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Socioeconomic and residence-based related inequality in childhood vaccination in Sub-Saharan Africa: Evidence from Benin

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Abstract

Background and Aims: Childhood vaccination remains a cost-effective strategy that has expedited the control and elimination of numerous diseases. Although coverage of new vaccines in low- and middle-income countries increased exponentially in the last two decades, progress on expanding routine vaccination services to reach all children remains low, and coverage levels in many countries remains inadequate. This study aimed to examine the pattern of wealth and residence-based related inequality in vaccination coverage through an equity lens.

Methods: We used data from the 2017–2018 Benin Demographic and Health Survey. Statistical and econometrics modeling were used to investigate factors associated with childhood vaccination. The Wagstaff decomposition analysis was used to disentangle the concentration index.

Results: A total of 1993 children were included, with 17% in the wealthiest quintile and 63% were living in rural areas. Findings showed that wealth is positively and significantly associated with vaccination coverage, particularly, for middle-wealth households. A secondary or higher education level of women and partners increased the odds of vaccination compared to no education ($p < 0.05$). Women with more antenatal care visits, with multiple births, attending postnatal care and delivery in a health facility had increased vaccination coverage ($p < 0.01$). Inequalities in vaccination coverage are more prominent in rural areas; and are explained by wealth, education, and antenatal care visits.

Conclusion: Inequality in child vaccination varies according to socioeconomic and sociodemographic characteristics and is of interest to health policy. To mitigate inequalities in child vaccination coverage, policymakers should strengthen the availability and accessibility of vaccination and implement educational programs dedicated to vulnerable groups in rural areas.

KEYWORDS
child, inequality, mother, vaccination, wealth

1 | INTRODUCTION

Childhood vaccination remains a cost-effective strategy that has aided to control and eliminate numerous diseases.[1,2] Since the beginning of the 20th century, numerous vaccine-preventable diseases (VPDs) have been prevented or even eradicated in many countries through vaccination. Vaccination resulted in the eradication of wild-type poliovirus in the Americas in 1990, the Western Pacific Region in 2000, and Europe in 2002, as well as the eradication of *Hemophilus influenza* type B in many countries within a few years of conjugate Hib vaccine introduction.[3] Measles, polio, and diphtheria−tetanus−pertussis vaccinations saved the lives of nearly 2.5 million children globally in the first decade of the 21st century.[4] Since 1924, 103 million instances of pediatric illnesses have been averted in the United States, with 26 million cases in the last decade.[5] In the United States, the number of instances of diphtheria, measles, paralytic poliomyelitis, and rubella decreased by more than 99% during the time before and after national vaccination recommendations. Mumps, pertussis, and tetanus cases decreased by more than 92%, while mortality decreased by 99% or more.[6] In Benin, pediatric bacterial meningitis is reported to have declined between 6.5% in 2012 to 1.0% in 2016 due to the introduction of the pneumococcal conjugate (PCV).[7]

Although coverage of new vaccines increased exponentially in low- and middle-income countries (LMICs) between 2000 and 2019, progress on expanding routine vaccination services to reach all children has stalled, and coverage levels in many countries remain below the 90% national coverage recommended by the World Health Organization.[8,9] In a review published in 2012 based on surveys dating back to 2007, 10% of all children living in LMICs were not vaccinated.[10] Given that vaccination is one of the most cost-effective methods for averting child mortality globally,[2] this estimate was a startling discovery.

Consequently, some vaccine-preventable illnesses such as measles, mumps, and pertussis have resurfaced and constitute a public health burden.[1,11] This re-emergence has been connected in part to reduced vaccination coverage among children, especially in Sub-Saharan Africa.[12] In LMICs, VPDs still constitute substantial causes of under-five morbidity and mortality and are also associated with social and economic consequences.[1] There are still significant incidences of child mortality among regions, within nations, and across countries.[13] Sub-Saharan Africa has the highest under-five mortality rate in the world, accounting for 52% of all mortalities in this age range. In 2018, the region's average under-five mortality rate was 78 deaths per 1000 live births.[13]

Many factors have been marked as impeding vaccination coverage. Among these are reduced public confidence, and other social factors such as education and socioeconomic factors.[14] There also exist reports of inequalities in vaccine coverage. This discrepancy between LMICs can be narrowed if all children, regardless of their geographic, socioeconomic, or demographic makeup, have equitable access to vaccination and its associated benefits.[15,16] This is not always the case, since many children in various countries are either under-vaccinated or unvaccinated.[17] As a result, vaccine-preventable illnesses continue to be a cause of morbidity and mortality in many LMICs. To avoid VPD epidemics, prompt and high vaccination coverage devoid of inequalities is critical as herd immunity occurs from an under-vaccinated and vulnerable population.[18]

Inequality refers to the observed differences in coverage between different populations. Measuring and tracking these disparities might aid in the development of health treatments that give priority to the most vulnerable groups.[19] In countries like Benin, it is reported that the achievement of full vaccination among infants remains a challenge due to inadequate maternal healthcare utilization[20] possibly due to sociodemographic and socioeconomic inequalities and other factors. The study further reports religion, level of education, wealth, and place of residence as significant factors impeding full vaccination among infants. In another study, inequality in zero-dose children was reported to be highest in Benin in a cohort of 25 Sub-Saharan African countries.[13] However, there exists scant information on trends and determinants of inequalities associated with access to childhood vaccination among Beninese. Thus, the factors impeding full vaccination in Benin need to be explored.

A study of 21 national surveys conducted between 2000 and 2013 found that diphtheria−pertussis−tetanus vaccination coverage decreased with time in four countries, including Benin, however these analyses did not explore the influence of family wealth.[17] To this end, this study examined the pattern of wealth and residence-based related inequality in vaccination coverage through an equity lens, focusing on the direction of inequality in vaccination coverage in Benin, using nationally-representative data. The study also assesses the factors influencing the enormous socioeconomic and sociodemographic disparities in child vaccination coverage among Beninese. The findings of the present study would aid policymakers in developing equity-focused vaccination strategies. This might also explain why some vaccination initiatives are more or less effective in reducing inequality in various circumstances.

2 | METHODOLOGY

2.1 | Data source and study design

Data for this study were obtained from the 2017−2018 Benin Demographic and Health Survey (BDHS). Specifically, the study used the individual record files of the DHS. BDHS is part of several surveys obtained from the MEASURE DHS Program, which contain information on several issues on population, health, and nutrition including childhood vaccination. The DHS is a comparatively nationally representative survey conducted in over 85 LMICs worldwide. DHS employed a descriptive cross-sectional design. The survey adopted a two-stage sampling design. The first stage was characterized by the selection of clusters across urban and rural locations from the entire nation. These constituted the enumeration areas for the study. The second stage involved the selection of households from the predefined clusters. Details of the methodologies employed in the various rounds of the surveys can be found in the final reports (National Institute of Statistics and Economic Analysis INSAE and ICF, 2019). Standardized structured questionnaires were used to collect data from the respondents on health indicators including vaccination. We included a total of 1993 children of married and cohabiting women. However, for size of the child at birth, there were 28 missing observations, resulting in a sample size of 1965 for that variable. The data set used is freely available upon request (https://dhsprogram.com/data/available-datasets.cfm). This manuscript was drafted with reference to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement guidelines.

2.1.1 | Outcome variable

The study used complete vaccination as the outcome variable. In this study, complete and full vaccination coverage are used interchangeably. The information on vaccination coverage was collected from either vaccination cards or from mothers' verbal responses to these questions "Did (NAME) ever receive vaccination against Measles?," "Did (NAME) ever receive vaccination against Polio?," "Did (NAME) ever receive vaccination against BCG?," and "Did (NAME) ever receive vaccination against DPT?." Responses were "Yes," "No," and "Don't Know." These were coded as "No" = 0, "Yes" = 1. For the purpose of the analysis, only women who provided definite responses (either "Yes" or "No") were included in the study. According to the WHO guideline (2017), "complete or full vaccination" coverage is defined as a child that has received one dose of BCG, three doses of pentavalent, PCV, oral polio vaccines; two doses of Rotavirus and one dose of measles vaccine. We recoded each variable (vaccinations) as "0" and "1" for children who didn't take the recommended doses and those who took them, respectively. The complete vaccination was obtained by creating a dichotomous variable which comprised all the vaccines administered. To provide a binary outcome (model 1), the two responses were coded as follows: "Incomplete" = 0 and "Complete" = 1."

For further analyses, we used a composite measure as a proxy for the vaccination scheme for robustness checks. Therefore, a composite index of vaccination (Model 2) of vaccination captures the level of vaccination coverage through a score or index. The principal component analysis (PCA) approach contributed to reducing the number of variables related to vaccination (eight dimensions) into a single. The first component of the PCA was related to the vaccination score given all different variables related to vaccination are highly correlated. Low values stand for individuals with a lower level of vaccination, whereas the highest value represents participants with a high vaccination. The Varimax rotation is used to maximize the variances of the sum of the loading. In the paper, we only retained the first component given that that axis exceeded 75% of the total explained intertia (Supporting Information: Files 1 and 2).

2.1.2 | Explanatory variables

Wealth index and place of residence were the measures of inequality in this study. In the DHS, the wealth index is constructed using household assets and ownership through PCA as described in detail here and is comparable across all the survey years. The wealth index includes five quintiles (poorest, poorer, middle, richer, richest), where the first quintile stands for the less wealthy respondents. Place of residence is a description of an individual's geographical area and is grouped into urban and rural.

According to the literature related to vaccination, this study used 17 explanatory variables. These variables were the size of the child at birth, twin status, type of delivery, sex of the child, number of antenatal care attendance, postnatal care attendance, distance to the health facility, place of delivery, mother's age, marital status, employment status, exposure to mass media, ethnicity, number of live births, mother's education, partner's education, and religious affiliation. We performed the stepwise backward selection to investigate the variables most pertinent and associated with the vaccination. Afterwards, the most pertinent variables were retained for the final modeling.

2.2 | Statistical and econometric analysis

We analyzed the data using Stata version 17. First, we presented the descriptive statistics of the vaccination across individual characteristics (Table 1). Second, using econometrics modeling, we examined the association between the measures of inequality, explanatory variables, and childhood vaccination (Equation 1). We applied the sample weights to obtain unbiased estimates according to the DHS guidelines. Also, the Stata survey command "svy" was used to adjust for the complex sampling structure of the data in the regression analyses.

$$\text{Vaccination}_i = \beta_0 + \beta_1\text{Residence}_i + \beta_2\text{Wealth}_i + \beta_k X_i + \epsilon_i \tag{1}$$

Where, Vaccination_i represents the outcome variable; Residence_i represents the residence area of the respondent (Urban/rural). Wealth_i variable is related to the five quintiles of the income category of the respondent. X_i is related to the other explanatory variables; β refers to the parameter estimate by the model. ϵ_i is the error term.

2.3 | Measures of inequality

To estimate wealth inequalities in childhood vaccination, a concentration index, concentration curve (CC), and decomposition analysis, which represent the degree of inequality were employed. The CC was obtained by plotting the cumulative proportion of childhood vaccination on the *y*-axis against the increasing percentage of the population ranked by the socioeconomic wealth index on the *x*-axis.

TABLE 1 Distribution of childhood vaccination across the explanatory variables.

	Vaccination coverage: Did not receive the full vaccination coverage (*N* = 859)		Received the full vaccination coverage (*N* = 1134)		Included population (*N* = 1993)	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Wealth						
Poorest	249	29.0	189	16.7	438	22.0
Poorer	180	21.0	202	17.8	382	19.1
Middle	174	20.3	278	24.5	452	22.7
Richer	139	16.2	238	21.0	377	18.9
Richest	117	13.5	227	20.0	344	17.3
Residence						
Urban	286	33.3	455	40.1	741	37.2
Rural	573	66.7	679	59.9	1252	62.8
Size of child at birth						
Larger than average	237	28.1	323	28.8	560	28.5
Average	483	57.3	651	58.0	1134	57.7
Smaller than average	123	14.6	148	13.2	271	13.8
Twin status						
Single birth	850	99.0	1.101	97.1	1951	97.9
Multiple birth	9	1.0	33	2.9	42	2.1
Type of delivery						
Vaginal birth	825	96.0	1.068	94.2	1.893	95.0
Cesarean birth	34	4.0	66	5.8	100	5.0
Gender						
Female	458	53.3	539	47.5	997	50.0
Male	401	46.7	595	52.5	996	50.0
Number of ANC visits						
Zero	214	24.9	46	4.1	260	13.0
One to three	282	32.8	429	37.8	711	35.7
Four+	363	42.3	659	58.1	1.022	51.3
PNC attendance						
No	695	80.9	882	77.8	1.577	79.1
Yes	164	19.1	252	22.2	416	20.9
Distance to HF						
Not a big problem	512	59.6	760	67.0	1.272	63.8
Big problem	347	40.4	374	33.0	721	36.2
Place of delivery						
Home	215	25.0	71	6.3	286	14.4
Health facility	644	75.0	1.063	93.7	1.707	85.6
Mother's age						
15–19	49	5.7	49	4.3	98	4.9
20–24	202	23.5	275	24.3	477	23.9
25–29	270	31.4	377	33.2	647	32.5

TABLE 1 (Continued)

	Vaccination coverage					
	Did not receive the full vaccination coverage (*N* = 859)		Received the full vaccination coverage (*N* = 1134)		Included population (*N* = 1993)	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
30–34	181	21.1	221	19.5	402	20.2
35–39	105	12.2	148	13.1	253	12.7
40–44	33	3.8	41	3.6	74	3.7
45–49	19	2.3	23	2.0	42	2.1
Marital status						
Married	699	81.4	866	76.4	1.565	78.5
Cohabiting	160	18.6	268	23.6	428	21.5
Employment status						
Not working	183	21.3	170	15.0	353	17.7
Working	676	78.7	964	85.0	1.640	82.3
Exposure to mass media						
Not exposed	377	43.9	398	35.1	775	38.9
Exposed	482	56.1	736	64.9	1.218	61.1
Ethnicity						
Adja and related	115	13.4	142	12.5	257	12.9
Bariba and related	116	13.5	144	12.7	260	13.0
Dendi and related	54	6.3	64	5.6	118	5.9
Fon and related	240	27.9	447	39.4	687	34.5
Yoa, lokpa and related	25	2.9	40	3.5	65	3.3
Betamaribe and related	39	4.5	103	9.1	142	7.1
Peulh and related	168	19.6	81	7.1	249	12.5
Yoruba and related	102	11.9	113	10.1	215	10.8
Number of live births						
One birth	165	19.2	231	20.3	396	19.9
Two births	151	17.6	223	19.7	374	18.8
Three births	145	16.9	197	17.4	342	17.2
Four+	398	46.3	483	42.6	881	44.1
Mother education						
No education	633	73.7	675	59.5	1.308	65.6
Primary	127	14.8	242	21.3	369	18.5
Secondary+	99	11.5	217	19.2	316	15.9
Partner education						
No education	549	63.9	564	49.7	1.113	55.8
Primary	143	16.6	242	21.3	385	19.3
Secondary+	167	19.5	328	29.0	495	24.9
Religious affiliation						
Christianity	349	40.6	626	55.2	975	48.9
Islam	354	41.2	309	27.2	663	33.3
Other	156	18.2	199	17.6	355	17.8

The curves show whether the wealth-related inequality in childhood vaccination (on the *x*-axis) prevails or not. If the curve is above the line of equality (45-degree line), that means the index value is negative; hence it shows that childhood vaccination is disproportionally concentrated among the poor and vice-versa. The concentration index measures the inequality of one variable (childhood vaccination) over the distribution of another variable (wealth index). The index ranges from −1 to +1, where the index value of 0 (zero) shows no socioeconomic inequality. Additionally, on either scale, the higher the value, the higher the extent of socioeconomic inequality. The study used Wagstaff decomposition analysis to decompose the concentration index. Wagstaff's decomposition demonstrated that the concentration index could be decomposed into the contributions of each factor to the wealth-related inequalities. The results of the decomposition method were reported using elasticity, concentration index value, absolute contribution, and relative contribution. Elasticity refers to the change in the childhood vaccination that results from a one-unit change in the explanatory variables. A positive or negative sign in the elasticity shows an increasing or decreasing trend in childhood vaccination due to a positive change in the explanatory variables. The distribution of the determinants in relation to the wealth quintiles is described using the concentration index values. A positive or negative concentration index value denotes whether childhood vaccination is more concentrated in rich or poor households. The percentage contribution indicates the relative contribution of each model component to the overall wealth-related inequality in childhood vaccination. The observed wealth-related inequality in childhood vaccination is increased by variables with positive percentage contributions and decreased by variables with a negative percentage contribution.[21]

A multivariate nonlinear decomposition approach was used for the residence-based inequality. In social science, it is common practice to quantify the contributions to group differences in the average predictions from multivariate models using a multivariate decomposition analysis. The method divides the components of a group difference in a statistic, such as a mean or proportion, into a component attributable to compositional differences between groups (i.e., differences in characteristics or endowments), and a component attributable to differences in the effects of characteristics. This technique was used to assess the variations in childhood vaccination between rural and urban women and identify how much each of the explanatory variables contributes to the variation.[22]

3 | RESULTS

3.1 | Descriptive statistics

Table 1 shows that more than half of the children had average size at birth (57.7%). At least, 9 out of 10 were twins (97.9%) and were born vaginally (95.0%). Male and female children were equally represented (50.0%). More than half of the women had 4 or more ANC visits (51.3%) and 79.1% had no PNC. For 63.8% of the mothers, distance to health facilities was not a big problem and 85.6% gave birth in health facilities. About 3 out of 10 of the mothers were aged 25–29 (32.5%) and 78.5% were married. We noted that 82.3% were employed, 61.1% had media exposure, and 22.0% were poorest. Those belonging to Adja and related ethnicity constituted 12.9%. A significant proportion of the mothers had 4 or more live births (44.1%), no education (65.6%), had partners without formal education (55.8%), and were Christians (48.9%).

On the prevalence of childhood vaccination, it was evident that 58.0% of children who were larger than average at birth were vaccinated. Similarly, vaccination was profound among children who were products of single birth (91.1%) and those who were born through vaginal birth (94.2%). The analysis showed that 52.5% of male children, a greater proportion of those whose mothers had 4 or more ANC visits (58.1%) as well as those who had no PNC (77.8%) received the vaccination. Childhood vaccination dominated among children whose mothers reported that distance to the health facility was not a big problem (67.0%), children born in health facilities (93.7%), and children whose mothers were aged 25–29 (33.2%). In the same vein, vaccination was high among children of married women (76.4%), children whose mothers were working (85.0%), those whose mothers had media exposure (64.9%), and children of the richest women (20.0%). We also observed high vaccination among children of Fon and related ethnicity (39.4%), those whose mothers reported 4 births (42.6%) and were not educated (59.5%) as well as children of Christian women (55.2%).

3.2 | Econometrics analyses of childhood vaccination among children

This section reports the significant findings from the adjusted model as shown in Table 2. Findings show that wealth is positively and significantly associated with vaccination coverage. Particularly, being a middle-wealth household increased by 45% the access to vaccination ($p < 0.01$). Ethnicity was statistically associated with the vaccination for *Bariba* and related ($p < 0.05$), *Fon* and related ($p < 0.01$), and *Betamaribe* and related ($p < 0.01$). Women with multiple births were more likely to receive vaccination coverage ($p < 0.01$). A secondary or higher education level of women and partners increased the vaccination compared to not educated ($p < 0.05$). Women with more antenatal visits (4+) induced and increased children vaccination coverage ($p < 0.01$). PNC attendance was more likely to significantly increase children's vaccination ($p < 0.01$). The place of delivery for women (health facility) was significantly associated with vaccination coverage ($p < 0.01$).

3.3 | Inequality analyses

3.3.1 | Inequality in childhood vaccination by wealth quintile

As evidenced in Figure 1, childhood vaccination increased with wealth status, such that each increment in wealth status was

TABLE 2 Multivariate analysis of childhood vaccination among children.

Variables	(1) Model 1	(2) Model 2
Residence—rural	−0.075	−0.099
	(0.070)	(0.109)
Wealth—poorest	Ref.	Ref.
Poorer	0.055	0.192
	(0.098)	(0.152)
Middle	0.200**	0.455***
	(0.098)	(0.152)
Richer	0.152	0.379**
	(0.106)	(0.166)
Richest	0.073	0.362*
	(0.125)	(0.197)
Ethnicity—Adja and related	Ref.	Ref.
Bariba and related	0.189	0.387**
	(0.119)	(0.190)
Dendi and related	0.138	0.101
	(0.150)	(0.238)
Fon and related	0.201**	0.291*
	(0.096)	(0.154)
Yoa, lokpa, and related	0.285	0.454
	(0.185)	(0.290)
Betamaribe and related	0.808***	0.853***
	(0.149)	(0.223)
Peulh and related	0.158	−0.082
	(0.137)	(0.212)
Yoruba and related	0.003	−0.204
	(0.120)	(0.193)
Twin status—multiple birth	0.641***	0.704**
	(0.224)	(0.323)
Mother's education—not educated	Ref.	Ref.
Primary	0.200**	0.247*
	(0.084)	(0.133)
Secondary+	0.236**	0.491***
	(0.099)	(0.157)
Partner's education—not educated	Ref.	Ref.
Primary	0.105	0.290**
	(0.086)	(0.135)
Secondary+	0.086	0.327**
	(0.091)	(0.143)
ANC—zero visit	Ref.	Ref.
One to three	0.894***	2.348***
	(0.118)	(0.178)
Four+	0.940***	2.445***
	(0.119)	(0.181)
PNC attendance—yes	0.003	0.357***
	(0.074)	(0.116)
Distance to HF—big problem	0.002	0.158
	(0.066)	(0.104)
Place of delivery—health facility	0.513***	1.648***
	(0.110)	(0.168)
Constant	−1.960***	−6.031***
	(0.228)	(0.332)
N of observations	1,993	1, 993
R^2	0.69[a]	0.343

Note: This table contains findings after stepwise backward selection. Model 1 is the logistic model with the vaccination variable as a binary outcome. Model 2 (linear model) presents the findings of the secondary analyses with the composite index of vaccination. Standard errors in parentheses; Source: Authors based on the 2017–2018 Benin Demographic and Health Survey (BDHS).
[a]Stands for the area under-curve (AUC), indicating a good quality of the model.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

associated with an increment in the proportion of children who had a vaccination. Clearly, whilst 66% of children from the richest households were vaccinated, less than half of those in the poorest wealth quintile (43%) were vaccinated.

In Figure 2, we presented the pictorial overview of the inequality in childhood vaccination by wealth quintile and place of residence using the CC. The straight diagonal line in red color depicts equality (i.e., equality line). The area around the equality line stands for the CC. The wider the gap between these two lines (green and yellow), the wider the disparity in childhood vaccination in favor of children from rich households. Therefore, the figure shows a higher concentration of childhood vaccination among the rich according to the residential areas. This means that children from the richest households in the urban area are more likely to benefit from vaccination compared with the poor living in the rural areas. The findings in Figure 2 confirms the positive concentration index among the richest (0.829) as shown in Table 3, thereby emphasizing higher concentration in childhood vaccination among children from rich households.

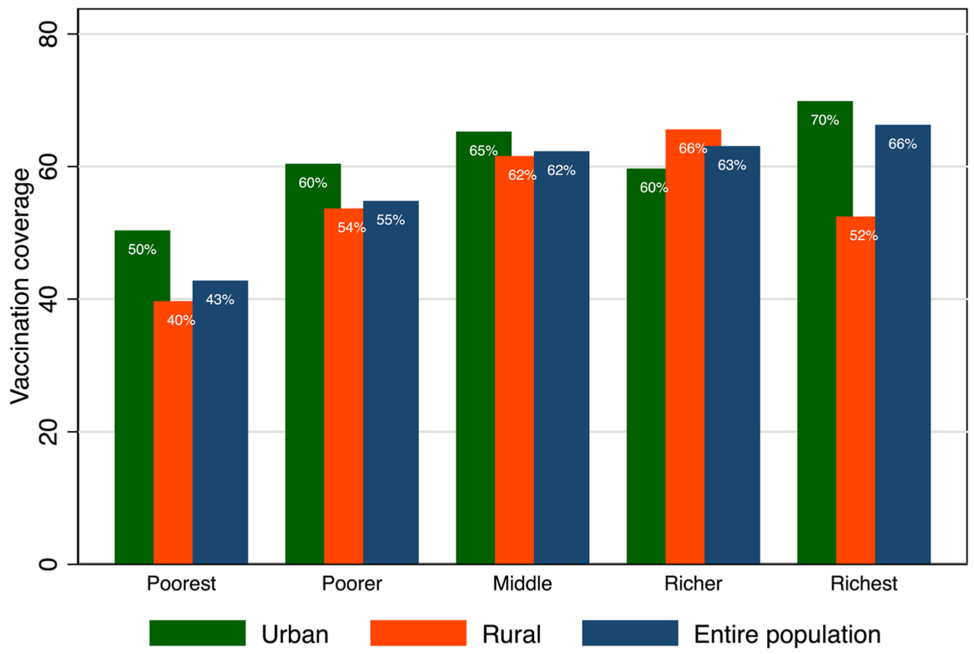

FIGURE 1 Inequality in childhood vaccination by wealth quintile.

3.3.2 | Contribution of sociodemographic characteristics based on the decomposition of concentration index analysis for childhood vaccination

Table 3 shows the results of the decomposition analysis on the contribution of children and maternal sociodemographic characteristics toward the inequality in childhood vaccination. We presented the findings through concentration index (absolute) and adjusted percentage contribution of inequality (percentage contribution) as shown in Table 3. It was evident that concentration in childhood vaccination disfavored children from the poorest households, ethnicity (Bariba, Dendi, Yoa, loka, Betamaribe, Peulh, and related), children whose mothers had multiple births, mothers that reported one to three ANC visits, and for mothers experiencing big problem with the distance to the health facility.

3.3.3 | Results of the residence-based decomposition analysis

In Table 4, we presented the findings from the decomposition analysis as well as the contribution of the sociodemographic characteristics in relation to the inequality in childhood vaccination. The overall rural-urban inequality attributable to variation in childhood and maternal characteristics represented 25.9% (and 74.1% for the difference due to the coefficient). The factors that contributed significantly toward this variation included Richer (6%), mother's education level (12%), partner's education level (11%), and four or more ANC visits (25%).

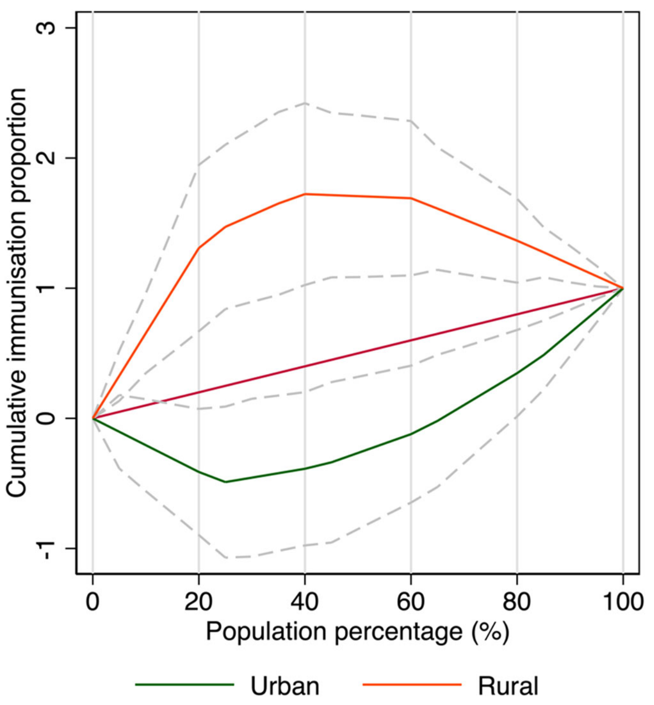

FIGURE 2 Inequality in childhood vaccination by wealth quintile and areas of residence.

4 | DISCUSSION

This study investigated the level and determinants of vaccination coverage in Benin and provides evidence of wealth and residence-based inequalities in vaccination coverage. The findings of the

TABLE 3 Contribution of sociodemographic characteristics based on the decomposition of concentration index analysis for childhood vaccination.

Variables	Elasticity	Concentration index	Absolute contribution	Percentage contribution
Wealth index—poorest				
Poorer	0.0196	−0.383	−0.0075	1.97
Middle	0.072	0.0429	0.003	7.22
Richer	0.054	0.468	0.025	5.48
Richest	0.034	0.829	0.028	3.38
Ethnicity—Adja and related				
Bariba and related	0.036	−0.144	−0.0053	3.68
Dendi and related	0.015	−0.0127	−0.0002	1.55
Fon and related	0.109	0.223	0.0243	10.92
Yoa, loka, and related	0.0122	−0.008	−0.0001	1.22
Betamaribe and related	0.067	−0.324	−0.021	6.75
Peulh and related	0.0110	−0.536	−0.0059	1.11
Yoruba and related	0.001	0.1703	0.0002	0.14
Twin status—single birth				
Multiple birth	0.020	−0.0642	−0.0013	2.029
Mother's educational level—no education				
Primary	0.052	0.205	0.010	5.1895
Secondary/higher	0.0528	0.4650	0.0245	5.280
Partners educational level—no education				
Primary	0.037	0.138	0.005	3.72
Secondary/higher	0.04	0.396	0.0169	4.26
Number of ANC visits—zero				
One to three	0.523	−0.088	−0.046	52.34
Four+	0.833	0.148	0.123	83.36
PNC attendance—yes	−0.003	0.121	−0.0004	−0.355
Distance to health facility—big problem	−0.009	−0.204	0.001	−0.9516

present study highlights important issues worth the needed attention in the implementation of vaccination programs in Benin and other places in the world. Although child vaccination remains an important initiative in preventing many diseases, its implementation and success had been hampered by some sociodemographic and socioeconomic factors.[19] As a result, many LMICs continue to experience health-related consequences due to vaccine-preventable illnesses.[23]

The level of vaccination coverage varies between countries and even within the same country and may be related to varying factors.[13,14] The present study showed that in 2018, approximately 58% of children were reported to have received full vaccination in Benin.[13] Full vaccine coverage reported in the present study was similar to a pooled prevalence of 59.40% in 9 Sub-Saharan African countries[24] and reflects the generally low vaccine coverage in the region. Recent studies have reported full childhood vaccination coverage of 33.3% in Ethiopia,[25] 45.3% in DR Congo,[26] 70.96% in Senegal,[27] and 79.4% in Kenya.[28] Differences in vaccination coverage as observed between Benin and other countries may be a result of differences in vaccine uptake policies, sociodemographic and economic factors, individual beliefs, vaccine education, and access to vaccination services.[13,29,30]

Even among the same population of Beninese, we observed disparities in vaccination, and these were associated with several factors. The findings show the presence of significant poor–rich, educated-uneducated, among other differences in the probability of a child being fully vaccinated in Benin. We observed that vaccination

TABLE 4 Decomposition of children and mothers' sociodemographic factors associated with inequality in childhood vaccination.

Variables	Difference dues to characteristics (E) Coefficient	%	Difference dues to coefficient (C) Coefficient	%
Wealth index				
Poorest	−0.004	4.770	−0.010	13.320
Poorer	−0.001	1.940	0.001	−1.620
Middle	0.008*	−10.270	0.002	−2.080
Richer	−0.004**	6.030	0.022**	−29.630
Richest	0.018	−24.570	−0.025	33.060
Ethnicity				
Adja and related	0.001**	−1.400	−0.002	2.620
Bariba and related	0.000	−0.390	−0.012	15.740
Dendi and related	0.005**	−6.770	−0.023***	30.800
Fon and related	−0.004	4.920	0.026	−35.400
Yoa, loka, and related	0.000	−0.640	0.007**	−8.880
Betamaribe and related	0.007***	−9.410	0.002	−3.090
Peulh and related	−0.003	3.460	0.003	−3.380
Yoruba and related	−0.001	1.870	0.002	−2.350
Twin status				
Single birth	0.001**	−1.680	0.002	−2.680
Multiple birth	0.001**	−1.680	−0.000	0.040
Mother's educational level				
No education	−0.009*	11.470	0.013	−16.940
Primary	−0.002	2.900	0.008	−11.210
Secondary/higher	−0.001	0.990	−0.015	20.560
Partners educational level				
No education	−0.008*	10.980	−0.010	13.960
Primary	−0.000	0.420	0.009	−11.430
Secondary/higher	−0.001	1.590	−0.007	8.930
Number of ANC visits				
Zero	−0.014***	18.290	−0.000	0.350
One to three	0.008***	−10.710	−0.007	9.940
Four+	−0.019***	25.390	0.016	−21.220
PNC attendance				
No	0.001	−1.210	0.022	−29.510
Yes	0.001	−1.210	−0.007	9.570
Distance to health facility				
Big problem	−0.000	0.420	0.001	−0.740
Not a big problem	−0.000	0.420	−0.000	0.310
% Total explained disparity	−0.019	25.90	−0.055*	74.10

Note: Source: Authors based on the 2017–2018 Benin Demographic and Health Survey (BDHS).
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

coverage was associated with ANC visits, PNC attendance, deliveries in health facilities, and mother's wealth similar to that observed in other studies.[31,32] Particularly, the results showed that when compared to children born to mothers in the poorest wealth index, children born to mothers in the richest wealth index are about 40% more likely to receive full vaccination. Similar to the present observation, child vaccination is reported to be high among children born to rich mothers in Ghana[33] and many African countries.[13] Contrary to the report of decreased vaccination among children to highly educated mothers, children born to mothers who are highly educated are likely to be fully vaccinated in Ghana.[33] In India, compared to children born to mothers with no education, children born to mothers with higher education had 2.3 times the odds of being fully vaccinated.[34] This may be attributed to health knowledge of maternal education and vaccination and enhanced health seeking behavior.[34,35] Maternal education generally has a significant effect on improved child health.[36,37] These findings point to the need for complementary initiatives to enhance care usage across the care continuum, from reproductive health services to childhood and adolescence.

Socioeconomic inequalities in childhood vaccination seem to be a great challenge in achieving increased vaccine coverage in LMICs. Through concentration indices (C_n) and decomposition analysis, we determined levels and determinants of inequalities in vaccination coverage at Benin. Vaccination coverage is pro-rich in most LMICs. Particularly, in countries such as Nigeria ($C_n = 0.547$), Pakistan ($C_n = 0.384$), Yemen ($C_n = 0.34$), Cambodia ($C_n = 0.296$), and Cameroon ($C_n = 0.273$), the situation is reported to be worse.[38] In Benin, we report an even more higher concentration index of 0.8265 among children from rich homes emphasizing higher concentration in childhood vaccination among children of the rich. This is about ninefolds increase over the C_n of 0.091 from 2010 to 2015 Demographic and Health Survey data.[38] On the contrary, in some LMICs such as Gambia ($C_n = -0.101$), the Kyrgyz Republic (C_n

= −0.097), and Namibia (C_n = −0.161), vaccination in favor of those with lower socioeconomic status is reported.[39] These findings suggest that socioeconomic inequality in childhood vaccination is a huge problem in Benin and demands strategic interventions to curtail it. These disparities may be explained by differences in vaccine policies among these populations. For instance, the pro-poor nature of vaccination in Gambia, the Kyrgyz Republic, and Namibia is attributed to the increased concentration of vaccination in rural compared to urban settings.[39,40] Reduced vaccination on the part of the poor may be a result of negative attitudes toward vaccination, remote settlement impeding vaccine access, and limited freedom in decision-making.[21] Poor−rich inequalities in maternity care exist in most developing countries[22] and this could invariably contribute to wealth-related inequality observed in this study.

The reasons for under- and non-vaccination may be complex and dependent on many factors. Results from the decomposition analysis suggest that a substantial proportion of the disparities observed in this study may be explained by single birth, falling within the richest wealth quintile, having a mother without formal education, lack of education of the partner, and ANC visits. The majority of the determinants of inequality in vaccination coverage observed in this study may be described and understood using the Socioeconomic Determinants of Health (SDH) report.[41] These have also been recognized in a study conducted by Wiysonge, Uthman[42] to explain low child vaccination coverage in Sub-Saharan Africa. This means that addressing the SDHs - distribution of power, income, products, and services, as well as people's living conditions, such as access to healthcare, schools and education, working and leisure conditions, and the status of their home and surroundings would lead to significant improvements in vaccination coverage and reduce inequalities associated with it.[41,43]

It is worth noting that achieving equality in child vaccination coverage is possible. In 2014, Vietnam achieved vaccination coverage among the rich and poor in almost equal coverage (C_n = 0.009) and this was achieved by increased disbursement of Expanded Program on Immunization staff across all areas of the country to ensure complete free vaccination for both the rich and the poor.[21] In addition, vaccine coverage with little or no inequality was demonstrated by South Africa in 2016, Ghana in 2014, Burundi in 2016/2017, and Uganda in 2016 through increased vaccination coverage.[13]

Our paper used nationally representative data; however, some limitations were identified through the analysis. First, the study is based on cross-sectional data where the vaccination scheme did not capture how children have received different vaccines over a certain period. Second, the analysis did not permit us to draw evidence on how full vaccination coverage has contributed to reducing child and maternal mortality in the country. Further studies may investigate the value for money of vaccination programs in the country to adjust the coverage to support regions in need and reduce persisting inequalities. Researchers could also investigate the number of lives saved or deaths averted during the implementation of vaccination programs for vulnerable groups, especially children and women.

5 | CONCLUSIONS

Inequality in childhood vaccination which is greatly driven by socioeconomic and sociodemographic variables as noted in Benin, is a cause for health policy concern. Policies aimed to improve child vaccination coverage among mothers in Benin may recognize these inequalities in vaccination coverage. Strategies such as increased availability and accessibility of vaccination as well as improved maternal education, and attention to the less privileged groups could be targeted to address this issue of concern.

AUTHOR CONTRIBUTIONS

Eugene Budu: Data curation; formal analysis; writing—original draft; writing—review & editing. **Bright O. Ahinkorah**: Formal analysis; investigation; validation; visualization; writing—original draft; writing—review & editing. **Wilfried Guets**: Formal analysis; methodology; writing—review & editing. **Edward K. Ameyaw**: Investigation; writing—review & editing. **Mainprice A. Essuman**: Investigation; writing—original draft. **Sanni Yaya**: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; supervision; validation; visualization; writing—review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data sets generated and/or analyzed during the current study are available in DHS Program—available data sets (83).

ETHICS STATEMENT

This was a secondary analysis of data and therefore no further approval was required since the data is available in the public domain. However, we sought for permission to use the data from MEASUREDHS. Further information about the DHS data usage and ethical standards is available at https://goo.gl/ny8T6X.

TRANSPARENCY STATEMENT

The lead author Sanni Yaya affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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