Research Square

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# The lethal gradient: wealth, education and geographic inequalities in neonatal, infant and under-five mortality in Nigeria, evidence from the 2023–24 Demographic and Health Survey

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**Research Article**

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## Abstract

# Background

Nigeria contributes a significant proportion of under-five mortality worldwide, but averages may be masking the disparities in the distributions of these risks. This study estimated socio-economic and geographic inequalities in neonatal, infant and under-five mortality, the attributable deaths and their predictors.

# Methods

This study examined 54 971 live births in the 10 years prior to the 2023-24 Nigeria Demographic and Health Survey and estimated mortality rates with the synthetic cohort life-table method, measured inequality using rate ratios, population attributable fractions and the Erreygers concentration index; and decomposed the latter. We used survey-weighted discrete-time survival models to study under-five mortality in 27 554 recent births.

# Results

The under-five mortality rate was 110.1 per 1000 live-births (95% CI 103.4-117.5) in the five years preceding the survey. Over ten years this was 139.7 per 1000 in the poorest wealth quintile and 49.1 in the richest, ratio 2.85, and 129.7 among children born to mothers without any education vs. 43.2 among children born to mothers with higher education. Inequality by wealth ratio increased to 1.43 (neonatal), 3.07 (post-neonatal) and 6.82 (1–4 years or child mortality). If all children experienced mortality rates of the richest quintile, 52.5% of under-five and 77.1% of 1–4-year-old deaths would not have occurred. Most of under-five mortality inequality was attributable to household wealth (45.5%), then to geopolitical zone (33.2%) and rurality (17.5%). Adolescent mothers, short birth interval (less than 24 months) and multiple birth increased risk.

# Conclusions

In Nigeria the impact of socio-economic disadvantage on death is most devastating after the first month of life. Abolishing wealth inequalities in mortality would eliminate 50% of all deaths in children under 5. Eliminating disparities demands child survival efforts in North West, North East and poor rural places, progress in girls' schooling and family planning, and quality newborn care.

## Background

Child mortality (death before age five) is the starkest indicator of health inequality. Child mortality has declined considerably over the last few decades, but this has been highly variable within and between

countries, and the reduction has been much faster at the national level than at the household level [1]. The majority of under-five child deaths now occur in sub-Saharan Africa, with Nigeria accounting for the largest number due to its large and growing births cohort, yet where this death takes place within the country and from which families remains poorly understood. The average death rate gives little insight into these questions and where inequality comes in. Numerous studies have documented socioeconomic gradients in child survival in low- and middle-income countries. Household survey analyses have shown the substantial increase in the risk of mortality for children in the poorest quintiles compared to the richest ones and that parental and particularly maternal education is one of the strongest and most robust determinants of child survival [1, 2]. Decomposition analysis of under-five mortality measures in sub-Saharan Africa have shown that wealth, maternal education and residence explain most of the inequality, although their relative contribution differed across countries [3]. In Nigeria, recent work has identified the north-south divide with regards to under-five mortality and the factors driving it, such as maternal education, fertility and health service coverage [4].

Two aspects of the gradient have received less focus. One is the pattern of inequality by age: neonatal mortality is mostly the result of complications of preterm birth, intrapartum and neonatal infections, and are consequently sensitive to delivery and neonatal care; versus post-neonatal deaths mostly due to infectious diseases, undernutrition and lack of access to essential health care, which are most strongly related to household circumstances. In this case, a steeper gradient in older children would call for a different policy focus on inequalities than does the gradient in the average. The second aspect is the deadly weight of inequality itself: how many child deaths could be prevented if children in all subgroups faced the death rates of the best-off subgroup, translating an abstractly calculated inequality statistic into a number that can be directly considered by policymakers [5]. A third route is via fertility behaviour. Short birth intervals, births by adolescent mothers, high birth order and multiple births are all linked to elevated child mortality in West Africa and elsewhere [6–8], and short birth intervals continue to be prevalent in high-fertility countries in the region [9]. Since each of these fertility patterns are themselves socially determined, they may serve to transmit part of the influence of poverty and low education on child mortality. Decomposition approaches enable us to quantify the proportion of the inequality that is mediated through each of these channels [10, 11]. Nigeria Demographic and Health Survey 2023-24 The latest, nationally representative birth histories of Nigeria are derived from the Nigeria Demographic and Health Survey (NDHS) 2023-24. This study sets out to (i) estimate neonatal, post-neonatal, infant, child and under-five mortality by household wealth, mother's education, place of residence, geopolitical zone and state; (ii) calculate the share of inequality in mortality accounted for by socioeconomic inequality; (iii) decompose the Erreygers concentration index of inequality into determinants of inequality and demand curve slopes; and (iv) determine the underlying drivers of inequality and of overall mortality risk.

## Data source and design

The study is a cross-sectional secondary data analysis of the 2023-24 NDHS (implemented by the National Population Commission with technical support from ICF) [12]. The NDHS sampled a stratified two-stage cluster sampling design: enumeration areas were selected using probability proportional to

size with 74 strata (state and urban or rural designations), then households were randomly sampled in each enumeration area. Fieldwork was conducted from December 2023 to May 2024. Interviewers randomly selected one woman aged 15–49 years in each household and completed a full history of live births in the last 5 years, recording each child's age at death, if applicable, and age at interview date. Data were analysed from the births recode file (NGBR8BFL), which contains one record per live birth.

# Outcomes

Five basic mortality rates were calculated: neonatal mortality (death during the first 28 days of life), post-neonatal mortality (infant minus neonatal mortality), infant mortality (death before age 1), childhood mortality (deaths between exact ages 1 and 5 years among children who had survived to age 1) and under-five mortality (death before age 5). All are given as ratios per 1,000 live births, except for child mortality, which is per 1,000 surviving children to age 1. Because these analyses use individual-level binary outcomes, we constructed three cohorts who were fully exposed to the risk of death so as not to censor early. Neonatal death refers to babies born 1–59 months before interview (n = 27 338). Infant death refers to babies born 12–59 months before interview (n = 22 061). Under-five death refers to babies born 60–119 months before interview (n = 27 417), who had either reached or died prior to their fifth year at the time of the survey.

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## Equity stratifiers and explanatory variables

Household wealth was the primary equity stratifier. DHS wealth index was based on the principal component analysis of household assets, type of materials and access to water and sanitation. Births were ordered along the continuous aggregate wealth score for the calculation of the concentration index and categorised into the national quintiles for rates and regression analysis. Maternal education, place of residence (urban or rural), geopolitical zone and state were considered as the other dimensions of inequalities. For regression and decomposition analyses, the following explanatory variables were used: household wealth quintile; maternal education (none, primary, secondary, higher); place of residence; zone of residence; maternal age at time of birth (less than 18 years, 18–34 years and 35 years or older); preceding birth interval (first birth, less than 24 months, 24–35 months and 36 months or more); birth order of five or higher; child sex; multiple birth; religion; health insurance of mother; sex of household head. No data were used on use of antenatal, delivery and postnatal care, as these are only available for recent births and are part of the causal pathway between socioeconomic position and survival.

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# Statistical analysis

Mortality was estimated by the synthetic cohort life-table approach used in the DHS programme. Age-specific probability of dying was derived for eight age groups (0, 1–2, 3–5, 6–11, 12–23, 24–35, 36–47 and 48–59 months) from deaths and exposure in the reference period and multiplying them together the resultant value is the cumulative probability. Rates by state and by subgroup are provided over the 10-year period before the survey in order to have stable estimates, while the rates by country are for the five-year period before the survey, the more commonly used period.10 Confidence intervals (95%) were derived from 150–200 bootstrap replicates resampling within cluster within strata. Absolute and relative inequalities were also summarized as gaps and ratios between the most and least advantaged. The burden attributable to inequality was estimated as a population attributable fraction (PAF), calculated as the national rate minus the rate in the most advantaged (richest quintile, or mothers with higher education), divided by the national rate. The PAF is the proportion of deaths that would not have occurred if all children had the same mortality as the most advantaged group.

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Wealth-related inequality in each binary outcome was measured with the Erreygers corrected concentration index, E = 4μC, where μ is the weighted mean of the outcome and C is the standard concentration index computed against each birth's weighted fractional rank in the wealth distribution [13, 14]. Negative values signify that deaths are more concentrated among poor children. Standard errors were derived from 300 bootstrap resamples of clusters. Concentration curves show the cumulative share of deaths according to the cumulative share of births ranked from poorest to richest.The Erreygers indices for infant and under-five death were decomposed into contributions from the explanatory variables following Wagstaff et al. [10] and O'Donnell et al. [11]. A weighted linear probability model was fitted, and each factor's contribution was calculated as $4 \times \beta_k \times \bar{x}_k \times C_k$, where $\beta_k$ is the regression coefficient, $\bar{x}_k$ the weighted mean and $C_k$ the concentration index of the factor with respect to wealth. Contributions with the same sign as the overall index widen inequality, and contributions with the opposite sign offset it. The neonatal index was not decomposed because it did not differ significantly from zero.

Adjusted associations with under-five death were estimated with a survey-weighted discrete-time survival model on person-period data for live births within the previous five years. Each live birth generated one observation per age segment experienced, and segment indicators were included to specify the baseline hazard along with all covariates. Live births were censored at the date of interview. Adjusted odds ratios (aORs), which approximate hazard ratios for rare events, are presented with 95% confidence intervals from a design-based sandwich variance estimator that controls for clustering and stratification, and multi-category variables are tested with joint Wald tests. Analyses were performed in Python 3 with the pandas and statsmodels packages, applying women's sampling weights, and the STROBE cross-sectional reporting guideline is followed..

## Ethical considerations

The NDHS interview protocol received ethical clearance from the ICF Institutional Review Board and appropriate national committee in Nigeria, and all respondents provided written and informed consent prior to interview. The present study was based on anonymized public-use data obtained with permission from the DHS Program and did not require ethical approval.

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## Use of artificial intelligence tools

An artificial intelligence assistant (Claude, Anthropic) was used to support statistical programming and the drafting of text. The author specified the research questions and analytic approach, checked all code, outputs and references, revised the manuscript and takes full responsibility for its content.

## Results

# Sample and national mortality levels

These included 54 971 live births over the ten years before the survey, including 27 554 in the five years before the survey. Table 1 shows recent births and ten-year mortality rates by background characteristics. Neonatal mortality in the five years before the survey was 41.1 (95% CI 37.2–45.1), post-neonatal mortality 22.3, infant mortality 63.3 (58.8–67.6), child mortality 49.9 and under-five mortality 110.1 (103.4-117.5) per 1000, while ten-year rates were 37.9, 21.3, 59.3, 46.9 and 103.3 respectively.

Table 1
Distribution of births and childhood mortality rates by background characteristics, Nigeria

| Characteristic | n | % | NMR (95% CI) | IMR (95% CI) | U5MR (95% CI) |
|---|---|---|---|---|---|
| **Household wealth quintile** | | | | | |
| Poorest | 7194 | 24.4 | 41.3 (36.4–46.5) | 71.6 (64.2–78.4) | 139.7 (129.4–149.0) |
| Poorer | 5582 | 22.8 | 42.4 (37.4–48.6) | 71.1 (63.6–78.7) | 135.7 (122.4–146.6) |
| Middle | 5342 | 20.2 | 36.9 (30.8–43.6) | 54.3 (48.8–61.1) | 93.1 (86.6–101.1) |
| Richer | 5078 | 17.5 | 36.3 (32.0–40.5) | 50.0 (44.5–54.6) | 69.8 (62.7–75.5) |
| Richest | 4358 | 15.1 | 28.9 (24.2–34.0) | 38.7 (33.2–43.9) | 49.1 (42.7–54.5) |
| **Maternal education** | | | | | |
| No education | 12161 | 47.0 | 41.0 (36.6–45.5) | 67.6 (62.0–72.9) | 129.7 (120.8–139.6) |
| Primary | 3183 | 11.9 | 38.0 (32.0–44.4) | 62.9 (56.3–71.3) | 107.8 (98.8–118.2) |
| Secondary | 9222 | 31.2 | 37.0 (33.4–40.9) | 52.4 (48.1–57.5) | 75.9 (69.3–82.8) |
| Higher | 2988 | 9.9 | 25.0 (19.7–30.2) | 33.5 (27.6–38.9) | 43.2 (36.7–49.1) |
| **Place of residence** | | | | | |
| Urban | 10606 | 38.4 | 31.5 (28.5–35.5) | 45.1 (41.5–50.3) | 68.8 (64.7–75.9) |
| Rural | 16948 | 61.6 | 42.0 (38.6–46.0) | 68.3 (64.3–72.9) | 125.7 (118.8–133.5) |
| **Geopolitical zone** | | | | | |
| North West | 8553 | 39.6 | 48.1 (43.4–53.1) | 76.5 (70.5–82.5) | 140.4 (130.5–149.0) |
| North East | 5837 | 19.8 | 40.1 (34.5–46.5) | 66.0 (59.1–74.1) | 126.7 (114.5–137.6) |

n: unweighted number of live births in the five years preceding the survey; %: weighted distribution of those births. Mortality rates are for the ten years preceding the survey (54 971 births), per 1000 live births, with 95% confidence intervals from a stratified cluster bootstrap. NMR: neonatal mortality rate; IMR: infant mortality rate; U5MR: under-five mortality rate.

| Characteristic | n | % | NMR (95% CI) | IMR (95% CI) | U5MR (95% CI) |
|---|---|---|---|---|---|
| **Household wealth quintile** | | | | | |
| North Central | 5007 | 16.4 | 27.7 (23.7–32.9) | 42.1 (37.3–48.1) | 64.9 (57.6–73.2) |
| South East | 3035 | 7.2 | 32.8 (26.1–37.5) | 47.8 (41.5–54.1) | 70.5 (62.2–77.8) |
| South South | 2638 | 7.4 | 25.0 (19.9–29.8) | 36.2 (30.7–41.5) | 50.1 (43.5–56.2) |
| South West | 2484 | 9.6 | 24.2 (18.7–30.5) | 32.7 (25.7–37.8) | 41.8 (34.4–48.5) |
| **Maternal age at birth (years)** | | | | | |
| Under 18 | 1182 | 4.7 | 56.7 (44.5–68.6) | 92.0 (78.8–106.3) | 150.1 (135.7–165.0) |
| 18–34 | 21604 | 78.3 | 35.4 (32.8–37.7) | 55.5 (52.1–58.9) | 98.7 (92.3–103.1) |
| 35 or older | 4768 | 17.0 | 44.0 (38.8–52.0) | 65.9 (58.2–75.9) | 108.4 (100.1–118.7) |
| **Preceding birth interval** | | | | | |
| First birth | 5517 | 20.0 | 43.9 (38.7–49.0) | 64.4 (57.1–70.4) | 98.9 (92.0–106.9) |
| Under 24 months | 5279 | 19.1 | 57.2 (51.6–63.4) | 85.3 (77.9–92.3) | 144.9 (135.8–154.6) |
| 24–35 months | 7536 | 27.1 | 30.3 (27.3–33.7) | 53.2 (49.3–57.7) | 100.4 (93.7–108.0) |
| 36 months or longer | 9222 | 33.8 | 26.5 (23.7–29.2) | 41.7 (38.4–45.2) | 75.9 (71.0–81.8) |
| **Sex of child** | | | | | |
| Male | 13939 | 50.8 | 42.6 (39.2–45.7) | 63.9 (60.0–67.9) | 105.7 (99.7–111.4) |
| Female | 13615 | 49.2 | 33.1 (29.9–35.3) | 54.5 (50.7–57.4) | 100.9 (96.2–105.4) |
| **Type of birth** | | | | | |
| Singleton | 26521 | 96.4 | 34.1 (32.2–36.9) | 54.5 (51.9–57.7) | 97.6 (93.6–102.4) |

n: unweighted number of live births in the five years preceding the survey; %: weighted distribution of those births. Mortality rates are for the ten years preceding the survey (54 971 births), per 1000 live births, with 95% confidence intervals from a stratified cluster bootstrap. NMR: neonatal mortality rate; IMR: infant mortality rate; U5MR: under-five mortality rate.

| Characteristic | n | % | NMR (95% CI) | IMR (95% CI) | U5MR (95% CI) |
|---|---|---|---|---|---|
| **Household wealth quintile** | | | | | |
| Multiple | 1033 | 3.6 | 143.4 (122.8–167.6) | 190.9 (166.7–215.4) | 265.0 (232.9–298.0) |

n: unweighted number of live births in the five years preceding the survey; %: weighted distribution of those births. Mortality rates are for the ten years preceding the survey (54 971 births), per 1000 live births, with 95% confidence intervals from a stratified cluster bootstrap. NMR: neonatal mortality rate; IMR: infant mortality rate; U5MR: under-five mortality rate.

## Socioeconomic and geographic gradients

Under-five mortality decreased as household wealth increased (139.7 in the poorest quintile, 135.7 in the second) to 93.1, 69.8 and 49.1 in the middle, fourth and richest quintiles (Fig. 1, Table 1). The under-five mortality rate was 129.7 per 1000 in children born to mothers with no education compared to 43.2 per 1000 in children born to mothers with higher education. The under-five mortality rate for children born in rural areas was 1.83 times higher than that for children born in urban areas (125.7 versus 68.8). Geographical region had the largest absolute difference in under-five mortality rate: 140.4 per 1000 in the North West and 126.7 in the North East compared with 64.9 in the North Central, 70.5 in the South East, 50.1 in the South and 41.8 in the South West.At state level, rates varied from less than 25 per 1,000 in Kwara, Ondo, Edo and Oyo to over 150 per 1,000 in Jigawa, Kebbi, Kano, Gombe and Kaduna (Fig. 2, Additional file 1). The very low state estimates are unexpectedly low and may in some cases reflect incomplete reporting of deaths.

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# The gradient steepens with age

Inequality by relative place of residence increased with age. For neonatal mortality the ratio was 1.43 (41.3 versus 28.9) for the poorest and the richest, 3.07 (30.3 versus 9.9) for the post neonatal and 6.82 (73.3 versus 10.7) for child mortality. The inequalities by maternal education is similar to those by richest-poorest (1.64 for neonatal to 6.67 for child mortality) and those by place of residence (1.33 for neonatal to 2.48 for child mortality). The concentration indices tell the same story (Fig. 3). Neonatal mortality was only marginally concentrated among the poor and the Erreygers index not significantly different from zero (0.006, 95% CI 0.013 to 0.002; $p = 0.134$). Infant mortality was modestly concentrated among the poor (0.021, 95% CI 0.032 to 0.011; $p < 0.001$). Under-five mortality among births 5–9 years preceding the survey was strongly concentrated among the poor (0.081, 95% CI 0.094 to 0.068; $p < 0.001$). The standard concentration indices were 0.035, 0.087 and 0.207.

# Deaths attributable to inequality

If all children had had the mortality rate of the richest quintile, 52.5% of under-five deaths would have been averted (Table 2). The attributable fraction was 23.9% for neonatal deaths, 53.7% for post-neonatal deaths and 77.1% for the 1–5-year age group. An even higher attributable fraction (58.2%) was achieved with the mortality of children with mothers with higher education as the counterfactual. Equally, 33.4% of under-five deaths could have been averted if the excess mortality of rural compared to urban areas had been eliminated..

Table 2
Socioeconomic inequalities and deaths attributable to inequality, by age at death, Nigeria

| Age at death | National rate | Poorest | Richest | Ratio poorest: richest | Ratio no: higher education | Ratio rural: urban | PAF wealth % | PAF education % |
|---|---|---|---|---|---|---|---|---|
| Neonatal | 37.9 | 41.3 | 28.9 | 1.43 | 1.64 | 1.33 | 23.9 | 34.1 |
| Post-neonatal | 21.3 | 30.3 | 9.9 | 3.07 | 3.10 | 1.94 | 53.7 | 59.9 |
| Infant | 59.3 | 71.6 | 38.7 | 1.85 | 2.02 | 1.52 | 34.6 | 43.4 |
| Child (1–4 years) | 46.9 | 73.3 | 10.7 | 6.82 | 6.67 | 2.48 | 77.1 | 78.7 |
| Under-five | 103.3 | 139.7 | 49.1 | 2.85 | 3.00 | 1.83 | 52.5 | 58.2 |

Rates per 1000 live births (child mortality per 1000 children surviving to age one) for the ten years preceding the survey. Ratios compare the poorest with the richest wealth quintile, mothers with no education with mothers with higher education, and rural with urban residence. PAF (population attributable fraction) is the percentage of deaths that would not have occurred if all children had experienced the rate of the richest quintile (wealth) or of children of mothers with higher education (education).

# Contributors to inequality

Results of the decomposition are shown in Table 4 and Fig. 4. The covariates explained almost all the inequality in each outcome (95.4% of infant death, 100.6% of under-five death). For under-five mortality, household wealth explained the largest share (45.5%), followed by geopolitical zone (33.2%) and residence (rural 17.5%). Short birth intervals and first births contributed 5.7%, high birth order explained 4.3% and maternal age at birth explained 2.2%. The contribution of maternal education was small, offsetting the contribution of other factors by 7.7% once wealth and geography had been taken into account. The factors were quite different for infant death. Geopolitical zone was the single most important contributor at 63.3% and significantly bigger than either the RE factors or education: Rural residence contributed 43.7%, while a mother's education contributed 27.7%. The interplay of the reproductive factors was less: birth interval 8.9%; mothers' age at child's birth 8.6%; and birth order 1.0%. The contribution of household wealth was all negative (− 51.0%) when these other variables were included.

Table 4
Decomposition of wealth-related inequality in infant and under-five deaths, Nigeria

| Factor | Infant death | | Under-five death | |
|---|---|---|---|---|
| | Contribution | % of index | Contribution | % of index |
| Household wealth | 0.0108 | −51.0 | −0.0369 | 45.5 |
| Maternal education | −0.0059 | 27.7 | 0.0062 | −7.7 |
| Geopolitical zone | −0.0134 | 63.3 | −0.0269 | 33.2 |
| Urban residence | −0.0092 | 43.7 | −0.0142 | 17.5 |
| Maternal age at birth | −0.0018 | 8.6 | −0.0017 | 2.2 |
| Birth interval/first birth | −0.0019 | 8.9 | −0.0047 | 5.7 |
| Birth order 5+ | −0.0002 | 1.0 | −0.0035 | 4.3 |
| Multiple birth | 0.0010 | −4.5 | 0.0014 | −1.8 |
| Child sex | 0.0000 | −0.2 | −0.0000 | 0.0 |
| Religion | 0.0007 | −3.2 | −0.0014 | 1.7 |
| Health insurance | −0.0001 | 0.3 | 0.0000 | −0.0 |
| Female-headed household | −0.0002 | 0.9 | 0.0001 | −0.1 |
| Total explained | −0.0202 | 95.4 | −0.0815 | 100.6 |
| Residual | −0.0010 | 4.6 | 0.0005 | −0.6 |
| Erreygers concentration index | −0.0212 | 100.0 | −0.0810 | 100.0 |

Contribution is 4 × β × mean × concentration index of each factor, summed across its categories, from a weighted linear probability model. Infant death: births 12–59 months before the survey (n = 22 061). Under-five death: births 60–119 months before the survey (n = 27 417). Because the overall indices are negative, positive percentages widen and negative percentages offset pro-poor inequality. Figures may not sum exactly because of rounding.

# Factors associated with under-five death

Discrete-time survival model had 27 554 births, 2180 deaths, and 152 295 person-years (Table 3). Adjusted for all factors, children in North Central (aOR 0.60, 0.95% CI 0.48–0.75), South East (aOR 0.56, 0.42–0.75), South (aOR 0.53, 0.39–0.72) and South West (aOR 0.60, 0.46–0.78) regions had 40–47% lower odds of death than those in North West (joint $p < 0.001$) and urban residence was protective (aOR 0.82, 0.70–0.96). Higher maternal education was independently associated with reduced risk (aOR 0.72, 0.52-1.00; $p = 0.050$). The effect of household wealth on under-five mortality was not significant with the adjustment of other covariates (joint p-value = 0.087).

Table 3
Adjusted odds ratios for under-five death from a discrete-time survival model, Nigeria

| Variable | aOR (95% CI) | p |
|---|---|---|
| **Household wealth (ref: poorest)** | | |
| Poorer | 1.14 (0.97–1.35) | 0.109 |
| Middle | 0.86 (0.68–1.08) | 0.182 |
| Richer | 0.93 (0.74–1.16) | 0.509 |
| Richest | 0.97 (0.72–1.31) | 0.843 |
| **Maternal education (ref: none)** | | |
| Primary | 1.13 (0.92–1.39) | 0.246 |
| Secondary | 0.97 (0.80–1.18) | 0.770 |
| Higher | 0.72 (0.52–1.00) | 0.050 |
| **Residence (ref: rural)** | | |
| Urban | 0.82 (0.70–0.96) | 0.015 |
| **Zone (ref: North West)** | | |
| North East | 0.93 (0.79–1.09) | 0.378 |
| North Central | 0.60 (0.48–0.75) | < 0.001 |
| South East | 0.56 (0.42–0.75) | < 0.001 |
| South South | 0.53 (0.38–0.72) | < 0.001 |
| South West | 0.59 (0.46–0.78) | < 0.001 |
| **Maternal age at birth (ref: 18–34)** | | |
| Under 18 | 1.45 (1.17–1.80) | < 0.001 |
| 35 or older | 1.16 (0.99–1.36) | 0.074 |
| **Preceding birth interval (ref: 24–35 months)** | | |
| First birth | 1.33 (1.10–1.61) | 0.003 |
| Under 24 months | 1.64 (1.41–1.91) | < 0.001 |
| 36 months or longer | 0.84 (0.72–0.96) | 0.014 |

Survey-weighted discrete-time survival (logistic) model fitted to 152 295 person-periods from 27 554 births in the five years preceding the survey (2180 deaths). The model also included indicators for the eight age segments. aOR: adjusted odds ratio; 95% confidence intervals from a design-based variance estimator accounting for stratification and clustering.

| Variable | aOR (95% CI) | p |
|---|---|---|
| **Household wealth (ref: poorest)** | | |
| **Birth order (ref: 1–4)** | | |
| 5 or higher | 1.09 (0.97–1.23) | 0.165 |
| **Child sex (ref: male)** | | |
| Female | 0.91 (0.82–1.01) | 0.065 |
| **Type of birth (ref: singleton)** | | |
| Multiple | 3.70 (2.98–4.59) | < 0.001 |
| **Religion (ref: Christian)** | | |
| Islam | 1.00 (0.81–1.22) | 0.979 |
| Traditional/other | 1.25 (0.76–2.05) | 0.382 |
| **Health insurance (ref: no)** | | |
| Yes | 0.92 (0.58–1.47) | 0.736 |
| **Household head (ref: male)** | | |
| Female | 0.94 (0.78–1.15) | 0.569 |

Survey-weighted discrete-time survival (logistic) model fitted to 152 295 person-periods from 27 554 births in the five years preceding the survey (2180 deaths). The model also included indicators for the eight age segments. aOR: adjusted odds ratio; 95% confidence intervals from a design-based variance estimator accounting for stratification and clustering.

Independently, reproductive and biological factors were strongly associated with mortality. Births to mothers under 18 years had higher odds of death than births to mothers 18–34 years (aOR 1.45, 1.17–1.80). Compared with births following an interval of 24–35 months, those following an interval less than 24 months were more likely to die (aOR 1.64, 1.41–1.91) whereas those following an interval of 36 months or more were less likely (aOR 0.84, 0.73–0.97), as were first births (aOR 1.33, 1.10–1.61). Multiple births were associated with increased odds of death, 3.7 times higher than singletons (aOR 3.70, 2.98–4.59).

# Discussion

The study found that unequal survival chances for children in Nigeria reveal an extremely skewed distribution of under-five mortality, with children in the poorest quintile of households nearly three times more likely to die before age five than children in the wealthiest quintile. Likewise, children of mothers with no education were about three times more likely to die than children of more educated mothers. These inequalities mean that about half of all under-five deaths and more than three-quarters of deaths in children ages 1–4 years could be avoided if all children experienced the same probability of survival as

children in the wealthiest quintile of households. The gradient in chance of survival was flat during the neonatal period, then became very steep. The magnitude of the observed wealth disparity is consistent with estimates across nations reporting that under-five mortality is 2–3 times higher in the poorest quintile than the richest within low- and middle-income countries [1]. The educational gradient aligns with global meta-analyses which found each additional year of maternal education to be significantly associated with lower child mortality [2]. The predominance of wealth, region and residence in the decomposition conforms to other research from sub-Saharan African countries [3] and between contrasting high- and low-mortality Nigeria regions [4].The age profile of inequality is by far the most policy-relevant result. Neonatal mortality rates are high across all wealth groups, and even in the richest quintile, nearly 30 per 1000 infants die in their first month of life, which is only weakly concentrated among the poor. This means that the greatest obstacle to neonatal survival in Nigeria is not access to care per se, but quality of care in the birth period, which is inadequate for rich and poor alike. The finding resonates with global analyses showing that many newborn deaths in low- and middle-income countries take place in infants born in the health facilities who received poor-quality care [15]. In contrast, after the first month of life death rates are strongly concentrated among the poor, with an eightfold gap in child mortality between rich and poor. There a variety of preventable or treatable diseases with immunisation, insecticide-treated nets and sanitation, adequate nutrition and prompt case management could significantly reduce under-5 child mortality [16]. The observed inequality at these ages is due to unequal access to such interventions-such as childhood immunisation, which is socially and geographically patterned in Nigeria [17, 18]-a phenomenon described by the inverse equity hypothesis [19].

The single most important structural factor was geography. The North West and North East had 2–3 times higher mortality rates than the southern zones, and even after controlling for wealth and education the zone remained significantly associated with both the instantaneous and expected risks of under-five death. There is probably also a combination of differences in health system capacity, the number of health workers and facilities, and the size of the insecurity burden that explain these differences. Insecurity was associated with infant deaths but did not significantly contribute to inequality in under-fives in the decomposition (data not shown), and armed conflict in the North East has been shown to be capable of negatively affecting vaccination services [20]. The impact of reproductive determinants was less but still significant. Births to young mothers, short spacing and multiple birth had a strikingly increased risk as in previous studies in sub-Saharan Africa [6–8]. As adolescent pregnancy and short birth intervals were more prevalent among women with lower educational levels and below than in better off women [9], these factors explained almost one fifth of the inequalities in infant mortality. Improving family planning access and keeping girls in school therefore benefits both reproductive health and child survival.

# Implications for policy

The results suggest a twin-track agenda. To eliminate the average level of neonatal mortality, focus should be on enhancing quality of care during every pregnancy and birth, including for emergencies, small and sick newborns and infection prevention. To eliminate the inequalities and the excess mortality

after the neonatal period, resources should be invested in the North West and North East, where the majority of excess death occurs. Improving primary health care, community case management of childhood illnesses, immunization, nutrition programmes and malaria prevention, as well as ensuring financial protection (for the very low percentage of the population covered by health insurance) can help achieve this. In the long run, the education of girls in secondary schools and voluntary contraception will reduce both the level of mortality and its social gradient. Regular subnational mortality monitoring by wealth, education and residence should be the norm; hence, progress for every girl and every child can be assessed by whether the gap is narrowing, not only by whether the average is declining [5].

# Strengths and limitations

Strengths of the study are the use of new and nationally representative birth histories, the standard life-table method for estimating mortality, the use of a bounded measure of inequality appropriate for binary results, and the integration of attributable-fraction, decomposition and survival analysis. Fully exposed cohorts for the concentration index were used to prevent bias due to censoring. Several limitations apply. Birth histories depend on maternal report and may be subject to death omission, distortions to birth dates and misreporting of age at death. The non-zero death rates in a few states indicate that death under-reporting is significant. The time of information collection (and change in household wealth, education and residence) may be substantial for those born 5–9 years earlier. Deaths of children to mothers who died or were un-interviewed are not included. The decomposition makes a linear probability approximation and a statistical (not causal) explanation. Even over ten years, death estimates for state are based on relatively small numbers of deaths and should be interpreted with care.

## Conclusions

Child mortality in Nigeria exhibits a sharp social and geographical gradient which intensifies with age. The total number of under-five deaths would be halved if all children experienced the same chances of survival as children in the richest households. Neonatal deaths are high everywhere, but well below average for children in the north and among the poorest households. Achieving equity in child health outcomes will need to focus on the quality of care at birth for all children, but prioritise between preventive and curative child health services, financial protection, education of girls and family planning in the poorest households and the northern zones where the killings of inequality take the most lives.

## Abbreviations

AOR
adjusted odds ratio
CI
confidence interval
DHS
Demographic and Health Survey
IMR

income mortality rate
NDHS
Nigeria Demographic and Health Survey
NMR
neonatal mortality rate
PAF
population attributable fraction
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
U5MR
under-five mortality rate

## Declarations

# Ethics approval and consent to participate

The 2023–24 NDHS protocol was approved by the ICF Institutional Review Board and the relevant national ethics committee in Nigeria. Informed consent was obtained from all respondents by the survey implementers. This secondary analysis used anonymised public-use data and did not require additional ethical approval.

## Consent for publication

Not applicable.

## Availability of data and materials

The data that support the findings of this article are publicly available from the DHS Program (https://dhsprogram.com/data/available-datasets.cfm) to registered users on reasonable request. The analysis code is available from the author upon reasonable request.

## Competing interests

The author states that he has no competing interests.

## Funding

This study received no specific funding.

## Authors' contributions

Kelvin Meyeyin-Bala proposed, designed and carried out the analysis, interpreted the results, drafted and edited the manuscript and read and approved the final version.

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# Figures

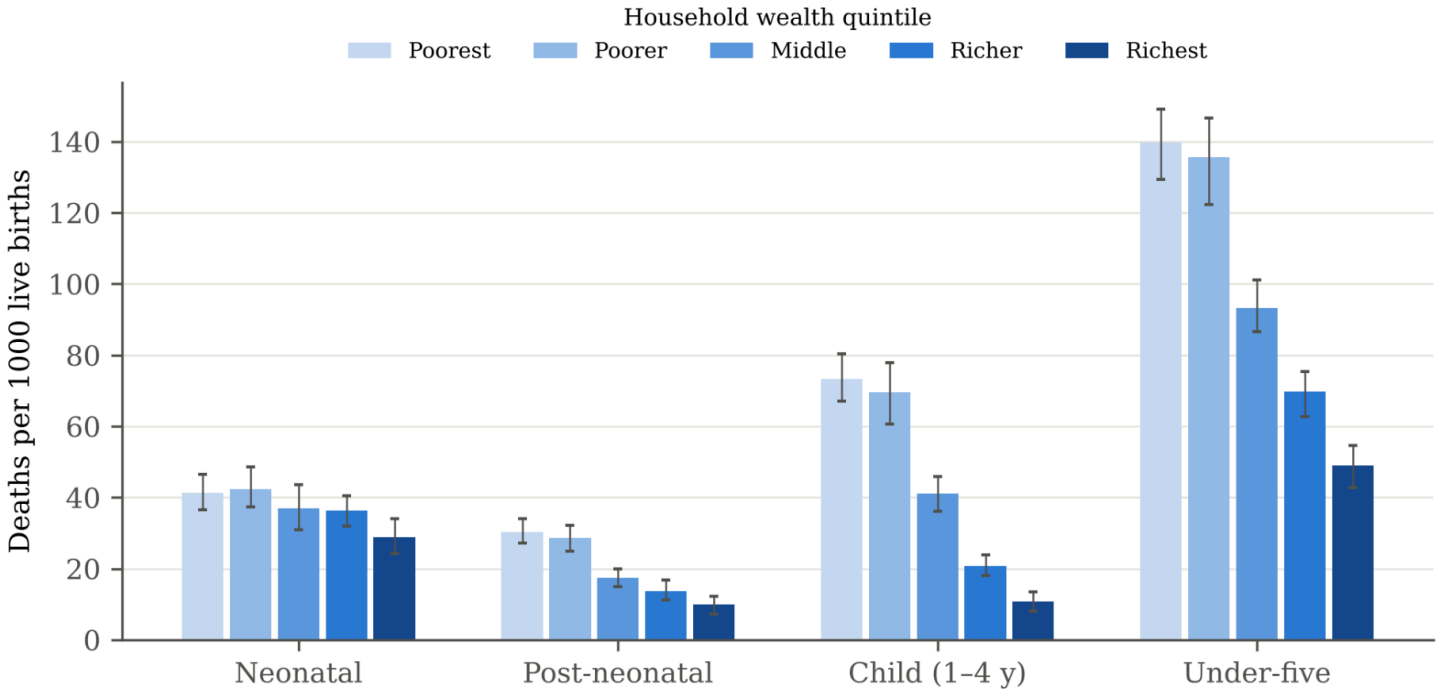



**Figure 1**

**Childhood mortality by age group and household wealth quintile, Nigeria 2014–2024**

Neonatal, post-neonatal and under-five – deaths per 1000 live births. Child (1-4 years) – deaths per 1000 children surviving to age one. Rates are based on estimates for the ten years prior to the 2023-24 Nigeria Demographic and Health Survey and are derived using the synthetic cohort life-table method. Error bars represent 95% confidence intervals based on a stratified cluster bootstrap.

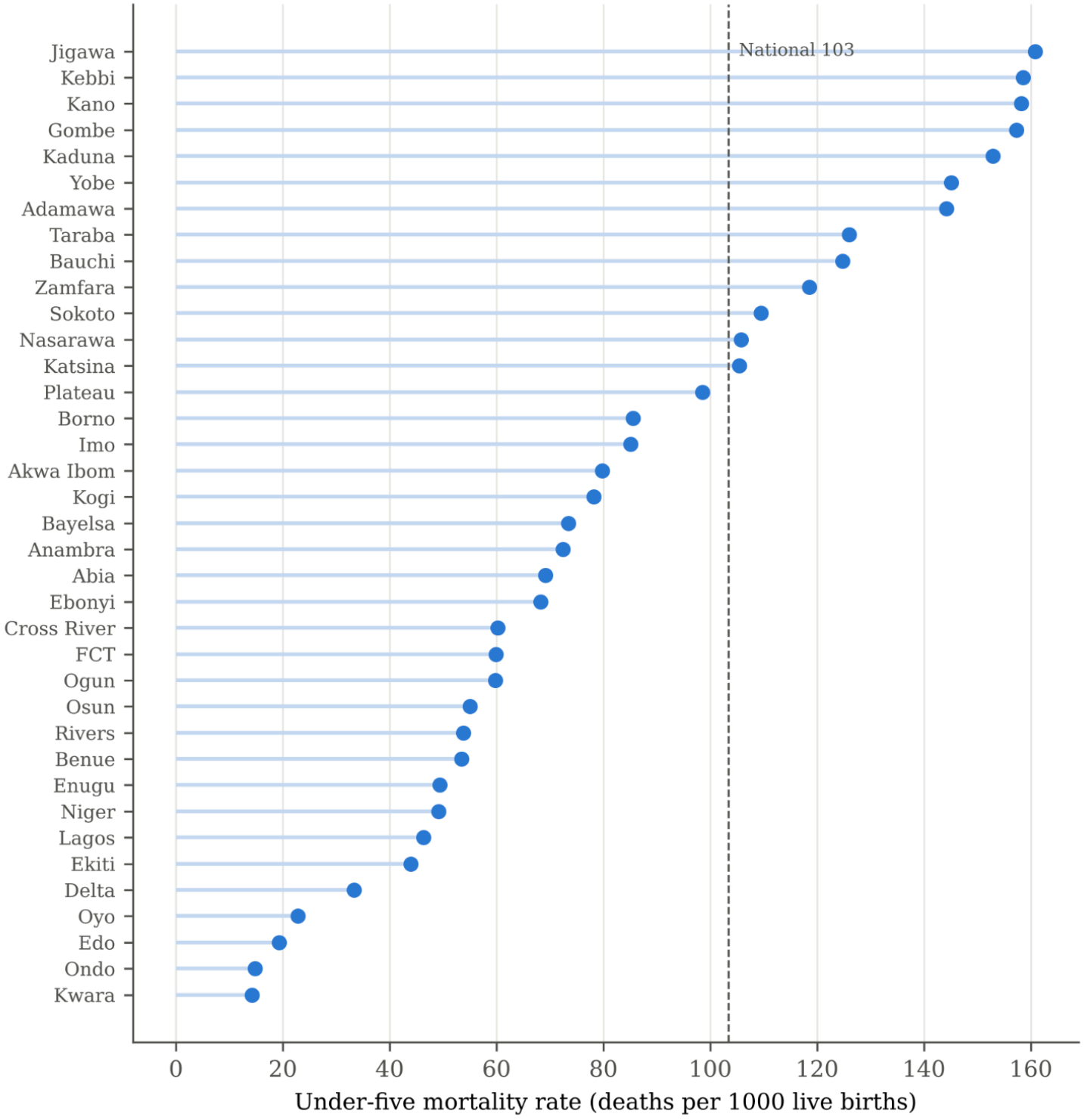



**Figure 2**

**Under-five mortality rate by state, Nigeria 2014–2024**

Number of children who die before reaching the age of five for every 1000 live births in the ten years prior to the survey. The dashed line indicates the national rate for that period. Very low estimates in some states may be due to under-reporting of deaths.

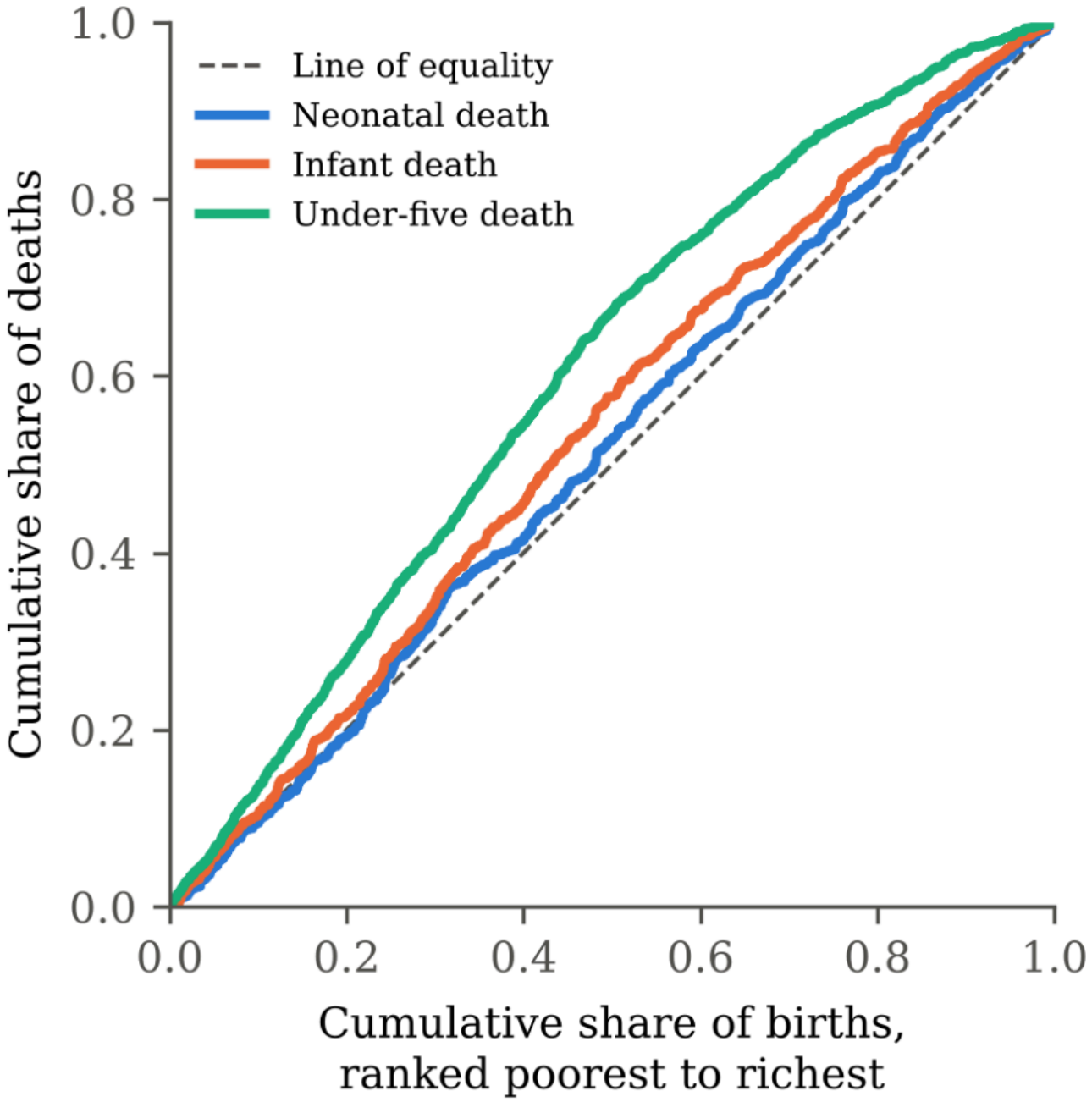



**Figure 3**

**Concentration curves for neonatal, infant and under-five deaths, Nigeria**

Cumulative proportion of deaths versus cumulative proportion of births by wealth ranking The DHS wealth score was used to rank births from poorest to richest. Neonatal: age at death 1-59 months before the survey; infant: age at death 12-59 months before; under- five: age at death 60-119 months before. The more the curve lies above the dashed line, the more the deaths are concentrated among the poor.

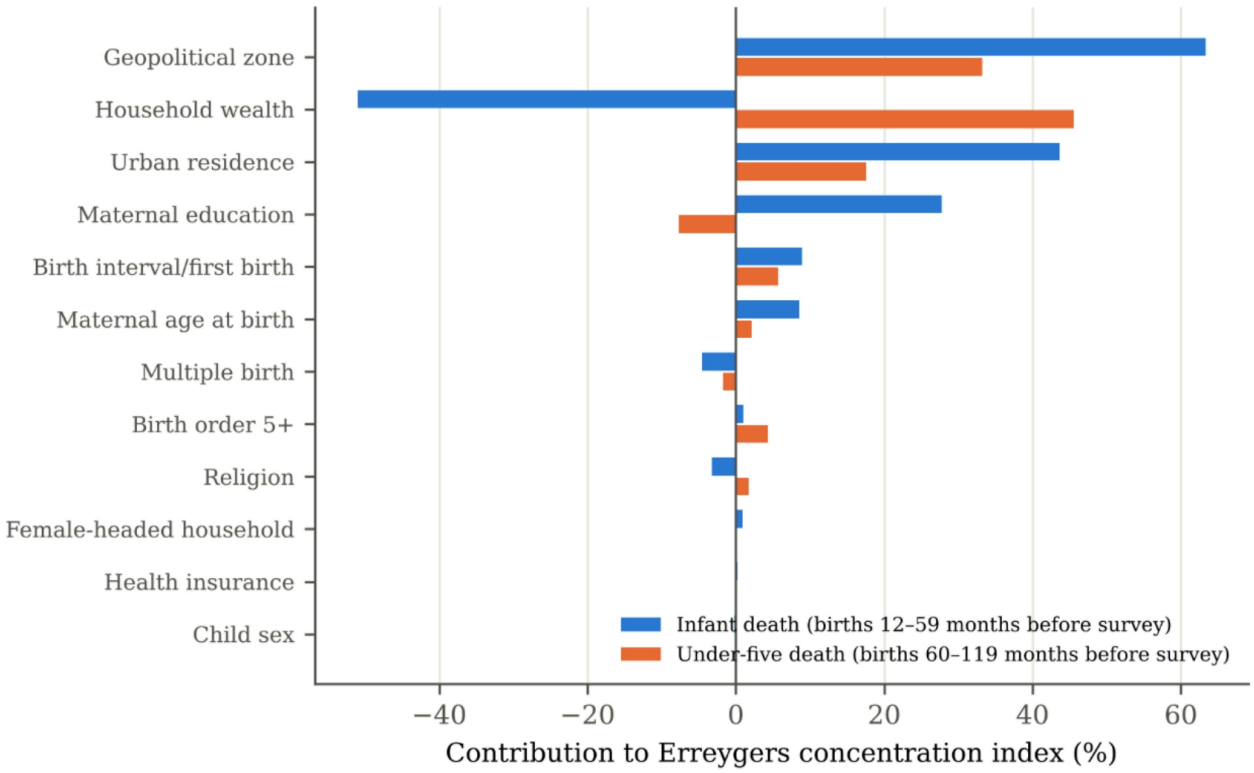



**Figure 4**

**Contributions of explanatory factors to wealth-related inequality in infant and under-five deaths**

Percentage contribution to the Erreygers concentration index of each factor, from a weighted linear probability decomposition. Both indices are negative (deaths concentrated among the poor), so negative percentages are factors that contribute to reducing inequality while positive percentages are factors that contribute to increasing inequality.

# Supplementary Files

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- Supplementary.docx