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Trends and inequalities in full immunisation coverage among one-year-olds in Sierra Leone, 2008–2019



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Abstract

Background Full immunisation of children by their first birthday is a crucial public health target. Vaccines protect children from preventable diseases, promoting individual and community health. In Sierra Leone, a country with a history of high childhood mortality rates, achieving full immunisation coverage is a critical step towards a healthier future. This study examined the trends and inequalities in full immunisation coverage among children aged one year in Sierra Leone from 2008 to 2019.

Methods Three rounds of the Sierra Leone Demographic and Health Survey (2008, 2013, and 2019) were analysed. A descriptive approach was adopted for the analysis. Simple [difference (D) and ratio (R)] and complex [population attributable risk (PAR) and population attributable fraction (PAF)] measures of inequalities were computed using the World Health Organization's Health Equity Assessment Toolkit (WHO's HEAT) software. The measures were computed separately for each of the three surveys, and their estimates were compared.

Results The findings revealed that full immunisation coverage for one-year-olds in Sierra Leone increased significantly between 2008 (40.1%) and 2013 (68.3%). However, there was a decrease in coverage in 2019 (56.5%). Region-related inequalities were the largest and increased slightly between 2008 (D = 13.8; R = 1.4; PAF = 17.8, PAR = 7.1) and 2013 (D = 20.7; R = 1.3; PAF = 14.2, PAR = 9.7) but decreased in 2019 (D = 18.2; R = 1.3; PAF = 15.3, PAR = 8.6). Substantial education-related inequalities were observed in 2008 (D = 10.1, R = 1.2, PAF = 19.4, PAR = 7.7), but this decreased in 2013 (D = 6.7, R = 1.1, PAF = 8.0, PAR = 5.4; and 2019 D = 5.0, R = 1.0, PAF = 4.7, PAR = 2.4). The age and sex of the child appeared to have minimal influence on the overall inequality in immunisation coverage.

Conclusion The study highlights education and region as key contributors to the inequalities. Mothers with lower education were less likely to get their children fully immunised. Immunisation coverage varies significantly across regions, with the Eastern region leading and the Northern region lagging. Age and sex have minimal impact. The government and partner organisations in Sierra Leone should focus outreach programs on these high-risk groups, implement geographically targeted strategies and invest in education and improve access to healthcare facilities. Ensuring vaccine availability, trained personnel, and data collection for monitoring could be useful. There is also the need to develop targeted interventions for regions with lower coverage. These steps are crucial to achieving universal immunisation coverage.

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Trial registration Registration was not necessary since we analysed a secondary dataset. **Keywords** Children, Global health, Immunization, Inequality, Sierra Leone

Introduction

Full immunization, define as the percentage of children who received one dose of measles and BCG vaccine, and three doses of polio and pentavalent vaccine, is crucial for the well-being and survival of children [1]. Although global immunisation coverage for newborns has improved in recent years, around 21.8 million infants worldwide still lack access to routine immunisation services [1–3]. Immunisation is a key component for achieving the United Nations Sustainable Development Goal 3 (SDG 3), which aims to reduce underfivemortality rate to 25 or fewer deaths per 1000 live births by 2030 [4–6].

To address this, the World Health Organisation (WHO) launched the Expanded Programme on Immunisation (EPI) in 1974, with the primary goal for improving child health and survival rates by ensuring widespread and routine immunisation is enhanced [7]. Since its inception, the EPI program has achieved global success, increasing immunisation coverage rate from 5 to 83% by 2014 [7]. However, despite WHO efforts to enhance immunisation coverage, progress has stagnated in lowand middle-income countries, particularly in the sub-Saharan African region [8].

Sierra Leone launched the National Expanded Programme on Immunisation (EPI)in 1978, later expanding it to include vaccines for five more diseases: yellow fever, rotavirus, hepatitis B, Haemophilus influenzae type b, and pneumococcal disease [9]. Following the program's launch, routine immunisations, including the third dose of the diphtheria-tetanus-pertussis-containing vaccine (DTPcv), improved from 6% in 1986 to 75% in 1990 during the final phase of the Universal Child Immunisation project, as reported by the World Health Organisation (WHO) and UNICEF [10]. However, vaccine coverage declined during periods of civil war from 1991 to 2002 and the Ebola Virus outbreak from 2014 to 2015 [11]. For example, while immunization coverage among children aged 12-23 months increased from 31% in 2008 to 58% in 2013, it declined to 49% in 2019 [12, 13]. In addition to challenges posed by the Ebola outbreak, Sierra Leone continues to face a significant public health issue with inadequate routine vaccine coverage and significant disparities in uptake. These disparities tend to favor children in urban areas, wealthier economic households, and children of mothers with higher education [13]. Factors such as poor communication at household levels, little awareness of immunization uptake among caregivers, and low economic status contribute to suboptimal vaccine coverage [14–16]. A study highlighted that cultural perceptions also play a role in poor vaccination rates; individuals'

misconceptions about vaccines were associated with their cultural background [17]. Addressing these challenges requires comprehensive strategies that consider the multifaceted nature of healthcare access in resourceconstrained settings. Systems strengthening, community engagement, culturally sensitive interventions, and targeted outreach programs can help overcome these barriers and reduce disparities in immunisation coverage across different subpopulations [18].

Previous studies have examined the coverage, access, and barriers of routine immunization in Sierra Leone [19–22], no study has specifically examined the trends and inequalities of full immunization coverage. This study seeks to fill that gap by analysing the trends and identifying inequalities based on socioeconomic factors such as region, urban-rural domicile, socioeconomic status, and maternal education. The findings aim to inform targeted interventions to improve routine vaccine uptake, particularly among disadvantaged groups.

Methods

Study design and population

This study employed a cross-sectional design, concentrating on one-year-old children in Sierra Leone. This specific age group was selected in alignment with WHO recommendations, which advocate for the administration of essential vaccines such as a single dose of measles and BCG vaccines, alongside three doses of polio and pentavalent vaccines should be administered within the first year of life [2].

Study setting and data source

This study was conducted in Sierra Leone. Sierra Leone, a small country in West Africa with a population of 7.1 million, is divided into five regions: North, Northwestern, East, West, and South. The EPI in Sierra Leone is primarily funded by the government through the Ministry of Health's healthcare budget. Additional support comes from international partners such as WHO, UNICEF, US CDC, and AFENET, as well as local community structures like healthcare workers, women support groups, traditional healers, and religious leaders. The EPI program targets children under one year of age and women of childbearing age (15 to 49 years). Immunization services are delivered through three main approaches: static (at health facilities and temporary vaccination sites), outreach (community-based sessions led by health professionals), and mobile (teams traveling to communities beyond a five-kilometer radius from health facilities) [18]. Immunization data is reported monthly to the District

Health Information System 2 (DHIS2). Health facilities compile and submit their data to the district's Monitoring and Evaluation (M&E) officer, who consolidates the reports and submits them to the DHIS2 by the fifth day of each new month.

Data was gathered from 2008, 2013, and 2019 SLDHS. The survey datasets can be accessed for free through the website https://dhsprogram.com/data/dataset admin/in dex.cfm. The SLDHS is a comprehensive survey conduct ed throughout the country to determine regular patterns and alterations in demographic indicators, health indicators, and social issues among individuals of all genders and age groups. The SLDHS utilised a cross-sectional design, where respondents were selected through a stratified multi-stage cluster sampling procedure. The comprehensive sampling approach has been emphasised in the SLDHS report (13). This study included children who received full immunisation doses within thier first year of bith before the survey. For the analysis, a sample of 1,060, 2,168, and 1,837 data points were selected from the 2008, 2013, and 2019 SLDHS datasets. The 2008, 2013, and 2019 SLDHS data were accessible for direct utilisation via the WHO HEAT online platform (23). This study was written carefully considering the requirements outlined in the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [24].

Variables

Outcome variable

The research examined full immunization among one year old children, which was used as the outcome variable. Following the criteria set by the World Health Organisation (WHO) and the Sierra Leone Ministry of Health [25], children who had received all the recommended vaccines by their first birthday were categorised as fully immunised (assigned the code as 1), while those with partial or no vaccines were categorised as not fully immunized (assigned the code 0). It is important to note that we did not recategorize the variables; instead, we utilized data directly obtained from the WHO HEAT online software, which applies population-weighted data to calculate full immunization coverage among one-year-olds in Sierra Leone for the years 2008, 2013, and 2019. This approach ensured consistency with WHO standards and methodologies.

Explanatory variables

The study utilised six variables as inequality stratifiers identified in existing literature [20, 26–28]. The WHO HEAT software included these stratifiers for evaluating disparities in several health and social indicators [23]. The stratifiers included age groups of children's mothers (15–19 and 20–49), educational attainment levels (no education, primary, and secondary and above), economic

status (poorest, poorer, middle, richer, and richest), place of residence (rural and urban), sex of the child (female and male), and sub-national regions (East, North, Northwestern, South, and West).

Statistical analysis

The WHO HEAT (Health Equity Assessment Toolkit) online software uses population-weighted data to calculate full immunization coverage among one-year-olds in Sierra Leone for the years 2008, 2013, and 2019. This ensures that coverage estimates are adjusted based on the population size of different demographic or geographic groups, providing a more accurate and representative measure of immunization rates across the country. The analyses were conducted using the online version of the World Health Organization's HEAT software, accessed through the WHO Health Equity Monitor database [29].

We analyzed the data using four summary measures of health inequity: Difference (D), Ratio (R), Population Attributable Risk (PAR), and Population Attributable Fraction (PAF). These measures are categorized as follows:

Measure	Туре	Definition	Formula/Application
D (Difference)	Absolute	Measures the absolute dif- ference in full immuniza- tion rates between two groups.	Subtracted the percentage of fully immunized individu- als in one group from another (e.g., rural vs. urban).
R (Ratio)	Relative	Measures the relative inequality by comparing full immuni- zation rates between two groups.	<i>R</i> = Yhigh/Ylow, where Yhigh and Ylow are the rates of fully im- munized individuals in the privileged and disadvantaged groups, respectively.
PAR (Population Attributable Risk)	Absolute	Measures the difference between the immuniza- tion rate of a reference category and the national average.	PAR = Yref- <i>l</i> , where Yref is the reference group and <i>l</i> is the national average.
PAF (Population Attributable Fraction)	Relative	Represents the relative inequality of PAR as a percentage of the national average.	PAF = PAR/I×100, where I is the national average.

We utilized these diverse metrics in response to the World Health Organization's recommendation that various summary measures are necessary for producing policy-relevant findings [30]. More detailed instructions on calculating these measures can be found in other sources [29, 31].

Application of summary measures in the current study

The following table outlines how the summary measures were applied to specific variables in this study:

Variable	D (Difference)	R (Ratio)
Sex of the Child	Difference between the proportion of fully immunized female children (Yhigh) and male children (Ylow).	Ratio of fully immu- nized female children (Yhigh) to male children (Ylow).
Wealth Quintile	Difference between the wealthiest group (Yhigh) and the poorest group (Ylow).	Ratio of fully immu- nized individuals in the wealthiest quintile (Yhigh) to the poorest quintile (Ylow).
Education	Difference between individuals with secondary/higher educa- tion (Yhigh) and those with no education (Ylow).	Ratio of fully immu- nized individuals with secondary/higher education (Yhigh) to those with no educa-
Place of Residence	Difference between urban (Yhigh) and rural (Ylow) residents.	Ratio of fully immu- nized urban (Yhigh) to rural (Ylow) residents.
Sub-National Region	Difference between the region with the highest estimate and the region with the lowest esti- mate for each survey round.	Not applicable for sub-national regions.

Additional notes on PAR and PAF

PAR Calculated as the difference between the estimated values for the reference categories (*Y*ref) and the national average (*l*) of full immunization among one-year-olds. Formula:

PAR = Yref - l.

Where *l* represents the national average of full vaccination coverage.

PAF Derived from PAR to represent the relative inequality as a percentage of the national average. Formula:

 $PAF = PAR/l \times 100.$

Additionally, 95% confidence intervals (CIs) were determined for the point estimates. Large inequalities exist when the lower and upper limits of D and PAR do not encompass zero.

Ethical consideration

Since the SLDHS dataset is publicly accessible, ethical clearance was not required for this work. The authorisation to utilise the dataset for publication was acquired from the Monitoring and Evaluation to Assess and Use Results Demographic and Health Surveys (MEASURE DHS). The specific ethical concerns outlined by the SLDHS can be found at the following website: https://dhs program.com/Methodology/Protecting-the-Privacy-of-D HS-Survey-Respondents.cfm.

Results

Trends in full immunisation coverage among one-yearolds in Sierra Leone by different inequality dimensions, 2008–2019

Figure 1 shows the trends in full immunisation coverage among one-year-olds in Sierra Leone from 2008 to 2019. The figure shows full immunisation coverage for oneyear-olds in Sierra Leone increased significantly between 2008 (40.1%) and 2013 (68.3%), attributed to successful immunization interventions. However, there was a decrease in coverage in 2019 (56.5%), attributed to the devastating Ebola outbreak between 2014 and 2015.



Fig. 1 Shows the trends in full immunisation coverage among one-year-olds in Sierra Leone from 2008 to 2019

Table 1 shows the trends in full immunisation coverage among one-year-olds in Sierra Leone from 2008 to 2019 by various inequality dimensions: mothers age, economic status, education, place of residence, sex, and region. Mothers between 15 and 19 years old showed the lowest coverage across all years. There's a trend of increasing coverage with higher wealth quintiles. Children of mothers with no education have consistently lower coverage than those of mothers with higher education. Coverage has been slightly higher among children residing in rural areas compared to urban areas. There's no significant difference in coverage between boys and girls. The eastern region consistently has the highest coverage, while the Northern region has the lowest. Data for the Northwestern region for 2008 and 2013 is missing. The Southern and Western regions fall in between.

Inequality indices of estimates of factors associated with full immunisation coverage among one-year-olds in Sierra Leone, 2008–2019

Table 2 presents inequality indices for factors associated with full immunisation coverage among one-year-olds in Sierra Leone from 2008 to 2019.

Age of mother

The D measure shows disparities in full immunisation across age groups between 2008 and 2019. However, whereas the disparity was positive but non-substantial in 2008 (5.6%) and 2019 (6.1%), showing a small inequality gap between children of older women and adolescents, it was negative in 2013 (-5.3), indicating that children born to older women were at a disadvantage with full immunisation in 2013. The PAF and PAR reveal that the setting average could have been 1.1 and 0.4% points higher in 2008 and 0.8 and 0.5% points higher in 2019 without age-related inequality. However, in 2013, both PAF and PAR had zero values, indicating that no further improvement can be achieved, i.e. children of women aged 15–19 have reached the same level of full immunisation as those of women aged 20–49.

Economic status

Between 2008 and 2019, the D measure showed disparities in full immunisation across economic statuses. Nonetheless, the disparity was positive but non-substantial in 2008 (1.6%) and 2019 (0.9%), showing a small inequality gap between the richest women and poorer women; it was negative in 2013 (-11.4), indicating that children born to poorer women were at a disadvantage with full immunisation in 2013. The PAF and PAR reveal that

Table 1	Trends in ful	l immunisation co	verage among	one-vear-old	ds in Sierra Leone	by different inequ	ality dimensions, 2008–2019
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Dimension	2008		2013		2019	
	N	% (95% CI)	N	%(95% CI)	N	%(95% CI)
Age						
15–19 years	89	35.0 (24.2, 47.5)	231	73.2 (65.5, 79.7)	149	50.9 (41.7, 60.0)
20-49 years	971	40.6 (36.3, 45.0)	1937	67.8 (64.3, 71.1)	1688	57.0 (54.2, 59.8)
Economic status						
Quintile 1 (poorest)	252	38.9 (31.6, 46.8)	520	73.8 (68.3, 78.6)	437	56.3 (50.6, 61.9)
Quintile 2	221	40.4 (33.5, 47.8)	462	66.3 (59.9, 72.1)	396	57.2 (51.3, 63.0)
Quintile 3	210	39.2 (30.8, 48.3)	464	66.7 (61.0, 72.0)	386	56.6 (50.4, 62.6)
Quintile 4	217	41.9 (33.2, 51.1)	401	70.3 (65.0, 75.1)	324	55.1 (49.1, 61.0)
Quintile 5 (richest)	158	40.6 (32.5, 49.2)	319	62.4 (52.7, 71.2)	293	57.3 (49.8, 64.5)
Education						
No education	803	37.7 (33.0, 42.7)	1423	67.1 (63.3, 70.7)	963	54.2 (50.3, 58.1)
Primary education	146	47.4 (38.6, 56.4)	313	66.4 (59.0, 73.0)	294	58.9 (52.4, 65.1)
Secondary or higher education	110	47.9 (37.6, 58.5)	431	73.8 (67.2, 79.6)	579	59.2 (54.2, 64.0)
Place of residence						
Rural	791	40.0 (35.1, 45.2)	1607	69.0 (65.2, 72.6)	1209	56.5 (52.9, 60.0)
Urban	269	40.4 (32.5, 48.8)	560	66.3 (59.4, 72.6)	628	56.6 (51.9, 61.2)
Sex						
Female	534	40.6 (35.3, 46.1)	1128	68.3 (63.8, 72.6)	931	58.2 (54.5, 61.8)
Male	525	39.7 (34.5, 45.1)	1039	68.3 (64.5, 71.9)	905	54.8 (50.8, 58.7)
Region						
East	225	47.3 (40.2, 54.5)	566	78.1 (71.9, 83.2)	382	61.4 (55.8, 66.6)
North	472	33.4 (25.9, 41.9)	858	62.1 (57.1, 66.8)	367	55.1 (48.6, 61.5)
Northwestern	N/A	N/A	N/A	N/A	347	47.0 (40.2, 53.8)
South	227	46.1 (38.9, 53.5)	443	75.5 (69.6, 80.6)	393	65.2 (59.9, 70.2)
West	135	41.6 (32.7, 51.0)	300	57.3 (46.2, 67.7)	346	52.4 (45.3, 59.5)

Dimension 2008				2013			2019		
	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound
Age									
D	5.6	-6.9	18.1	-5.3	-13.2	2.4	6.1	-3.5	15.8
PAF	1.1	1.1	1.1	0	-0.0	0.0	0.8	0.8	0.8
PAR	0.4	-0.4	1.3	0	-0.6	0.6	0.5	-0.1	1.1
R	1.1	0.8	1.6	0.9	0.8	1.0	1.1	0.9	1.3
Economic status									
D	1.6	-9.6	12.9	-11.4	-22.0	-0.7	0.9	-8.3	10.2
PAF	1.0	0.8	1.2	0	-0.0	0.0	1.3	1.2	1.4
PAR	0.4	-6.6	7.4	0	-4.8	4.8	0.7	-4.4	5.9
R	1.0	0.7	1.3	0.8	0.7	0.9	1.0	0.8	1.1
Education									
D	10.1	-1.4	21.8	6.7	-0.4	13.9	5.0	-1.2	11.3
PAF	19.4	19.1	19.6	8.0	7.9	8.0	4.7	4.6	4.7
PAR	7.7	-1.0	16.5	5.4	1.7	9.2	2.6	-0.6	6.0
R	1.2	0.9	1.6	1.1	0.9	1.2	1.0	0.9	1.2
Place of residence									
D	0.3	-9.2	9.9	-2.7	-10.2	4.8	0.1	-5.6	5.9
PAF	0.6	0.5	0.7	0	-0.0	0.0	0.1	0.1	0.2
PAR	0.2	-4.8	5.3	0	-3.3	3.3	0.0	-3.0	3.2
R	1.0	0.7	1.2	0.9	0.8	1.0	1.0	0.9	1.1
Sex									
D	-0.9	-8.4	6.5	-0.0	-5.7	5.7	-3.4	-8.7	1.9
PAF	0	-0.0	0.0	0	-0.0	0.0	0	-0.0	0.0
PAR	0	-2.9	2.9	0	-2.0	2.0	0	-2.3	2.3
R	0.9	0.8	1.1	0.9	0.9	1.0	0.9	0.8	1.0
Region									
D	13.8	3.1	24.6	20.7	8.5	33.0	18.2	9.7	26.8
PAF	17.8	17.7	18.0	14.2	14.2	14.2	15.3	15.2	15.4
PAR	7.1	1.4	12.9	9.7	6.6	12.8	8.6	4.4	12.9
R	1.4	1.0	1.8	1.3	1.1	1.6	1.3	1.1	1.6

Table 2 Inequality indices of estimates of factors associated with full immunisation coverage among one-year-olds in Sierra Leone, 2008–2019

the setting average could have been 1.0 and 0.4% points higher in 2008 and 1.3 and 0.7% points higher in 2019 without economic inequality. However, in 2013, both PAF and PAR had zero values, indicating that no further improvement can be achieved, i.e. children of poorer women have reached the same level of full immunisation as those of richest women.

Education of mother

The D measure shows disparities in full immunisation across education between 2008 and 2019. The disparity was positive and substantial in 2008 (10.1%), 2013 (6.7), and 2019 (5.0%), showing an inequality gap between secondary/higher education women and non-educated women. The PAF and PAR reveal that the setting average could have been 19.4 and 7.7% points higher in 2008, 8.0 and 5.4% points higher in 2013, and 1.3 and 0.7% points higher in 2019 without education inequality.

Place of residence

The D measure shows disparities in full immunisation across places of residence between 2008 and 2019. However, whereas the disparity was positive but non-substantial in 2008 (0.3%) and 2019 (0.1%), showing a small inequality gap between urban women and rural women, it was negative in 2013 (-2.7), indicating that children born to rural women were at a disadvantage with full immunisation in 2013. The PAF and PAR reveal that the setting average could have been 0.6 and 0.2% points higher in 2008 and 0.1 and 0.0% points higher in 2019 if there had been no place of residence inequality. However, in 2013, both PAF and PAR had zero values, indicating that no further improvement can be achieved, i.e. children of rural women have reached the same level of full immunisation as those of urban women.

Region

The D measure shows disparities in full immunisation across regions between 2008 and 2019. The disparity was

positive and substantial in 2008 (13.8%), 2013 (20.7), and 2019 (18.2%) showing an inequality gap between children whose parents are from Eastern region and Northern region children. The PAF and PAR reveal that the setting average could have been 17.8 and 7.1% points higher in 2008, 14.2 and 9.7% points higher in 2013, and 15.3 and 8.6% points higher in 2019 if there had been no region inequality.

Discussion

This study investigated the trends and inequalities in full immunisation coverage among children aged one in Sierra Leone between 2008 and 2019. The study highlights socioeconomic factors as key contributors to the inequities. Immunisation coverage varies significantly across regions, with the Eastern region leading and the Northern region lagging. Age and sex have minimal impact.

The findings revealed that full immunisation coverage for one-year-olds in Sierra Leone increased significantly between 2008 (40.1%) and 2013 (68.3%). However, there was a decrease in coverage in 2019 (56.5%). The reasons behind the rise and fall of full immunisation coverage for one-year-olds in Sierra Leone are complex and multifaceted. Between 2008 and 2013, there was possibly increased funding for vaccination programs by the Sierra Leonean government, which could have led to better resource allocation, improved outreach, and potentially free or subsidised vaccines [32]. Investments in healthcare infrastructure and service delivery, such as new clinics or mobile vaccination units, and free healthcare initative might have made it easier for families in rural areas to reach vaccination sites and access it [33]. Campaigns promoting the importance of vaccination and addressing vaccine hesitancy could have raised awareness and influenced behaviours [15]. Improved vaccine supply chain management, including storage and transportation, could have ensured consistent availability of vaccines at health facilities [15]. The decrease in coverage (2013– 2019) may be due to the emergence of other health priorities, such as outbreaks of infectious diseases or increased strain on healthcare systems, which might have diverted resources away from routine vaccination programs [34]. Misinformation or mistrust about vaccines could have led to some parents delaying or refusing vaccinations for their children [27].

The study revealed that children from wealthier homes were more likely to receive complete immunisation than those from poor households. The D measure shows disparities in full vaccination across economic status between 2008 and 2019. However, whereas the disparity was positive but non-substantial in 2008 (1.6%) and 2019 (0.9%), showing a small inequality gap between richest women and poorer women, it was negative in 2013 (-11.4), indicating that children born to poorer women were at a disadvantage with full immunisation in 2013. This finding is consistent with the earlier research conducted in Ghana [26], Nigeria [35], and India [36]. Poorer families may lack awareness about the benefits of vaccines or have difficulty understanding the vaccination schedule [37]. Transportation costs could be a barrier for poorer families, making it difficult to travel for vaccination appointments. Even if free or subsidised vaccinations exist, poorer families might struggle with indirect costs like missing work to attend appointments or childcare for other children [38]. Wealthier families might have better access to information about the importance of immunisation through media or education [39]. Wealthier families might have social networks with better healthcare knowledge and access, influencing their behaviour.

Our study revealed that children from secondary/ higher education homes in Sierra Leone were more likely to receive full immunisation compared to those from households with no education. The disparity was positive and substantial in 2008 (10.1%), 2013 (6.7), and 2019 (5.0%), showing an inequality gap between secondary/ higher education women and non-education women. This finding is consistent with the previous studies [26, 40-46]. In the Ghana study [26], the authors reported Children of educated mothers with secondary education or higher had higher vaccine uptake (86.7% in 1993 to 80% in 2014) than their counterpart with mothers of no education recording the lowest prevalence (42.2 in 1993 to 76.5 in 2014). Parents with secondary or higher education likely understand the importance of vaccinations and the recommended schedule [47]. They may be more familiar with the benefits and risks of vaccine-preventable diseases. Higher education can equip parents with better information seeking skills. They might be more likely to seek information about vaccinations through media, healthcare professionals, or educational resources [48]. Higher education could lead to a greater understanding of the healthcare system and potentially more trust in healthcare providers, making them more likely to utilise vaccination services [48]. These factors highlight the role of education in empowering parents to make informed decisions and navigate the healthcare system to ensure their children's well-being.

The study revealed that children residing in the Eastern region of Sierra Leone are more likely to have full immunisation coverage, while those living in the Northern region had lower full immunisation coverage. The disparity was positive and substantial in 2008 (13.8%), 2013 (20.7), and 2019 (18.2%) showing an inequality gap between children whose parents are from Eastern region and Northern region children. Transportation infrastructure might be more developed in the East, allowing families to reach vaccination sites more easily [49].

The Northern region might have been more affected by past conflicts or civil wars, which could have disrupted healthcare infrastructure and immunisation programs [50]. Cultural beliefs or traditional practices in the North might make some communities more hesitant towards modern medicine or vaccinations [51]. The Northern region might have more geographically remote areas or challenging terrain, making it difficult to deliver vaccines and reach all communities [52]. To understand the exact reasons, further investigation would be needed. This could involve comparing healthcare infrastructure data between the regions, analysing the distribution of public health campaigns, and studying socioeconomic factors and education levels in both regions. By addressing these potential disparities, Sierra Leone can work towards achieving equitable access to full immunisation coverage for all children throughout the country.

Policy and practice implications

The findings of our study hold significant implications for policy and practice in Sierra Leone's immunisation efforts. The study highlights the need for policies prioritising reaching children from disadvantaged backgrounds. This could involve vouchers, conditional cash transfers to offset transportation, or lost wages due to vaccination appointments. Deploying trained community health workers to educate mothers, address vaccine hesitancy in low-income areas, and set up mobile clinics in remote areas to improve access to immunisation services. Develop culturally sensitive campaigns that address vaccine hesitancy and misinformation, especially targeting mothers with lower education levels. This can involve collaborating with local leaders and leveraging radio, community events, and mobile phone messaging. Ensure a reliable supply chain and cold chain infrastructure to maintain vaccine potency throughout the country. Invest in training and support for healthcare workers, especially in underserved regions, to ensure proper immunisation practices and communication with mothers. Develop region-specific interventions that address the unique challenges faced in each area. For example, the Northern region with lower coverage might require a more intensive outreach program than the Eastern region partner with local authorities to understand regional needs and develop culturally appropriate outreach strategies. Consider providing childcare services during immunisation appointments to address childcare barriers for mothers. By implementing these policy and practice changes, Sierra Leone can strive towards achieving equitable and sustained improvements in full immunisation coverage for all children.

Strengths and limitations

The DHS provides data collected from a large, representative sample of households across Sierra Leone. This ensures that our findings are generalisable to the national population of one-year-olds. Data from three-time points (2008, 2013, 2019) allows for analysing trends in immunisation coverage over time. This can reveal progress made and identify periods of stagnation or decline. The DHS collects data on household wealth, maternal education, and other socioeconomic factors. This allows us to explore the link between these factors and immunisation coverage, a key strength of the WHO's HEAT framework. While valuable, it has some limitations. Immunisation information is based on maternal recall, which can be prone to inaccuracies. While the DHS provides data from multiple years, it is still considered cross-sectional at each time point. This limits the ability to establish causal relationships between factors and immunisation coverage. Sampling bias or social desirability bias might influence the data. For example, mothers more aware of the importance of immunisation might be more likely to participate in the survey or accurately report their child's immunisation status.

Conclusion

Full immunisation coverage for one-year-olds in Sierra Leone increased significantly from 2008 to 2013, reflecting the successful interventions. However, the subsequent decline by 2019 underscores the need to address obstacles that impede sustained progress. The study indentifies socioeconomic factors, such as education and economic status, as major contributors to inequities. This highlights the importance of targeted programs aimed at reaching disadvantaged groups. Immunisation coverage also shows marked regional disparities, with the Eastern region performing best and the Northern region falling behind. To address these gaps, region-specific strategies are essential, including campaigns focused on geographically underserved areas and support for mothers from lower socioeconomic backgrounds. Efforts to improve access to healthcare access and reduce economic barriers such as providing financial assistance, offering flexible clinic hours, and childcare options during appointments should be prioritized. Additionally, ensuring a consistent vaccine supply, training healthcare personnel, and strengthening data collection system for monitoring progress are vital for achieving long-term improvement.

Abbreviations

SLDHS	Sierra Leone Demographic and Health Survey
D	Difference
HEAT	Health Equity Assessment Toolkit
PAF	Population Attributable Fraction
PAR	Population Attributable Risk
R	Ratio
SDG	Sustainable Development Goal

STROBE	Strengthening the Reporting of Observational Studies in
	Epidemiology
WHO	World Health Organization

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Author contributions

AO, CB, and BOA contributed to the study design and conceptualisation. AO, CB, and BOA performed the analysis. AO, CB, and BOA developed the initial draft. US provided valuable feedback on the data interpretation, methodological approach, and manuscript clarity. All the authors critically reviewed the manuscript for its intellectual content. All authors read and amended drafts of the paper and approved the final version. AO had the final responsibility of submitting it for publication.

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Data availability

The dataset used can be accessed at https://whoequity.shinyapps.io/heat/.

Declarations

Ethics approval and consent to participate

This study did not seek ethical clearance since the WHO HEAT software, and the dataset are freely available in the public domain.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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