Research Square

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Beyond the first dose: socioeconomic inequality in pentavalent and measles vaccine dropout among Nigerian children, evidence from the 2023–24 Demographic and Health Survey

Kelvin Meyeyin-Bala

kelvinmeyeyin@gmail.com

Walden University

Research Article

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Abstract

Background

Few countries have as many under-immunised children as Nigeria. Catch-up programmes rightly prioritise zero-dose children, but children who begin the schedule and then fall away form a large, readily traceable group whose distribution is poorly understood. We estimated dropout from the first to the third dose of pentavalent vaccine (Penta1–Penta3) and from the first to the second dose of measles-containing vaccine (MCV1–MCV2), measured wealth-related inequality in each, and identified the factors that account for it.

Methods

From the children's file of the 2023–24 Nigeria Demographic and Health Survey, we drew two samples: 3,164 Penta1 recipients aged 12–23 months and 2,314 MCV1 recipients aged 24–35 months. We estimated design-adjusted prevalences, measured inequality with the Erreygers corrected concentration index, identified correlates with survey-weighted logistic regression, and apportioned inequality among them by regression-based decomposition.

Results

Coverage reached 53.8% for Penta3 and 30.5% for MCV2. Of children who started each series, 14.5% did not complete pentavalent vaccination and 36.6% did not receive MCV2. Penta dropout was 17% in the poorest and 8% in the richest quintile; for measles the figures were 46% and 31%. Dropout was concentrated among poorer children (Erreygers index − 0.083 for Penta and − 0.105 for MCV), but much less strongly than first-dose coverage was concentrated among richer children (Penta1 + 0.422). Penta dropout odds were lower in the richest households (aOR 0.37, 95% CI 0.21–0.66) and with higher maternal education (aOR 0.40, 0.23–0.71), and higher for urban children once wealth was considered (aOR 2.35, 1.70–3.26). Wealth and maternal education contributed most to inequality in both outcomes, and place of delivery contributed substantially for MCV.

Conclusions

Most of the wealth-related inequity in Nigeria's immunisation programme arises when children enter the schedule, but it does not disappear after first contact and is greater in the second year of life. Services should trace defaulters, strengthen the second-year-of-life contact and target the urban poor, children of less-educated mothers and children born at home.

Background

Routine childhood vaccination is among the most cost-effective ways of averting child deaths, yet in several high-burden countries progress has stalled. According to global estimates, the COVID-19 pandemic interrupted four decades of coverage gains and left many countries short of the Immunization Agenda 2030 goals [1]. Nigeria sits at the centre of this problem. A very large annual birth cohort, patchy primary health care and, in parts of the country, insecurity together mean that Nigeria accounts for a considerable fraction of the world's unvaccinated and under-vaccinated children [2].

In recent years, equity efforts in immunisation have focused heavily on the zero-dose child, that is, a child who has never received a first dose of a diphtheria–tetanus–pertussis-containing vaccine. There are good grounds for this emphasis, because zero-dose children cluster in marginalised and hard-to-reach households and communities that miss other essential services as well [2]. Cascade analyses show, however, that children are not lost only at the first step. Many children who receive an initial dose never return for later ones, and the proportion lost grows towards the end of the schedule and into the second year of life [3, 4].

Programmes conventionally judge their ability to keep children in care by dropout from Penta1 to Penta3, and dropout of less than 10% is widely regarded as the mark of a functioning service [5]. Dropout from MCV1 to MCV2 reflects retention into the second year, a period in which scheduled visits to health services become rare. A multilevel analysis of pooled Demographic and Health Survey (DHS) data from sub-Saharan Africa estimated that roughly one child in five who began the pentavalent series failed to finish it [6]. Work from The Gambia, Ethiopia and other settings has tied dropout to antenatal and delivery care, keeping the vaccination card, place of residence and household wealth [7–9], and coverage of the second measles dose trails far behind that of the first [10]. Nigerian studies of incomplete immunisation have shown a strong individual, community and subnational socioeconomic gradients [11, 12], as has similar research from elsewhere in Africa [13]. What is not known is whether dropout is simply a generalised problem that manifests across all groups, with certain groups inevitably facing a larger share of the burden – as the poor in many countries. And the answer to this latter question has different implications for action than if the burden of the problem were simply distributed evenly across all groups. That is why an analysis based on equity must quantify inequality as such, rather than associating an uneven distribution with risk factors [14, 15].

In the inverse equity hypothesis, better-off groups adopt new interventions early in order to be disadvantaged for a period before coverage increases across the entire population [16]. When a schedule involves multiple doses, inequity can manifest at entry, at completion, or both, and knowing where reveals whether programme managers should focus on locating children who were missed or on maintaining those already within the system. Decomposition techniques partition the observed inequality into the extent attributable to the various determinants, thereby providing a list of issues rather than a descriptive gap [17, 18], as exemplified by their application to immunisation in Ethiopia and Malawi [8, 19].

Drawing on the most recent nationally representative data, the 2023–24 Nigeria Demographic and Health Survey (NDHS), this study set out to (i) estimate Penta1–Penta3 and MCV1–MCV2 dropout; (ii) measure wealth-related inequality in dropout and set it against inequality in first-dose coverage; (iii) identify factors independently associated with dropout; and (iv) quantify how much each factor contributes to inequality in dropout.

Methods

Study design and data source

We performed a cross-sectional secondary analysis of the 2023–24 NDHS, the seventh DHS undertaken in Nigeria. The survey was carried out by the National Population Commission (NPC) under the Federal Ministry of Health and Social Welfare, with technical support from ICF [20]. Sampling took place in two stages. Enumeration areas were first drawn with probability proportional to size from 74 strata, created by splitting each of the 36 states and the Federal Capital Territory into urban and rural parts; a fixed number of households was then chosen in every selected area. Data were collected from December 2023 to May 2024. The analysis used the children recode file (NGKR8BFL), which holds a record for each birth in the five years preceding the survey to women aged 15–49 years who were interviewed, and which spans 1,375 clusters in 74 strata.

Study population

Vaccination histories for living children came from a home-based record, such as a vaccination card, or, if no record existed or a dose was not written down, from the mother's recall. Under Nigeria's schedule, the three pentavalent doses are due at 6, 10 and 14 weeks of age, MCV1 at 9 months and MCV2 at 15 months. We built two analytic samples. The first consisted of living children aged 12–23 months (n = 4,937); the 3,164 among them who had received Penta1 formed the denominator for Penta1–Penta3 dropout. The second consisted of living children aged 24–35 months (n = 4,599); the 2,314 among them who had received MCV1 formed the denominator for MCV1–MCV2 dropout. We used the older age group for measles since a child younger than 24 months may still be within a reasonable catch-up window after the MCV2 due date at 15 months. Sample sizes are reported unweighted and all percentages are weighted.

Outcome variables

A child was classed as a Penta1–Penta3 dropout (coded 1) if Penta1 had been given but Penta3 had not, and as a completer (coded 0) if both had been given. MCV1–MCV2 dropout was defined in the same way for the two measles doses. A dose counted as given if a date or mark appeared on a record or if the mother reported it; following DHS convention, "don't know" answers were treated as not vaccinated. To allow comparison with programme data, we also computed population-level dropout with the World

Health Organization formula, (first-dose coverage − last-dose coverage) / first-dose coverage. To locate the points in the cascade at which children were lost, we estimated coverage among children aged 12–23 months of Bacillus Calmette–Guérin (BCG) vaccine, Penta1, Penta3, the third dose of oral poliovirus vaccine excluding the birth dose (Polio3), MCV1, full basic vaccination (BCG, three pentavalent and three poliovirus doses, and MCV1) and zero-dose status (no Penta1), and among children aged 24–35 months of MCV1 and MCV2.

Equity stratifier and explanatory variables

Household wealth served as the main equity stratifier. The DHS wealth index summarises, through principal component analysis, what a household owns, its water supply and toilet type, and the materials and features of its dwelling. We ranked children on the continuous wealth score when computing concentration indices and used national wealth quintiles for tabulation. Drawing on earlier studies of immunisation completion [6, 13], we specified the following explanatory variables before analysis:

- household wealth quintile (poorest, poorer, middle, richer, richest);
- maternal education (none, primary, secondary, higher);
- place of residence (urban, rural);
- geopolitical zone (North West, North East, North Central, South East, South South, South West);
- maternal age (15–19, 20–34, 35–49 years);
- birth order (first, second–third, fourth–fifth, sixth or higher);
- sex of the child;
- place of delivery (health facility, or home or other);
- whether distance to a health facility was a big problem when seeking medical help;
- exposure to newspapers, radio or television at least weekly;
- maternal health insurance;
- religion (Christian, Islam, traditional or other);
- ethnicity (Hausa, Fulani, Yoruba, Igbo, other); and
- sex of the household head.

We did not include possession of a vaccination card, because holding a card is partly a result of being vaccinated as well as a factor in which doses get recorded.

Statistical analysis

Every analysis took account of the sampling weights, clustering and stratification. Prevalences are shown with 95% confidence intervals (CI) computed on the logit scale using Taylor-linearised standard errors, and design-adjusted Wald tests were used for bivariate comparisons of dropout. To measure wealth-related inequality we used the Erreygers corrected concentration index, which is preferred for

bounded binary outcomes because the limits of the ordinary concentration index shift with the outcome mean [21, 22]. It is calculated as E = 4μC, in which μ is the weighted mean of the outcome and C is the ordinary concentration index computed against each child's weighted fractional rank by wealth. E lies between − 1 and + 1: a negative value means the outcome is concentrated among poorer children, a positive value means it is concentrated among richer children, and zero means equality. Standard errors came from 300 bootstrap replicates resampled by cluster. Concentration curves were drawn by plotting, for each outcome, the cumulative percentage of dropouts against the cumulative percentage of children ranked by wealth from poorest upwards.

Independent correlates of each dropout outcome were identified with survey-weighted multivariable logistic regression (fittted with all explanatory variables simultaneously). Adjusted odds ratios (aOR) and 95% CIs were calculated using design-based sandwich variance estimators, and joint Wald tests were conducted for variables with more than two categories. Variance inflation factors were calculated to evaluate multicollinearity, with the largest factor at 7.5 (well below the standard cut-off of 10) and later broke down the Erreygers index for each outcome into contributions for the explanatory variables, as per Wagstaff et al. [17] and the adaptation for the corrected index [18]. Using the weighted linear probability model, the index was expressed as $E = 4 \Sigma \beta_k \bar{x}_k C_k$ + residual, where β_k is the coefficient of factor k, $\bar{x}_k$ its weighted mean and C_k its concentration index by wealth. A factor's contribution depends on the association with dropout as well as on the inequality of distribution between wealth groups. Contributions are positive if they have the same sign as the overall index, increasing it, or negative otherwise. Contributions for each factor by category were summed. $P < 0.05$ was considered statistically significant. All analyses were performed using Python 3 with the pandas and statsmodels packages and reporting followed the STROBE guidelines.

Ethical considerations

The protocol for the NDHS was approved by the ICF Institutional Review Board and the Nigeria National Health Research Ethics Committee, and all survey participants provided informed consent prior to interview. Ethics approval for this study was not required as it used anonymised public-use dataset released with permission from The DHS Program.

Use of artificial intelligence tools

Artificial intelligence assistants (Claude, Anthropic) helped with the statistical programming and drafting of the text. The author set out the research questions and analysis approach, reviewed all code, outputs and references, edited the manuscript, and takes full responsibility for the contents.

Results

Characteristics of the analytic samples

Table 1 provides description of the two analytic samples: The 3,164 Penta1 recipients aged 12–23 months were just under half urban (49.3%), 28.6% had no formal maternal education, 59.0% were born in a facility, and only 3.8% had mothers with health insurance. Sample distribution was relatively evenly spread across regions, with the largest share (28.0%) from the North West. The 2,314 MCV1 recipients aged 24–35 months were similar overall, but had a greater proportion urban (55.0%) and born in a health facility (64.4%), indicating that MCV1 is more socially targeted than Penta1.

Table 1
Characteristics of the analytic samples and vaccine dropout, Nigeria DHS 2023–24

Characteristic	Penta n	Penta weighted %	Penta dropout %	MCV n	MCV weighted %	MCV dropout %
Household wealth quintile (Penta p < 0.001; MCV p = 0.006)						
Poorest	522	16.3	16.7	296	13.0	45.8
Poorer	487	17.0	19.6	309	14.1	40.8
Middle	611	19.2	16.1	434	19.3	37.2
Richer	763	23.2	14.3	593	24.5	35.8
Richest	781	24.3	8.3	682	29.1	30.5
Maternal education (Penta p < 0.001; MCV p < 0.001)						
No education	827	28.6	17.1	477	23.8	40.1
Primary	356	11.9	17.3	242	10.5	41.3
Secondary	1,439	43.3	14.9	1,102	45.6	38.0
Higher	542	16.3	6.4	493	20.1	26.6
Place of residence (Penta p = 0.267; MCV p = 0.288)						
Urban	1,555	49.3	15.4	1,248	55.0	35.3
Rural	1,609	50.7	13.6	1,066	45.0	38.1
Geopolitical zone (Penta p = 0.009; MCV p = 0.008)						
North West	628	28.0	13.7	364	22.9	30.0
North East	647	20.1	16.8	425	19.1	43.4
North Central	529	15.3	19.0	388	15.3	43.6
South East	503	10.7	14.1	424	12.3	36.1
South South	458	11.5	8.5	391	14.0	32.6
South West	399	14.4	12.9	322	16.4	35.0
Maternal age, years (Penta p = 0.486; MCV p = 0.391)						

Penta: Penta1 recipients aged 12–23 months (n = 3,164); MCV: MCV1 recipients aged 24–35 months (n = 2,314). Sample sizes (n) are unweighted; percentages are weighted. Weighted % is the column distribution within each analytic sample; dropout % is the weighted percentage in each category who did not receive Penta3 (12–23 months) or MCV2 (24–35 months). p values are from design-adjusted Wald tests of the bivariate association between each characteristic and dropout. Distance was "a big problem" in getting medical help for the mother herself. Media exposure denotes reading a newspaper, listening to the radio or watching television at least once a week.

Characteristic	Penta n	Penta weighted %	Penta dropout %	MCV n	MCV weighted %	MCV dropout %
15–19	96	3.0	19.0	32	1.7	41.9
20–34	2,295	73.3	14.2	1,621	70.1	37.4
35–49	773	23.7	14.7	661	28.2	34.0
Birth order (Penta p = 0.803; MCV p = 0.043)						
First	688	21.4	14.3	532	22.3	32.1
Second–third	1,163	36.2	14.3	877	37.9	35.7
Fourth–fifth	753	23.7	13.7	542	22.9	41.6
Sixth or higher	560	18.8	16.0	363	17.0	37.6
Sex of child (Penta p = 0.384; MCV p = 0.631)						
Male	1,588	50.2	13.8	1,182	50.1	37.1
Female	1,576	49.8	15.1	1,132	49.9	36.0
Place of delivery (Penta p = 0.058; MCV p = 0.002)						
Health facility	1,953	59.0	13.3	1,577	64.4	33.5
Home/other	1,211	41.0	16.1	737	35.6	42.1
Distance to facility a big problem (Penta p = 0.174; MCV p = 0.197)						
Yes	762	22.1	16.4	539	21.4	39.5
No	2,402	77.9	13.9	1,775	78.6	35.7
Weekly exposure to mass media (Penta p = 0.003; MCV p = 0.050)						
Yes	1,483	46.2	12.1	1,152	49.3	34.1
No	1,681	53.8	16.5	1,162	50.7	38.9
Mother covered by health insurance (Penta p = 0.374; MCV p = 0.210)						
Yes	122	3.8	10.6	104	4.3	29.2
No	3,042	96.2	14.6	2,210	95.7	36.9

Penta: Penta1 recipients aged 12–23 months (n = 3,164); MCV: MCV1 recipients aged 24–35 months (n = 2,314). Sample sizes (n) are unweighted; percentages are weighted. Weighted % is the column distribution within each analytic sample; dropout % is the weighted percentage in each category who did not receive Penta3 (12–23 months) or MCV2 (24–35 months). p values are from design-adjusted Wald tests of the bivariate association between each characteristic and dropout. Distance was "a big problem" in getting medical help for the mother herself. Media exposure denotes reading a newspaper, listening to the radio or watching television at least once a week.

Characteristic	Penta n	Penta weighted %	Penta dropout %	MCV n	MCV weighted %	MCV dropout %
Religion (Penta p = 0.007; MCV p = 0.173)						
Christian	1,606	43.0	13.0	1,357	51.0	37.9
Islam	1,544	56.6	15.4	951	48.8	35.0
Traditional/other	14	0.4	38.4	6	0.2	73.4
Ethnicity (Penta p = 0.321; MCV p = 0.040)						
Hausa	696	30.2	13.3	395	24.4	30.4
Fulani	226	6.4	17.9	123	5.1	40.8
Yoruba	359	12.0	14.5	295	14.0	34.5
Igbo	610	14.6	11.9	503	16.2	35.9
Other	1,273	36.8	15.8	998	40.3	40.7
Sex of household head (Penta p = 0.302; MCV p = 0.197)						
Male	2,725	87.6	14.2	1,946	85.6	36.0
Female	439	12.4	16.4	368	14.4	40.1

Penta: Penta1 recipients aged 12–23 months (n = 3,164); MCV: MCV1 recipients aged 24–35 months (n = 2,314). Sample sizes (n) are unweighted; percentages are weighted. Weighted % is the column distribution within each analytic sample; dropout % is the weighted percentage in each category who did not receive Penta3 (12–23 months) or MCV2 (24–35 months). p values are from design-adjusted Wald tests of the bivariate association between each characteristic and dropout. Distance was "a big problem" in getting medical help for the mother herself. Media exposure denotes reading a newspaper, listening to the radio or watching television at least once a week.

Coverage across the cascade and magnitude of dropout

Among all children aged 12–23 months, BCG coverage was 66.7%, Penta1 62.7%, Penta3 53.8%, Polio3 47.2% and MCV1 51.1%. In total, 38.2% (95% CI 36.1–40.3) were fully vaccinated with all basic vaccines, and 37.3% (95% CI 35.2–39.5) were zero-dose (Table 2). Among children aged 24–35 months, 47.8% had received MCV1 but only 30.5% (95% CI 28.5–32.5) had received MCV2. Of children who began the pentavalent series, 14.5% (95% CI 13.0–16.1) had not completed it, and of those given MCV1, 36.6% (95% CI 34.0–39.1) had not received MCV2. The WHO formula produced close population-level figures of 14.2% for pentavalent and 36.2% for measles dropout. Nationally, pentavalent dropout was above the 10% benchmark, and measles dropout was more than three times that level.

Table 2
Vaccination coverage, dropout and wealth-related inequality among Nigerian children, 2023–24

Indicator	National % (95% CI)	Poorest %	Richest %	Gap (pp)	Ratio	Erreygers index (95% CI)
BCG	66.7 (64.5–68.8)	47.2	94.8	47.6	2.01	0.408 (0.359 to 0.456)
Penta1	62.7 (60.5–64.8)	43.1	93.2	50.1	2.16	0.422 (0.376 to 0.468)
Penta3	53.8 (51.6–55.9)	36.1	85.6	49.6	2.38	0.409 (0.363 to 0.456)
Polio3	47.2 (45.1–49.3)	36.0	67.8	31.8	1.89	0.265 (0.213 to 0.317)
MCV1 (12–23 months)	51.1 (49.0–53.3)	35.3	83.5	48.2	2.37	0.392 (0.344 to 0.441)
Full basic vaccination	38.2 (36.1–40.3)	27.3	60.3	33.0	2.21	0.265 (0.216 to 0.313)
Zero-dose (no Penta1)	37.3 (35.2–39.5)	56.9	6.8	−50.1	0.12	−0.422 (− 0.468 to − 0.376)
MCV1 (24–35 months)	47.8 (45.5–50.0)	27.1	83.1	56.0	3.06	0.457 (0.407 to 0.508)
MCV2 (24–35 months)	30.5 (28.5–32.5)	14.7	58.2	43.5	3.96	0.342 (0.299 to 0.385)
Penta1–Penta3 dropout	14.5 (13.0–16.1)	16.7	8.3	−8.4	0.50	−0.083 (− 0.119 to − 0.047)
MCV1–MCV2 dropout	36.6 (34.0–39.1)	45.8	30.5	−15.3	0.67	−0.105 (− 0.167 to − 0.042)

Children aged 12–23 months (n = 4,937) except MCV1 and MCV2 for children aged 24–35 months (n = 4,599). Dropout indicators are restricted to children who received the first dose (Penta1 n = 3,164; MCV1 n = 2,314). Gap is richest minus poorest in percentage points (pp); ratio is richest divided by poorest; gaps and ratios are calculated from unrounded estimates. Erreygers index confidence intervals are from 300 cluster bootstrap replicates; all indices differ from zero at $p \leq 0.001$. Positive values indicate concentration among richer children, negative values among poorer children.

Socioeconomic and geographic inequality

Every coverage indicator rose steeply with wealth (Fig. 1). Between the poorest and richest quintiles, Penta1 coverage increased from 43.1% to 93.2%, MCV2 coverage from 14.7% to 58.2% and full basic vaccination from 27.3% to 60.3%. Erreygers indices were + 0.422 (95% CI 0.376 to 0.468) for Penta1, + 0.409 for Penta3 and + 0.342 for MCV2 (Table 2).

Dropout ran in the opposite direction. Pentavalent dropout was 16.7% in the poorest quintile, reached 19.6% in the poorer quintile, and then declined to 16.1%, 14.3% and 8.3% in the middle, richer and richest

quintiles, so that only the richest quintile fell below the 10% benchmark (Fig. 2a). Measles dropout declined steadily from 45.8% in the poorest quintile to 30.5% in the richest (Fig. 2a). Both outcomes were concentrated among poorer children: the Erreygers index was − 0.083 (95% CI − 0.119 to − 0.047) for pentavalent and − 0.105 (− 0.167 to − 0.042) for measles dropout, and the corresponding uncorrected concentration indices were − 0.144 and − 0.071. Both concentration curves lay above the line of equality, the pentavalent curve more clearly so, in line with its larger uncorrected index (Fig. 3). The degree of inequality in dropout was only around one fifth to one quarter of that in first-dose coverage (Penta1 + 0.422; MCV1 at 24–35 months + 0.457),which suggests that most of the inequity in the cascade is generated at the first step.

Dropout was also patterned by maternal education, falling from 17.1% for pentavalent and 40.1% for measles among children whose mothers had no schooling to 6.4% and 26.6% among those whose mothers had higher education. Across zones, pentavalent dropout peaked in the North Central (19.0%) and North East (16.8%) and was lowest in the South South (8.5%); measles dropout peaked in the North Central (43.6%) and North East (43.4%) and was lowest in the North West (30.0%) (Fig. 2b). The comparatively low measles dropout in the North West needs to be read together with the zone's very low MCV1 coverage, which leaves only a small, selected group of children who could drop out. State estimates of pentavalent dropout (Additional file 1) carried very wide confidence intervals owing to small samples, but pointed to dropout above 25% in Borno, Benue, Zamfara and Plateau and of 6% or less in Cross River, Jigawa and Ogun.

Factors associated with dropout

In the adjusted model for pentavalent dropout (Table 3), household wealth (joint $p < 0.001$), maternal education (joint $p = 0.007$) and zone (joint $p = 0.013$) were each independently associated with the outcome. Compared with the poorest quintile, children in the richest quintile had 63% lower odds of dropout (aOR 0.37, 95% CI 0.21–0.66), and compared with children of mothers without schooling, those whose mothers had higher education had 60% lower odds (aOR 0.40, 95% CI 0.23–0.71). With wealth and the other factors held constant, urban children had over twice the odds of dropout of rural children (aOR 2.35, 95% CI 1.70–3.26). Children of mothers who followed traditional or other religions had higher odds than children of Christian mothers (aOR 3.61, 95% CI 1.44–9.03), although very few children fell into this group.

Table 3
Adjusted odds ratios for pentavalent and measles vaccine dropout, Nigeria 2023–24

Variable	Penta1–Penta3, aOR (95% CI)	p	MCV1–MCV2, aOR (95% CI)	p
Household wealth (ref.: poorest)				
Poorer	1.18 (0.80–1.75)	0.409	0.83 (0.55–1.27)	0.396
Middle	0.85 (0.55–1.33)	0.488	0.74 (0.48–1.14)	0.166
Richer	0.61 (0.37–1.00)	0.050	0.71 (0.45–1.13)	0.154
Richest	0.37 (0.21–0.66)	< 0.001	0.64 (0.38–1.08)	0.094
Maternal education (ref.: none)				
Primary	0.92 (0.60–1.40)	0.686	1.03 (0.67–1.59)	0.896
Secondary	0.89 (0.59–1.34)	0.578	0.94 (0.65–1.36)	0.753
Higher	0.40 (0.23–0.71)	0.002	0.62 (0.39–0.98)	0.041
Residence (ref.: rural)				
Urban	2.35 (1.70–3.26)	< 0.001	1.12 (0.85–1.48)	0.403
Zone (ref.: North West)				
North East	0.92 (0.59–1.43)	0.704	1.42 (0.85–2.38)	0.180
North Central	1.37 (0.81–2.32)	0.235	1.76 (1.07–2.90)	0.025
South East	1.62 (0.58–4.53)	0.355	1.00 (0.50–2.00)	0.997
South South	0.55 (0.28–1.08)	0.083	0.94 (0.54–1.64)	0.828
South West	0.84 (0.39–1.81)	0.663	1.22 (0.66–2.27)	0.522
Maternal age (ref.: 20–34)				
15–19	1.21 (0.66–2.23)	0.543	1.39 (0.57–3.38)	0.465
35–49	1.24 (0.90–1.73)	0.192	0.79 (0.60–1.05)	0.102
Birth order (ref.: first)				
Second–third	0.93 (0.66–1.31)	0.684	1.17 (0.90–1.52)	0.247
Fourth–fifth	0.79 (0.52–1.19)	0.254	1.48 (1.09–2.02)	0.011

aOR: adjusted odds ratio from survey-weighted logistic regression including all listed variables, with design-based (stratum and cluster) standard errors. Penta1–Penta3 model: children aged 12–23 months who received Penta1 (n = 3,164). MCV1–MCV2 model: children aged 24–35 months who received MCV1 (n = 2,314). The traditional/other religion category contains fewer than 20 children in each sample, and its estimate is imprecise.

Variable	Penta1–Penta3, aOR (95% CI)	p	MCV1–MCV2, aOR (95% CI)	p
Sixth or higher	0.76 (0.47–1.25)	0.282	1.36 (0.89–2.08)	0.158
Child sex (ref.: male)				
Female	1.12 (0.89–1.43)	0.333	0.94 (0.78–1.14)	0.522
Delivery (ref.: home/other)				
Health facility	0.91 (0.69–1.21)	0.518	0.68 (0.53–0.87)	0.003
Distance a big problem (ref.: no)				
Yes	1.05 (0.78–1.40)	0.754	1.00 (0.77–1.30)	0.987
Weekly media exposure (ref.: no)				
Yes	0.92 (0.69–1.22)	0.551	1.08 (0.86–1.35)	0.512
Health insurance (ref.: no)				
Yes	1.29 (0.55–3.03)	0.558	1.08 (0.61–1.93)	0.782
Religion (ref.: Christian)				
Islam	0.98 (0.67–1.43)	0.913	0.72 (0.50–1.04)	0.083
Traditional/other	3.61 (1.44–9.03)	0.006	4.06 (0.58–28.41)	0.158
Ethnicity (ref.: Hausa)				
Fulani	1.43 (0.83–2.47)	0.195	1.37 (0.79–2.35)	0.260
Yoruba	1.62 (0.80–3.26)	0.180	1.41 (0.78–2.54)	0.250
Igbo	0.79 (0.30–2.09)	0.640	1.54 (0.81–2.95)	0.190
Other	1.31 (0.84–2.04)	0.235	1.34 (0.84–2.15)	0.216
Household head (ref.: male)				
Female	1.19 (0.83–1.69)	0.348	1.22 (0.91–1.62)	0.178

aOR: adjusted odds ratio from survey-weighted logistic regression including all listed variables, with design-based (stratum and cluster) standard errors. Penta1–Penta3 model: children aged 12–23 months who received Penta1 (n = 3,164). MCV1–MCV2 model: children aged 24–35 months who received MCV1 (n = 2,314). The traditional/other religion category contains fewer than 20 children in each sample, and its estimate is imprecise.

For measles dropout, lower odds were associated with birth in a health facility (aOR 0.68, 95% CI 0.53–0.87) and with higher maternal education (aOR 0.62, 95% CI 0.39–0.98), and higher odds with living in the North Central zone (aOR 1.76, 95% CI 1.07–2.90) and with being a fourth- or fifth-born child (aOR 1.48, 95% CI 1.09–2.02). Wealth followed the expected direction (richest versus poorest aOR 0.64, 95%

CI 0.38–1.08) without reaching statistical significance (joint p = 0.568), which suggests that its influence on measles dropout may run through place of delivery, education and geography.

Decomposition of wealth-related inequality

Table 4 and Fig. 4 present the decomposition. For pentavalent dropout, the explanatory variables accounted for 93.3% of the Erreygers index. Household wealth made the largest contribution to the concentration of dropout among poorer children (125.8%), followed by maternal education (45.0%), geopolitical zone (13.1%), facility delivery (6.8%) and media exposure (6.6%). Other factors partly counteracted this pro-poor inequality, above all urban residence (− 85.9%), because urban children tend to live in wealthier households yet, at a given level of wealth, are more likely to drop out; ethnicity (− 8.7%) and birth order (− 8.7%) also worked in this direction.

Table S1
State-level Penta1 coverage and vaccine dropout, Nigeria DHS 2023–24

State	Penta1 coverage %	n (Penta1)	Penta dropout %	n (MCV1)	MCV dropout %
Abia	94.5	77	15.7	61	25.9
Adamawa	70.9	106	16.1	78	45.5
Akwa Ibom	84.9	70	14.3	45	32.8
Anambra	85.1	82	7.7	84	37.4
Bauchi	62.7	124	7.1	41	19.9
Bayelsa	80.9	65	9.3	48	16.2
Benue	66.2	63	31.9	44	56.4
Borno	68.3	105	38.2	88	54.9
Cross River	97.2	67	2.7	66	44.7
Delta	92.4	100	6.2	87	22.6
Ebonyi	97.0	170	21.1	113	44.3
Edo	96.3	76	12.3	65	33.9
Ekiti	94.0	47	19.3	36	47.8
Enugu	87.2	65	6.4	58	34.9
Federal Capital Territory	93.8	85	9.6	67	50.8
Gombe	65.5	116	8.6	64	58.1
Imo	93.3	109	10.6	108	31.9
Jigawa	65.7	132	5.3	93	27.0
Kaduna	54.4	120	11.8	96	26.8
Kano	57.6	154	17.5	63	34.8
Katsina	60.2	121	11.5	55	30.3
Kebbi	16.0	44	17.0	16	66.2
Kogi	43.0	55	12.8	34	61.2

Penta1 coverage among all living children aged 12–23 months. Penta dropout among Penta1 recipients aged 12–23 months; MCV dropout among MCV1 recipients aged 24–35 months. Sample sizes are unweighted; percentages are weighted. Estimates based on fewer than 50 children are imprecise and should be interpreted with caution.

State	Penta1 coverage %	n (Penta1)	Penta dropout %	n (MCV1)	MCV dropout %
Kwara	48.3	48	24.6	47	43.9
Lagos	95.3	103	8.1	69	42.3
Nasarawa	79.0	110	14.2	79	40.5
Niger	43.4	69	15.3	51	16.5
Ogun	78.7	88	6.0	70	35.6
Ondo	76.5	42	16.5	42	22.8
Osun	87.1	56	23.0	39	32.1
Oyo	70.1	63	23.4	66	28.7
Plateau	64.7	99	27.2	66	55.0
Rivers	77.3	80	8.2	80	40.0
Sokoto	13.5	29	18.7	16	9.6
Taraba	59.3	69	16.8	42	60.9
Yobe	59.4	127	13.7	112	33.8
Zamfara	17.4	28	27.5	25	33.4

Penta1 coverage among all living children aged 12–23 months. Penta dropout among Penta1 recipients aged 12–23 months; MCV dropout among MCV1 recipients aged 24–35 months. Sample sizes are unweighted; percentages are weighted. Estimates based on fewer than 50 children are imprecise and should be interpreted with caution.

Table 4
Decomposition of wealth-related inequality in vaccine dropout, Nigeria 2023–24

Factor	Penta contribution	Penta % of index	MCV contribution	MCV % of index
Household wealth	−0.1049	125.8	−0.0679	64.9
Maternal education	−0.0375	45.0	−0.0481	46.0
Geopolitical zone	−0.0109	13.1	−0.0149	14.3
Urban residence	0.0716	−85.9	0.0155	−14.9
Facility delivery	−0.0057	6.8	−0.0471	45.0
Media exposure	−0.0055	6.6	0.0093	−8.9
Birth order	0.0072	−8.7	−0.0139	13.3
Ethnicity	0.0073	−8.7	0.0269	−25.8
Religion	−0.0002	0.2	0.0286	−27.3
Maternal age	−0.0002	0.2	−0.0069	6.6
Health insurance	0.0018	−2.2	0.0018	−1.8
Distance a big problem	−0.0012	1.5	0.0001	−0.1
Female-headed household	0.0010	−1.2	0.0021	−2.0
Child sex	−0.0005	0.6	0.0005	−0.4
Total explained	**−0.0777**	**93.3**	**−0.1140**	**109.0**
Residual	−0.0056	6.7	0.0094	−9.0
Erreygers concentration index	**−0.0834**	**100.0**	**−0.1046**	**100.0**

Penta: Penta1–Penta3 dropout; MCV: MCV1–MCV2 dropout. Contribution is 4 × β × mean × concentration index of each factor, summed across its categories, from a weighted linear probability model. Percentages are relative to the overall Erreygers index; because the overall indices are negative, positive percentages widen and negative percentages offset pro-poor inequality. Figures may not sum exactly because of rounding.

For measles dropout, household wealth was again the leading contributor (64.9%), followed by maternal education (46.0%), facility delivery (45.0%), geopolitical zone (14.3%) and birth order (13.3%). Religion (− 27.3%), ethnicity (− 25.8%), urban residence (− 14.9%) and media exposure (− 8.9%) counteracted the inequality. The unexplained residual was small for both outcomes, at 6.7% and − 9.0% of the index.

Discussion

Using nationally representative data from the 2023–24 NDHS, we found that around one in seven Nigerian children who started the pentavalent series, and around one in three who received a first measles dose, did not go on to complete it. Dropout was more common among poorer children, but the wealth gap in dropout was far narrower than the gap in first-dose coverage. Much of the inequality in both outcomes was explained by household wealth and maternal education; place of delivery was a major source of inequality in measles dropout; and, once wealth was accounted for, urban children were at a disadvantage.

Pentavalent dropout was lower than the sub-Saharan African estimate of roughly one in five [6] but still above 10% in every wealth group apart from the richest. Losses between MCV1 and MCV2 were considerably larger. This matches Ethiopian evidence that MCV2 coverage lags well behind MCV1 [5, 10], and it reflects how schedules are organised across the region: no routine contact is due between the nine-month visit and the 15-month dose, families have fewer reasons to attend a clinic, and home-based records may neither prompt nor capture the second dose. Our findings point to this stage as the weakest link in Nigeria's routine schedule at present.

The key equity comparison in this study is between inequality in coverage and inequality in dropout. On the Erreygers index, inequality in Penta1 coverage was about five times as great as inequality in Penta1–Penta3 dropout. The bulk of wealth-related inequality in Nigeria's programme thus arises at first contact, which agrees with cascade analyses showing that zero-dose status drives most incomplete immunisation in low- and middle-income countries [3, 4], and supports the priority given to zero-dose children. Inequity does not end after first contact, however: poorer children are more prone to drop out, and absolute dropout is high. Among the poorest children who received MCV1, 45.8% had not received MCV2, so close to half of them are not fully protected against measles. In keeping with the inverse equity hypothesis [16], the richest households already retain 92% of children through the pentavalent series, while other groups trail some way behind.

As with deprivation, wealth and maternal education are the main determinants of inequality, as decomposition analyses from Malawi [19] and Ethiopia [8] have shown, and as meta-analysis of the evidence linking maternal education to completion would expect [23]. Education surely influences completion via knowledge of the schedule, willingness to confront health workers and capacity to keep track of return visits. Wealth accounts for the cost of each extra contact (transport, income foregone, opportunity cost) which grows with number of contacts. After adjustment for education, facility birth and geography, wealth was no longer a significant predictor of measles dropout, suggesting that these factors may be routes through which poverty undermines completion in the second year.

The link between facility delivery and measles dropout, and the large share (45.0%) of inequality in that outcome attributed to facility delivery, underline the value of continuity of care. A facility birth makes it likelier that a child receives the birth doses and a vaccination card, and that the mother hears about the vaccination schedule before going home. Comparable associations between home birth and dropout have been described in The Gambia and Ethiopia [7, 9]. Because facility delivery is itself strongly

patterned by wealth, raising skilled birth attendance among poorer women should help narrow inequality in later immunisation as well as in other maternal and child health indicators.

The finding for urban children merits attention. Unadjusted pentavalent dropout differed little between urban and rural areas, but with wealth and other factors controlled, urban children had over twice the odds of dropout, and in the decomposition urban residence cancelled out much of the pro-poor inequality. An urban excess in dropout was likewise reported from The Gambia [7]. By contrast, a Ugandan study found children in Kampala's slums more likely to be fully immunised than children in a rural district [24], which suggests that urban disadvantage depends on context. Plausible explanations include frequent changes of residence, the time cost to working mothers of waiting at busy public clinics, care split between public and private providers, and less active follow-up of the urban poor than of rural communities served by outreach. For the Big Catch-Up and later routine efforts, the urban poor should not be assumed to be well served simply because facilities are close by.

Variation between regions was considerable. Dropout for both outcomes was highest in the North Central and North East zones, and several of the highest state estimates came from states affected by conflict and insecurity, such as Borno. Interrupted outreach sessions and insecurity that prevents families from returning for later doses are likely to contribute to high dropout in north-eastern Nigeria [25].

Implications for policy and practice

These findings carry several implications for the Big Catch-Up and for routine immunisation thereafter. First, children who have started but not finished the schedule are already known to the health system, and they can be returned to the schedule by using facility registers, home-based records and community health workers to trace those who have defaulted; in low- and middle-income settings, reminders, recall and community-based activities have all been shown to raise coverage [26]. Second, the second year of life contact should be explicitly reinforced, say by combining MCV2 with other services, and ensuring MCV2 catch-up campaigns reach that age group. Third, routine monitoring should disaggregate dropout by wealth, mother's education and place of residence at the state level [15].

Strengths and limitations

Some strengths of the study are the use of the newest nationally representative Nigerian data, an inequality measure appropriate for bounded binary outcomes, following infants for dropout as well as children in the second year, and a decomposition that measures more than just associations. Looking at dropout among children enrolled in each series adds to zero-dose analyses by disentangling access versus retention. Limitations include the following: a cross-sectional design precludes causal interpretations. Because several children did not have a home-based record, vaccination status was at least partly based on maternal recall, which can misreport doses, and treating "don't know" responses as unvaccinated could slightly increase dropout estimates. Limiting each sample to children who had received the first dose of vaccine created socially selected samples, which was most pronounced where

coverage was lowest. The decomposition used a linear probability model and makes no causal claims about our noncausal statistical contributions. The survey did not collect data on supply-side factors; in particular, vaccine stock-outs, session frequency, or health worker presence. State estimates and those for traditional and other religions are based on small sub-sample sizes and should be viewed with caution.

Conclusions

In Nigeria, most of the inequality in wealth-related immunisation in childhood occurs before the child is enrolled, although dropout after initial contact is prevalent and highly concentrated in poorer children. Among children who received immunisation, the inequality escalates in the second year of life versus infancy. Wealth, maternal education, place of delivery and geography explain the lion's share of this inequality and, after controlling for household wealth, children living in urban areas are significantly more likely to drop out. Restoring coverage and reaching zero-dose children will have more sustainable equity effects if children are retained in care, using a strong second-year-of-life platform, defaulter tracing and follow-up of high-risk households.

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Abbreviations

aOR
adjusted odds ratio
BCG
Bacillus Calmette–Guérin
CI
confidence interval
DHS
Demographic and Health Survey
MCV1
first dose of measles-containing vaccine
MCV2
second dose of measles-containing vaccine
NDHS
Nigeria Demographic and Health Survey
NPC
National Population Commission
Penta1
first dose of pentavalent vaccine
Penta3
third dose of pentavalent vaccine

Polio3
third dose of oral poliovirus vaccine
pp
percentage points
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
WHO
World Health Organization.

Declarations

Ethics approval and consent to participate:

Approval for the 2023–24 NDHS was given by the ICF Institutional Review Board and Nigeria's National Health Research Ethics Committee, and the survey implementers obtained written or verbal informed consent from all respondents. As this secondary analysis relied on anonymised public-use data, no further ethical approval was needed.

Consent for publication:

Not applicable.

Competing interests:

The author declares no competing interests.

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Author Contribution

The author conceived, wrote and analyse data in the manuscripts

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Availability of data and materials:

Registered users can request the dataset analysed in this article from The DHS Program (https://dhsprogram.com/data/available-datasets.cfm).

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Figures

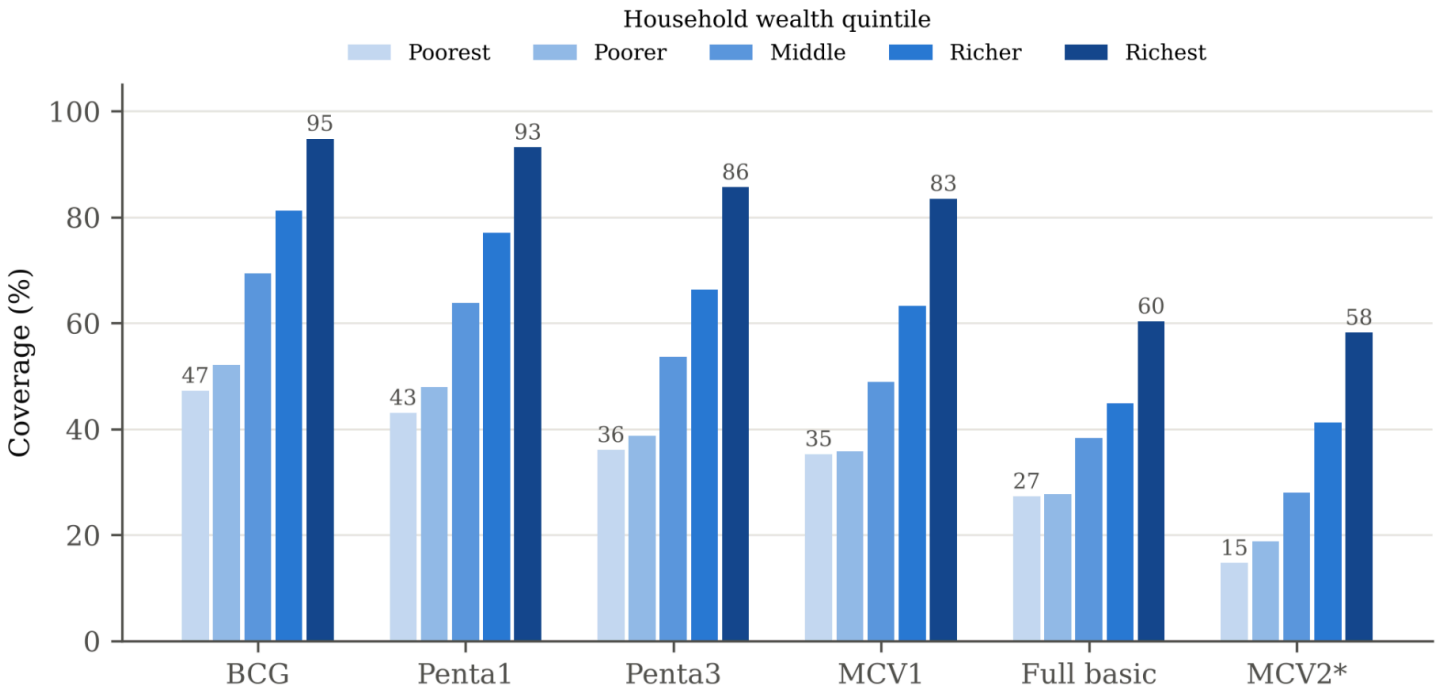


Figure 1

Coverage of selected vaccines by household wealth quintile, Nigeria 2023–24

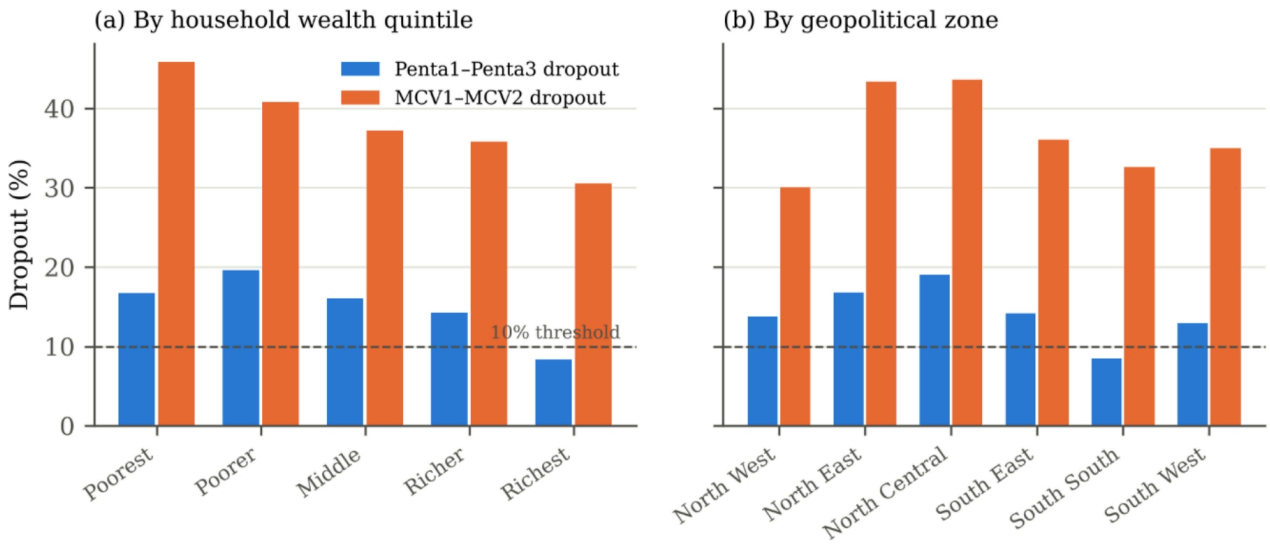


Figure 2

Vaccine dropout by household wealth quintile and geopolitical zone, Nigeria 2023–24

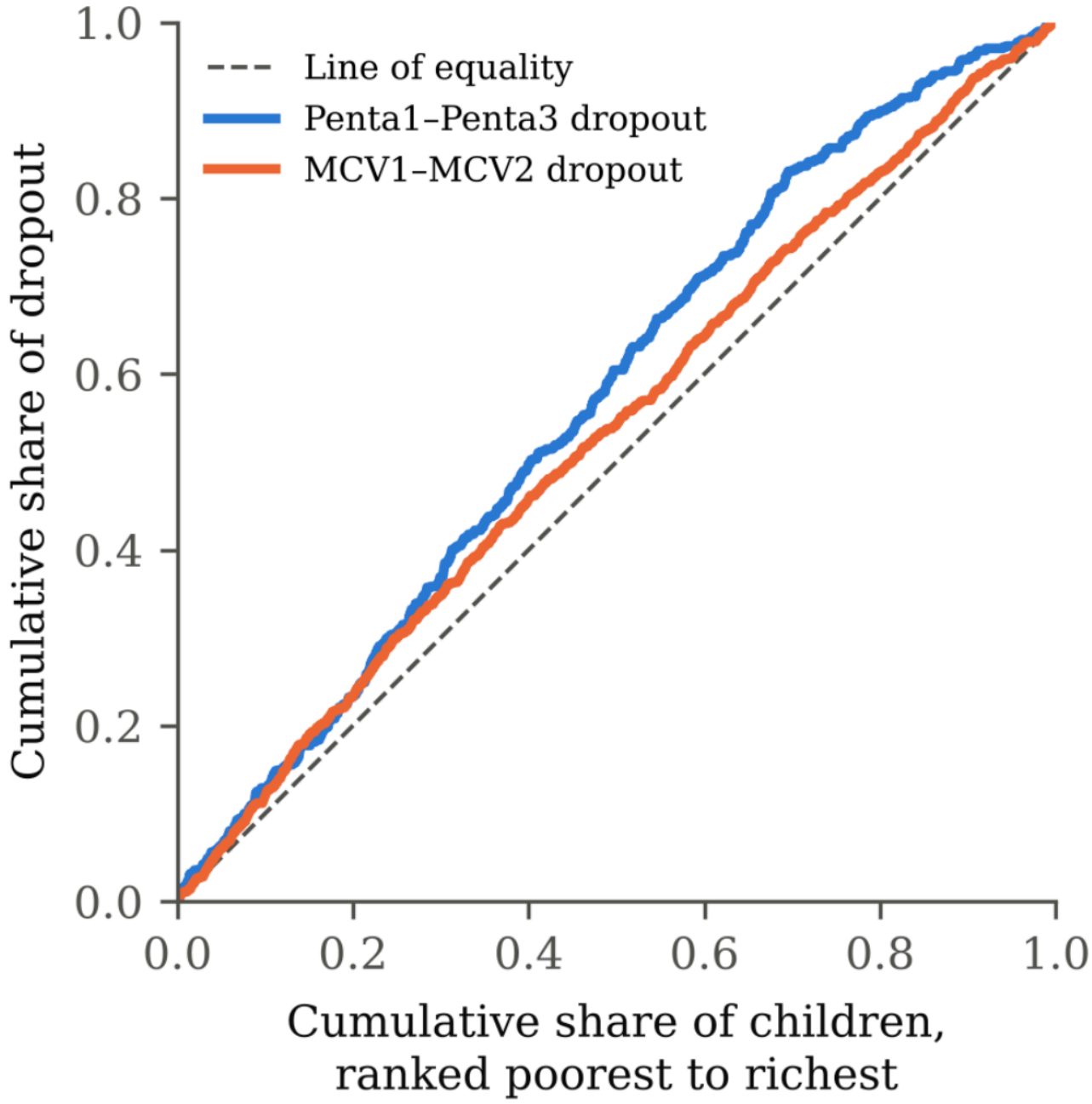


Figure 3

Concentration curves for pentavalent and measles vaccine dropout, Nigeria 2023–24

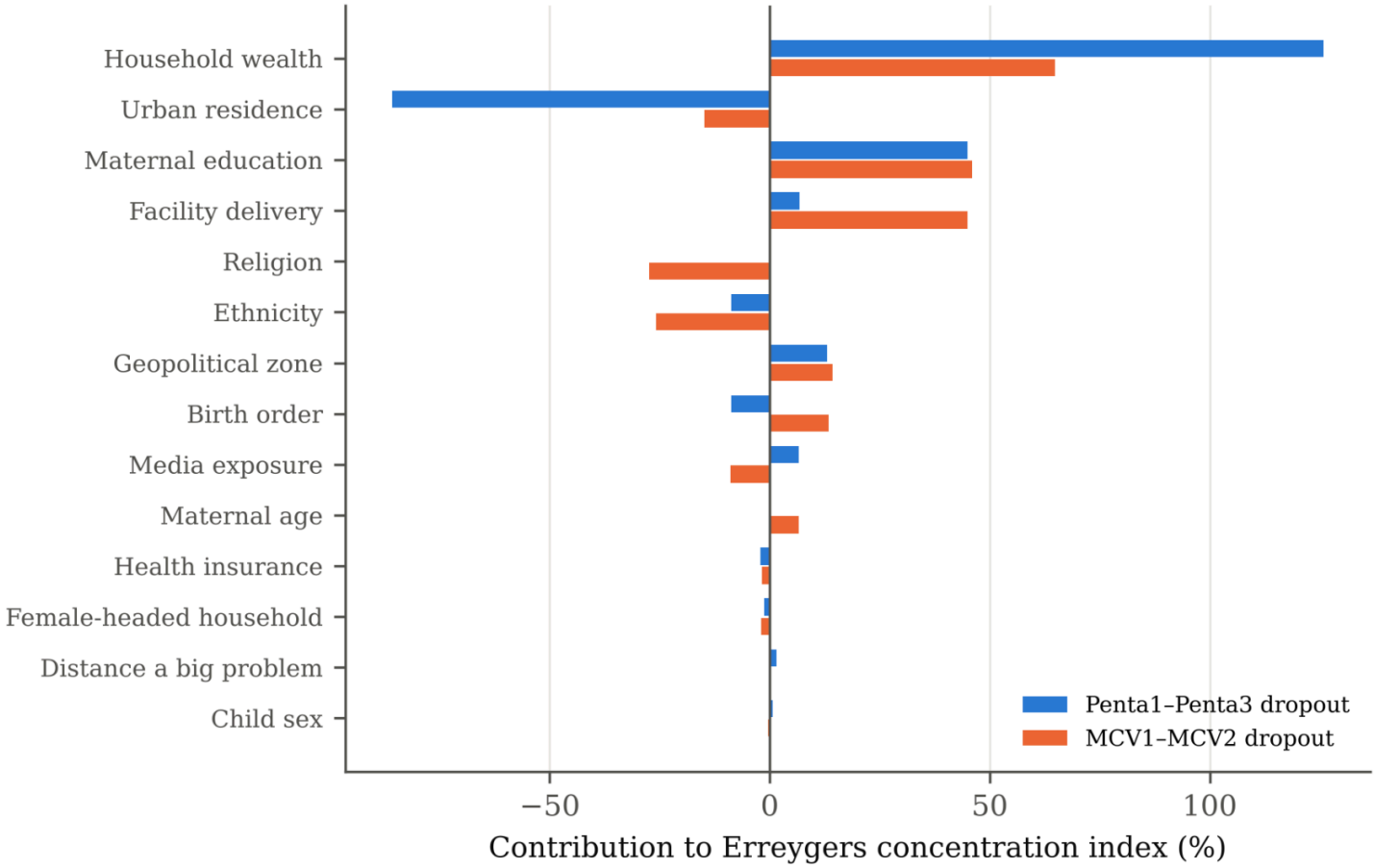


Figure 4

Contributions of explanatory factors to inequality in vaccine dropout, Nigeria 2023–24