years but not for each year), sex of child, region, rurality, religion, ethnicity (model 1), and socioeconomic variables including wealth index and mother’s education (model 2), and both the demographic and socioeconomic variables (model 3). Among the exposures, low birth weight was only analysed based on all years rather than each year due to the limited sample size with a large amount of missing data. The corresponding variable for adjustment was removed if the same variable was used as exposure. In addition, we also applied model 1 only to analyze the associations of wealth index, mother’s education, insurance status and rurality with infant mortality, because these four factors are strongly correlated and could have an intersected impact on the IM outcome. Considering that many (a total of 15) exposures were investigated, and the results might be significant by chance, we applied multiple comparisons analysis to further confirm the significant results from the logistic regression models. The confirmation was considered when the p value from the logistic regression was less than the value of 0.05 divided by the number of the exposures, which is 0.003 (0.05/15). Data management and statistical analyses were conducted using Stata SE 15.

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Results

Infant mortality

The details of IMR by population characteristics are presented in Table 1. The overall IMR from 2013 to 2017 was 61.5 (95% CI 58.0, 65.3) per 1000 live births. In each year (from 2013 to 2016), the rate was 50.1 (44.0, 56.9), 60.1 (53.8, 67.1), 68.5 (61.5, 76.3) and 68.6 (61.2, 76.9) per 1000 live births, respectively, as a whole indicating an increasing trend; while in 2017, the rate decreased to 59.9 (52.1, 68.9) per 1000 live births (Figure 1). Nigeria’s IMR was far higher than the average of IMR worldwide and was also higher compared to IMR of Africa in 2014–2017 (Supplemental Figure 1). The details of the number of infant births and deaths by population characteristics are documented in Supplemental Table 1.

By population’s characteristics at the regional level, the North-West and North-East regions had the highest IMRs of 75.0 (68.1, 82.6) and 67.2 (59.8, 75.3) per 1000 live births respectively between 2013 and 2017; the South-West, South-East and South-South regions had lower IMRs of 42.6 (34.4, 52.6), 44.2 (37.5, 52.2) and 45.0 (36.3, 55.6) per 1000 live births, respectively between 2013 and 2017 (Table 1). In the five-year period, the disparity in IMR by region was more evident in 2015, 2016 and 2017 (Table 1, Supplemental Figure 1). Disparities also existed as seen from the results of the mothers’ age, rurality, religion, ethnicity, education level, wealth index, place of delivery, number of ANC visits, and ANC at home or skilled provider. Specifically, we point out that the high IMR was among mothers aged ≤18 years old, with 86.5 (75.0, 99.6) per 1000 live births between 2013 and 2017 (Table 1).

Figure 2 further shows the regional disparity of IM by state in Nigeria between 2013 and 2017. A higher IMR was more apparent in the Northern part of Nigeria compared to the Southern part. Specifically, Kebbi in the North-West region, Gombe and Sokoto in the North-East region had the highest IMR, of 104.9 (89.0, 123.3), 100.3 (87.8, 145.9) and 102.9 (80.6, 130.5) per 1000 live births, respectively; Bayelsa in the South-West region and Ogun in the South-West region had the lowest IMR, of 19.0 (10.8, 33.3) and 21.7 (12.0, 39.1) per 1000 live births, respectively. The IMR of each region from 2013 to 2017 discrete years are presented in Supplemental Table 2.

Risk factors for infant mortality

In Table 2, we summarize selected results of model 3 (adjusted for demographic and socio-economic variables) indicating risk factors for IM in NDHS data; all detailed results of three models can be found in Supplemental Table 3. According to the logistic regression, results of 2013–2017 data indicated that risk factors of the IMR were: male children (odds ratio (OR) in female: 0.84 [95% CI 0.74, 0.95]), mother aged ≤18 years old (OR: 1.37 [1.17, 1.62]), mother aged ≥26 years old (OR: 1.18 [1.01, 1.37]), religion of Islam (OR: 1.35 [1.10, 1.65]), no ANC visit (OR: 1.69 [1.21, 2.35]), 1–3 ANC visits (OR: 1.53 [1.04, 2.26]), >4 ANC visits (OR: 1.70 [1.23, 2.34]), ANC not at home or skilled provider (OR of ANC at home or skilled provider: 0.40 [0.35, 0.46]), C-section (OR: 1.83 [1.18, 2.84]), and first child (OR: 1.23 [1.07, 1.42]). The multiple comparisons analysis further confirmed the associations of IM with mother aged ≤18 years old, religion of Islam, no ANC visit, >4 ANC visits, ANC not at home or skilled provider, and first child.

In each of 2013–2017, results were still statistically significant for ANC at home or skilled provider, regardless of the model. The significant association results indicated by the logistic regression and confirmed by the multiple comparisons analysis were found in: rurality in 2013 (OR: 1.66 [1.25, 2.11]), Islam in 2015 (OR: 2.07 [1.32, 3.27]) and 2016 (OR: 1.83 [1.21, 2.78]), no ANC visit in 2017 (OR: 2.42 [1.37, 4.29]), ANC at home or skilled provider in 2015 (OR: 0.53 [0.40, 0.70], 2016 (OR: 0.26 [0.20, 0.34]) and 2017 (OR: 0.36 [0.26, 0.49]), and the first child in 2014 (OR: 1.63 [1.24, 2.14]) (Table 2).

Discussion

This study used the 2018 NDHS dataset to understand the epidemiological statistics of IMR and its risk factors in Nigeria, for the years of 2013–2017. The results show that IMR in Nigeria increased from 50.1 per 1000 live births in 2013 to 59.9 per 1000 live births in 2017 with aggregate figure of 61.5 per 1000 live births over the five-year period. This rate reinforces Nigeria’s rank as one of the leading countries with infant mortality.

At the regional level, our findings show that between 2013 and 2017, the IMR increased for all regions except for the North-East and South-South. Nevertheless, the Northern regions continue to bear the highest burden of infant mortality, particularly the North-West with the highest mortality rate of 77.0 per 1000 live births in 2017. The Northern part of the country is rife with poverty, poor access to antenatal care and insecurity that may prevent access to quality maternal healthcare services. With regards to the determinants of infant mortality, we observed that at the individual level, the gender of the child, birth order, and the mother’s age are risk factors for infant mortality. As our findings show, male infants are more likely to experience death relative to female infants. This result is consistent with findings from other studies using the NDHS dataset from prior years. In addition, children born to women having their first birth are more likely to experience mortality relative to children born to women who have had more than one birth. Lastly, children born to women aged less than 18 and greater than 35 years are at a higher
| Characteristics | 2013 Infant mortality rate (N=6489) | 2014 Infant mortality rate (N=6825) | Change (%) | 2015 Infant mortality rate (N=6752) | Change (%) | 2016 Infant mortality rate (N=6343) | Change (%) | 2017 Infant mortality rate (N=5503) | Change (%) | 2013-2017 Infant mortality rate (N=32,003) |
|-----------------|------------------------------------|------------------------------------|------------|------------------------------------|------------|------------------------------------|------------|------------------------------------|------------|------------------------------------|
|                 | Total                              | 50.1 (44.0, 56.9)                 | 20%        | 68.5 (61.7, 76.3)                 | 14%        | 68.6 (61.7, 76.9)                 | 0%         | 59.9 (52.1, 68.9)                 | -12.7%     | 61.5 (58.0, 65.3)                 |
|                 | Region                              |                                    |            |                                    |            |                                    |            |                                    |            |                                    |
|                 | North-central                       | 42.2 (30.7, 57.7)                 | 34%        | 73.2 (56.1, 94.9)                 | 29%        | 58.6 (45.3, 75.6)                 | -20%       | 60.3 (43.7, 82.6)                 | -3%        | 58.3 (51.4, 66.0)                 |
|                 | North-East                          | 59.8 (46.5, 76.5)                 | 10%        | 81.6 (67.4, 98.4)                 | 39%        | 78.3 (61.9, 98.5)                 | -4%        | 56.6 (43.8, 72.8)                 | -28%       | 67.2 (59.8, 75.3)                 |
|                 | North-West/North-West               | 61.9 (50.4, 75.7)                 | 66%        | 65.8 (58.8, 93.8)                 | 16%        | 70.7 (67.0, 107.0)                | 15%        | 77 (61.0, 96.8)                   | -15%       | 75 (68.1, 82.6)                   |
|                 | South-East                          | 39.7 (28.7, 54.5)                 | 33%        | 40.1 (28.1, 57.0)                 | 39%        | 31 (19.5, 48.9)                  | -23%       | 46.6 (32.5, 66.2)                 | 50%        | 44.2 (37.5, 52.2)                 |
|                 | South-South                         | 36.3 (22.0, 59.2)                 | 59%        | 46.6 (28.5, 69.2)                 | 35%        | 40.6 (27.7, 60.5)                 | -9%        | 33.8 (21.7, 50.0)                 | -17%       | 45 (36.3, 55.6)                   |
|                 | South-West/South-West              | 29.7 (16.2, 53.6)                 | 28%        | 53.5 (34.9, 81.3)                 | 13%        | 52.5 (35.8, 76.5)                 | -2%        | 44.7 (29.6, 67.0)                 | -15%       | 42.6 (34.4, 52.6)                 |
|                 | Sex of child                        |                                    |            |                                    |            |                                    |            |                                    |            |                                    |
|                 | Male                                | 52.2 (44.1, 61.7)                 | 35%        | 76.4 (66.0, 88.3)                 | 15%        | 72.2 (62.6, 83.1)                 | -5%        | 62.8 (52.6, 74.8)                 | -13%       | 66.3 (61.5, 71.4)                 |
|                 | Female                              | 47.9 (40.5, 57.3)                 | 4%         | 60.4 (51.9, 70.3)                 | 13%        | 64.8 (54.0, 77.7)                 | 7%         | 56.7 (45.1, 71.1)                 | -13%       | 56.6 (51.6, 62.0)                 |
|                 | Mother's age                        |                                    |            |                                    |            |                                    |            |                                    |            |                                    |
|                 | <=18                                | 78.4 (57.4, 106.3)                | 2%         | 94.2 (71.2, 123.6)                | 12%        | 76.7 (58.3, 100.4)                | -19%       | 97.4 (65.2, 142.9)                | 27%        | 86.5 (75.0, 99.6)                 |
|                 | 19-35                               | 45.3 (38.8, 52.9)                 | 6%         | 64.9 (57.2, 73.6)                 | 16%        | 66.5 (57.8, 76.4)                 | 2%         | 52.2 (44.5, 61.2)                 | -21%       | 57.2 (53.4, 61.2)                 |
|                 | >=36                                | 57.2 (41.4, 78.6)                 | 4%         | 68.7 (50.9, 92.1)                 | 14%        | 74.8 (57.7, 96.5)                 | 9%         | 80.4 (60.6, 105.9)                | 7%         | 68.4 (60.2, 77.6)                 |
|                 | Rurality                            |                                    |            |                                    |            |                                    |            |                                    |            |                                    |
|                 | Urban                               | 34.1 (26.5, 43.7)                 | 24%        | 55.9 (45.2, 69.1)                 | 0%         | 56.5 (46.6, 67.9)                 | 1%         | 54.6 (43.0, 69.0)                 | 3%         | 51.2 (46.1, 56.8)                 |
|                 | Rural                               | 60.7 (52.3, 70.4)                 | 4%         | 76.2 (67.3, 86.2)                 | 21%        | 76.4 (66.3, 87.9)                 | 0%         | 63.2 (53.2, 75.0)                 | -17%       | 68.1 (63.3, 73.1)                 |
|                 | Religion                            |                                    |            |                                    |            |                                    |            |                                    |            |                                    |
|                 | Christian                           | 35.8 (28.2, 45.2)                 | 25%        | 44.2 (35.8, 54.5)                 | -26%       | 39.8 (32.0, 49.4)                 | -10%       | 47.3 (38.3, 58.4)                 | 19%        | 45.1 (40.9, 49.7)                 |
|                 | Islam                               | 59 (50.6, 68.8)                   | 4%         | 81.7 (71.9, 92.7)                 | 35%        | 85.6 (75.2, 97.3)                 | 5%         | 67 (56.2, 97.9)                   | -2%        | 70.8 (65.9, 76.1)                 |
|                 | Traditional                        | 31.8 (9.2, 103.6)                 | 2%         | 91.3 (37.4, 206.4)                | -19%       | 80.2 (17.4, 299.8)                | -12%       | 71.2 (16.6, 258.5)                | 1%         | 70.6 (40.0, 121.7)                |
|                 | Ethnicity                           |                                    |            |                                    |            |                                    |            |                                    |            |                                    |
|                 | Igbo                                | 40.3 (30.3, 53.6)                 | 13%        | 51.5 (39.0, 67.7)                 | -15%       | 43.8 (31.8, 60.2)                 | -15%       | 39.9 (28.8, 55.0)                 | -9%        | 47.2 (41.2, 53.9)                 |

Table 1 (Continued)
| Characteristics | 2013 Infant mortality rate (N=6489) | 2014 Infant mortality rate (N=6825) | Change (%) | 2015 Infant mortality rate (N=6752) | Change (%) | 2016 Infant mortality rate (N=6434) | Change (%) | 2017 Infant mortality rate (N=5035) | Change (%) | 2013-2017 Infant mortality rate (N=32,003) |
|-----------------|----------------------------------|----------------------------------|------------|----------------------------------|------------|----------------------------------|------------|----------------------------------|------------|----------------------------------|
| Hausa           | 60.6                             | (51.1, 71.8)                     | 8%         | 79.4                             | 21%        | 83.1                             | 5%         | 74.7                             | −10%       | 72.6                             |
| Yoruba          | 30.2                             | (16.2, 55.6)                     | 24%        | 44.9                             | 20%        | 53.1                             | 18%        | 39.7                             | −25%       | 40.9                             |
| Other           | 43.9                             | (34.5, 55.7)                     | 33%        | 65.9                             | 13%        | 60.6                             | −8%        | 51.9                             | −14%       | 56.5                             |
| Mother's education |                                  |                                  |            |                                  |            |                                  |            |                                  |            |                                  |
| No education    | 62.8                             | (53.4, 73.7)                     | 3%         | 82.2                             | 27%        | 91.7                             | 12%        | 70.5                             | −23%       | 74.3                             |
| Primary education | 44.1                           | (32.5, 59.4)                     | 46%        | 66                               | 3%         | 49                               | −26%       | 62.2                             | 35%        | 57.7                             |
| Secondary education | 40.9                         | (31.1, 53.7)                     | 34%        | 47.8                             | −13%       | 52.3                             | 9%         | 41.7                             | −20%       | 47.6                             |
| Higher education | 17.7                             | (9.6, 32.2)                      | 137%       | 38.2                             | −43%       | 59.4                             | 53%        | 44.9                             |            |                                  |
| Wealth index    |                                  |                                  |            |                                  |            |                                  |            |                                  |            |                                  |
| Poorest         | 68.5                             | (54.4, 86.0)                     | 0%         | 82.5                             | 21%        | 103.4                            | 25%        | 56.3                             | −46%       | 76.3                             |
| Poorer          | 59.8                             | (46.9, 75.9)                     | 19%        | 79.6                             | 12%        | 69.7                             | −12%       | 75.1                             | 8%         | 71                               |
| Middle          | 50.8                             | (39.3, 65.5)                     | 17%        | 72.1                             | 21%        | 54.2                             | 9%         | 59.7                             | 7%         | 59.6                             |
| Richer          | 41.2                             | (28.5, 59.2)                     | 18%        | 51.4                             | 6%         | 55.8                             | 9%         | 66                               | 7%         | 51.1                             |
| Richest         | 20.6                             | (13.3, 31.8)                     | 123%       | 46                               | 0%         | 50.9                             | 11%        | 44.7                             | −12%       | 41.5                             |
| Covered by insurance |                                  |                                  |            |                                  |            |                                  |            |                                  |            |                                  |
| No              | 49.7                             | (43.7, 56.5)                     | 23%        | 69                               | 13%        | 69.4                             | 1%         | 60.3                             | −13%       | 62                               |
| Yes             | 64.7                             | (33.1, 122.5)                    | −66%       | 45.5                             | 108%       | 37.2                             | −18%       | 42.4                             | 14%        | 42.3                             |
| Place of delivery |                                  |                                  |            |                                  |            |                                  |            |                                  |            |                                  |
| Home            | 42.6                             | (33.1, 122.5)                    | 54%        | 76.9                             | 17%        | 78.1                             | 2%         | 62.1                             | −20%       | 70.2                             |
| Skilled provider | 26.6                             | (16.5, 43.5)                     | 100%       | 56.1                             | 6%         | 56.1                             | 0%         | 55.8                             | −1%        | 54                               |
| Other           | 27.6                             | (15.9, 43.5)                     | −24%       | 43.9                             | 17%        | 28                               | −36%       | 76.7                             | 174%       | 41.1                             |
| # of ANC visit  |                                  |                                  |            |                                  |            |                                  |            |                                  |            |                                  |
| No visit        | 47.5                             | (35.3, 59.5)                     | −26%       | 45                               | 28%        | 47.4                             | 5%         | 61.2                             | 29%        | 50.9                             |
| NA              | 47.5                             | (35.3, 59.5)                     | −26%       | 45                               | 28%        | 47.4                             | 5%         | 61.2                             | 29%        | 50.9                             |

**Table 1 (Continued)**
| Characteristics | 2013 Infant mortality rate (N=6489) | 2014 Infant mortality rate (N=6825) | Change (%) | 2015 Infant mortality rate (N=6752) | Change (%) | 2016 Infant mortality rate (N=6434) | Change (%) | 2017 Infant mortality rate (N=5503) | Change (%) | 2013-2017 Infant mortality rate (N=32,003) | Change (%) |
|-----------------|-----------------------------------|-----------------------------------|------------|-----------------------------------|------------|-----------------------------------|------------|-----------------------------------|------------|-----------------------------------|------------|
| 1-3 visits      | 0                                 | 44.7                              | −96%       | 46.7                              | 4%         | 34.4                              | −26%       | 51.6                              | 50%        | 43.4                              |            |
|                 | NA                                | (19.8, 97.9)                      |            | (26.6, 80.7)                      | NA         | (23.9, 49.1)                      | NA         | (36.5, 72.5)                      | NA         | (34.4, 54.7)                      |            |
| 4 visits        | 0                                 | 36.1                              | −96%       | 34.9                              | −3%        | 22.3                              | −36%       | 26.5                              | 19%        | 27.4                              |            |
|                 | NA                                | (18.9, 67.9)                      |            | (19.3, 62.4)                      | NA         | (12.6, 39.0)                      | NA         | (16.7, 41.6)                      | NA         | (21.0, 35.8)                      |            |
| >4 visits       | 12.9                              | 31.3                              | 143%       | 38.4                              | 23%        | 32.2                              | −16%       | 44.2                              | 37%        | 36.9                              |            |
|                 | NA                                | (21.0, 46.5)                      | (−206%, 491%)| (27.9, 52.8)                      | (−40%, 85%)| (24.8, 41.6)                      | (−51%, 18%)| (35.0, 55.6)                      | (−12%, 86%)| (32.1, 42.4)                      |            |
| ANC at home or skilled provider |                      |                                    |            |                                    |            |                                    |            |                                    |            |                                    |            |
| No              | 51.3                              | 66.1                              | 29%        | 81.4                              | 23%        | 115.3                             | 42%        | 103.7                             | −10%       | 74.8                              |            |
|                 | (45.1, 58.3)                      | (58.7, 74.4)                      | (8%, 50%)  | (72.6, 91.1)                      | (4%, 42%)  | (101.0, 131.4)                    | (17%, 66%) | (87.2, 123.0)                     | (−29%, 8%) | (70.0, 79.9)                      |            |
| Yes             | 9.2                               | 37.6                              | 308%       | 39.2                              | 4%         | 30.8                              | −21%       | 42.3                              | 37%        | 36.9                              |            |
|                 | (2.3, 36.1)                      | (27.6, 51.0)                      | (−272%, 888%)| (50.5, 50.1)                      | (−37%, 46%)| (25.4, 37.3)                      | (−46%, 4%) | (35.3, 50.7)                      | (0%, 75%)  | (33.2, 41.0)                      |            |
| C-section       | No                                | 33.5                              | 80%        | 68.9                              | 14%        | 68.6                              | 0%         | 57.6                              | −16%       | 63.1                              |            |
|                 | (54.0, 67.6)                      | (58.7, 74.4)                      | (17%, 144%)| (61.7, 76.9)                      | (−3%, 31%) | (61.1, 77.1)                      | (−16%, 15%)| (50.3, 66.0)                      | (−30%, −2%)| (59.2, 67.3)                      |            |
|                 | Yes                               | 71.2                              | 28%        | 56.1                              | 10%        | 75.2                              | 34%        | 147.8                             | 97%        | 80.5                              |            |
|                 | (25.4, 99.7)                      | (27.6, 51.0)                      | (−272%, 888%)| (26.6, 114.3)                     | NA         | (41.2, 133.4)                     | NA         | (76.6, 266.3)                     | NA         | (55.7, 115.0)                      |            |
| First child     | No                                | 50.0                              | 10%        | 64.8                              | 18%        | 72.2                              | 11%        | 58.6                              | −19%       | 60.2                              |            |
|                 | (43.3, 57.7)                      | (48.8, 62.1)                      | (−10%, 30%)| (57.4, 73.2)                      | (−1%, 37%) | (64.4, 80.9)                      | (−6%, 29%) | (50.8, 67.5)                      | (−34%, −4%)| (56.5, 64.1)                      |            |
|                 | Yes                               | 50.3                              | 57%        | 83.0                              | 5%         | 53.2                              | −36%       | 65.4                              | 23%        | 66.7                              |            |
|                 | (38.3, 65.6)                      | (63.4, 98.2)                      | (6%, 109%) | (66.6, 103.0)                     | (−27%, 37%)| (38.8, 72.5)                      | (−61%, −11%)| (48.1, 88.4)                      | (−21%, 67%)| (39.1, 75.2)                      |            |
| Low birth weight| No                                | NA                                | NA         | NA                                | NA         | NA                                | NA         | NA                                | NA         | 25.5                              |            |
|                 | Yes                               | NA                                | NA         | NA                                | NA         | NA                                | NA         | NA                                | NA         | (21.3, 30.6)                      | 37.3       |
|                 |                                   |                                   |           |                                   |            |                                   |            |                                   |            | (21.9, 31.1)                      |            |

Table 1: Infant mortality by population characteristics in 2013–2017 (per 1000 births).
ANC: Antenatal care; C-section: Caesarean section; NA: Not applicable.
Note: Due to the small sample size or large variation, confidence intervals cannot be calculated in which “not applicable (NA)” is marked.
risk of experiencing death relative to children born to women aged 19 to 35.

At the demographic level, we observed that rurality and religion are risk factors for infant mortality. Children born to women living in the rural areas relative to urban areas are more likely to experience death as infants. Living in rural areas could be associated with higher levels of poverty and dearth of quality health services to prevent infant mortality. This pattern has been documented severally in the literature. In addition, our findings show that children born to women who reported Islam as a religion were more likely to experience death as infants. This association may have nothing to do with Islamic practice but could be because of the prevalence of high mortality rate in the North, where Islamic religion is more predominant.

At the level of healthcare delivery, the number of ANC visits, type of delivery, and location of ANC visits are risk factors for infant mortality. With regards to the number of ANC visits, our findings show that children born to women who had less than the recommended ANC visits of 4 were more likely to experience death relative to women who went for the recommended visits. ANC visit is a strong predictor of health facility delivery by a skilled health professional and postnatal care utilization. Thus, ensuring that pregnant women have access to timely ANC services is crucial to reducing infant mortality. However, we also observed that children born to women who went for more than the recommended ANC visits of 4 were more likely to experience death. The mechanism for this result is unclear since high ANC visits should correlate with better health outcomes. Our hypothesis is that there might be some health-related conditions among the women or their babies so that they have to visit ANC more than the recommended time. However, the type and quality of services received during the visit is not known and may influence the outcome of care for the infants.

Furthermore, children born to women who received C-section during delivery were more likely to experience death as infants relative to children born to women who did not deliver through C-section. The higher likelihood of death for infants born through C-section could be due to the complexity of the procedure, category of the C-section (primary or repeat) and the lack of a quality skilled health provider to oversee the process and address any complications that may arise during child delivery. In fact, many studies have documented the association between C-section and infant mortality.

Finally, the location of ANC visits is extremely crucial. Children born to women who received ANC at home or from a skilled provider were more likely not to experience death relative to children born to women who did not receive ANC at home or from a skilled provider. The place where ANC is received is important, particularly when it is delivered by an untrained person, who may not be able to recognize signs of complications and provide necessary guidance on how to receive timely and quality care. In Nigeria, particularly in the rural areas, there is a prevalence of cultural practices that promotes the use of traditional birth attendants during pregnancy and delivery. Studies have shown that care received at this level and through such personnel is more likely to be suboptimal and lack the clinical components necessary for a good-quality care.

With regards to reducing the high IMR, Nigeria has implemented several interventions and policies to improve infant mortality. An example is the Nigeria Midwives Service Scheme (MSS), a public sector collaborative initiative established in December 2009 by the National Primary Health Care Development Agency (NPHCDA). The goal of MSS was to facilitate an
increase in the coverage of skilled Birth Attendance (SBA) to reduce maternal, newborn and child mortality in rural, underserved areas in Nigeria by December 2015. MSS was implemented by deploying midwives, including newly qualified, unemployed, and retired midwives to selected primary health care (PHC) facilities in rural communities equipping clinics to provide basic emergency obstetric care. The first phase of the initiative took place in 652 PHC facilities across the 36 states in Nigeria with over 10 million people served. Based on our results, however, the persistent high IMR means that Nigeria is not on track to achieving the SDG target of reducing child mortality by 2030 despite interventions and policies like the MSS. The Nigerian government would need to fully evaluate the design and impact of all old and current policies, learn from them, and use the findings to re-create context-specific interventions that would help mitigate the high prevalence of infant mortality in the country.

A recent comparison study linked the socioeconomic inequalities in the North with the high prevalence of IMR in the region.23 The government must continue to work intentionally and collaboratively with the private sector, international donors, healthcare providers and community actors to prioritize maternal and childcare interventions in the North if it hopes to reverse the increasing infant mortality trend in the country. Evidence abounds in the literature linking children of younger mothers to having poorer health outcomes including mortality.24−26 Studies have also shown the association between older maternal age and adverse birth and child outcomes.27,28 Having children born to both younger and elderly women at higher risk of infant mortality means that interventions to reduce child mortality must be targeted to address the entire spectrum of a woman’s reproductive period.

According to our results and the previous evidence, specifically, some interventions for improving the mothers’ condition need to be considered. Such as improving antenatal to postnatal care across regions to ensure a healthy pregnancy, labor, and delivery for both the mother and the infant; evaluating the delivery method procedures in cases such as c-section, to avoid preventable complications during child delivery that could lead
to death. Additionally, strategies to maintain the availability of health care workers in low resource settings need to be sustained to improve maternal care quality. Lastly, with the recent development of the pandemic on an already strained health system, we recommend further research into the effect of COVID-19 on the SDG target of reducing child mortality by 2030.

This is a large, population-level study analyzing IMR in Nigeria. Along with the descriptive demonstration of cross-sectional and trend analyses on overall IMR and IMR by participants’ characteristics, we also investigated how the characteristics could be associated with the risk of IM. For the analysis on the association, we used rigorous methods including the application of
careful adjustment in the statistical models as well as the use of multiple comparisons analysis to confirm the statistical significance from the models. However, this study is not without any limitations. The NDHS was conducted in a retrospective manner at a population-level scale. Accordingly, the survey is not specifically designed to investigate infant mortality and its risk factors. Also, it is likely that some responses to the survey would have been limited due to potential recall bias and a small sample size of participants. Especially for the association between low birth weight and IM, the quality of the variable, low birth weight (small sample size with a large amount of missing data in the NDHS), mainly accounted for the non-positive result on its association with IMR, which should be considered as non-meaningful value for data interpretation. Potentially valuable variables that are missing in the study include gestational age, diseases occurring during the infant period, mothers’ and infants’ nutrition status, etc. For a potential risk factor, the impact of these variables deserves to be investigated among Nigerian people in future studies. Some of these variables (e.g., low birth weight, gestational age) could be valuable as used for adjustment; again, we failed to fully use the variables due to the availability or quality as mentioned. Furthermore, the results from our study may not indicate a causal effect between risk factors and IM, due to the cross-sectional design. This is the main reason we investigated the associations for each year separately between 2013 and 2017, to know whether a temporary effect could occur in the associations. However, the investigations by year were affected by the limited sample size. Regarding sample size, we did not provide a sample size estimate in the research, since the NDHS is likely the largest population-level survey with available variables to investigate IMR and its risk factors in the country.

In conclusion, higher risks for infant mortality rates in Nigeria were found for women who were less than 18 years old, from rural areas, have limited or no access to health care/skilled providers, and women who delivered their first child. The associations are influenced by mothers’ community, financial hardship, and inability to access quality of care.

Contributors
Literature search – D.M.S., A.O., and F.M.E.; Study Design – Y.Z., J.Z., and H.O.S.; Data collection, Data Analysis – Y.Z., D.M.S., and J.Z.; Data Interpretation, Result – Y.Z., J.Z., and D.M.S.; Figures – Y.Z., D.M.S., and J.Z.; Discussion – H.O.S., D.M.S., and J.Z.; Conclusion – D.M.S.; Writing, review and editing – D.M.S., H.O.S., J.Z., F.M.E., A.O. Each author substantially contributed to conducting this study, adding intellectual content and approved the final draft. All authors had full access to the data in the study and take responsibility for the integrity and accuracy of the data analysis.

Data sharing statement
The data used to produce the analysis are readily available upon request from: https://dhsprogram.com/data/dataset_admin/login_main.cfm.

Declaration of interests
The authors declare no conflicts of interests.

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Supplementary materials
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