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situations remain susceptible to death before their first birthday from preventable causes such as diarrhea, malaria, pneumonia, as well as perinatal conditions such as preterm birth complications, birth asphyxia, congenital anomalies, and neonatal infections. Most of these deaths occur in Sub-Saharan Africa [1, 3, 6–9] requiring urgent attention to achieve Sustainable Development Goal (SDG) 3.2, which aims to reduce under-5 and neonatal mortality [6, 10]. While SDG 3.2 does not specifically target infant mortality, around two-thirds of under-5 deaths occur in the first year of life.

The global IMR in 2021 was 38 deaths/1000 LBs compared to 74/1000 LBs in Sub-Saharan Africa [1, 2]. In Sierra Leone, the IMR was 75/1000 LBs in 2019, with 1 in 13 children dying before their first birthday. The under-five mortality rate was 122/1000 LBs that year, with 9 out of 13 (69%) under-five deaths being infant deaths, thus the focus on this population.

While there has been a steady decline in under-five mortality in Sierra Leone, from 156 deaths/1000 LBs (2013) to 122 deaths/1000 in 2019 [9], but is the highest under-five mortality rate in sub-Saharan Africa [1]. These death rates far exceed the 2030 target for Sustainable Development (SDG 3.2) which aims to reduce under-five mortality to less than 25 deaths/1000 LBs and neonatal mortality to less than 12 deaths/1000 LBs [10].

In April 2010, in a bid to reduce the IMR and accelerate progress towards MDG 4 and 5, the Government of Sierra Leone launched the Free Healthcare Initiative (FHCI) in collaboration with non-governmental organizations and development partners [11–14]. This initiative provides free care to pregnant and lactating mothers, and children under five years at all public health facilities. Prior to the FHCI, user fees had been cited as a major barrier to accessing healthcare [11, 13].

Despite the FHCI, there has been uneven health service utilization among children under five, with disparities across regions, place of residence and wealth levels [15, 16]. Indirect costs contribute to inequality in healthcare utilization [16–19]. This study examines socio-economic and geographical inequalities in infant mortality rates in Sierra Leone from 2008 to 2019.

## Methods

### Study setting and data source

Data from the 2008, 2013, and 2019 Sierra Leone Demographic Health Survey (SLDHS) were utilised. These comprehensive, national population-based surveys, designed to identify patterns in demographic and health indicators, and social issues, target households across Sierra Leone, collecting data from men and women of reproductive age, typically women aged 15–49 and men aged 15–59 [9]. The SLDHS employed a cross-sectional

design, selecting participants through a stratified multi-stage cluster sampling procedure [9]. They are carefully designed to comply with the standards and guidelines established in Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [20]. This study focused on women who had given birth to a live infant in the one year prior to the respective SLDHS periods. The data were accessed through the World Health Organization (WHO) Health Equity Assessment Toolkit (HEAT) online platform [21].

### Outcome variable and Inequality measures

The study's outcome is the infant mortality rate. To evaluate inequalities in infant mortality, six variables were examined: maternal age (15–19 and 20–49), economic status measured as wealth quintile (1, 2, 3, 4, 5), maternal education (none, primary, secondary/higher education), place of residence (rural, urban), child sex (female, male), and sub-national region (East, North, South, West).

### Statistical analysis

The analysis used the web-based iteration of the HEAT developed by the WHO [21]. The HEAT software is

unfavorable conditions. An absence of further development is indicated by values of PAF and PAR approaching zero, suggesting that all subgroups have reached parity with the reference subgroup.

## Results

Table 1 shows a decline in the IMR in Sierra Leone between 2008 and 2019, from 111.1/1,000 live births (LBs) in 2008 to 77.4/1,000 LBs in 2019, with most of the improvement between 2013 and 2019. There are significant differences in the IMR across the variables of interest. The poorest quintile (quintile 1) consistently had the highest rates, the richest (quintile 5) the lowest. Likewise, for education, those without education had the highest IMR. Despite inequalities, all groups showed lower IMR over time, indicating progress in reducing infant mortality across Sierra Leone. The Northwestern province had the highest IMR in 2019 at 101.0/1,000 LBs and the Northern province the lowest at 53.9/1,000 LBs. With no data available for the Northwestern province before 2019, initial rates

were highest in the Eastern and Northern provinces and lower in the Western and Southern province. The Northern province experienced the most significant decline.

### Age of the mother

Table 2 shows inequality indices for IMR in Sierra Leone from 2008 to 2019. There was a decrease in inequality for maternal age between children of older and younger mothers, from 20.1/1,000 LBs in 2008 to 14.7/1,000 LBs in 2019. The PAF and PAR for age suggests that if the age disparity in IMR were eliminated, the IMR could be reduced by  $-3.5$  and  $-3.8/1,000$  LBs in 2008,  $-3.4$  and  $-3.7/1,000$  LBs in 2013, and  $-3.5$  and  $-2.7/1,000$  LBs in 2019.

### Maternal economic status

The economic inequality in the IMR between children of the richest (Q5) and poorest (Q1) mothers declined from 54.9/1,000 LBs in 2008 to 30.4/1,000 LBs in 2019.

The PAR for maternal economic status suggests that

**Table 1** Trends in the prevalence of infant mortality rates (deaths per 1000 live births) by different inequality dimensions in Sierra Leone, 2008–2019

**Table 2** Inequality measures of estimates of factors associated with infant mortality rates (deaths per 1000 live births) in Sierra Leone, 2008–2019

Dimension	2008			2013			2019		
	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound
<b>Age</b>									
D	20.1	-0.3	40.7	20.6	5.5	35.8	14.7	1.9	27.4
PAF	-3.5	-3.5	-3.4	-3.4	-3.4	-3.4	-3.5	-3.5	-3.5
PAR	-3.8	-6.6	-0.9	-3.7	-5.6	-1.8	-2.7	-4.6	-0.8
R	1.1	1.0	1.4	1.1	1.0	1.3	1.1	1.0	1.3
<b>Economic status</b>									
D	54.9	24.3	85.5	15.4	-4.2	35.2	30.4	11.8	49.0
PAF	-16.3	-16.4	-16.2	-8.9	-9.0	-8.8	-22.1	-22.2	-22.0
PAR	-18.1	-31.1	-5.2	-9.8	-18.9	-0.6	-17.1	-25.1	-9.1
R	1.5	1.21	2.0	1.1	0.9	1.3	1.5	1.1	1.9
<b>Education</b>									
D	28.9	6.8	50.9	9.6	-5.5	24.9	9.7	-2.2	21.8
PAF	-23.3	-23.5	-23.2	-6.7	-6.8	-6.9	-10.5	-10.6	-10.4
PAR	-25.9	-41.0	-10.8	-7.4	-17.1	2.2	-8.1	-14.3	-1.9
R	1.3	1.0	1.7	1.0	0.9	1.2	1.1	0.9	1.3
<b>Place of residence</b>									
D	7.4	-15.6	30.6	7.1	-7.8	22.0	13.8	1.9	25.8
PAF	-4.9	-5.0	-4.8	-4.8	-4.9	-4.7	-11.7	-11.8	-11.7
PAR	-5.4	-14.7	3.7	-5.3	-11.9	1.3	-9.1	-14.1	-4.1
R	1.0	0.8	1.3	1.0	0.9	1.2	1.2	1.0	1.4
<b>Sex of child</b>									
D	-12.8	-30.3	4.6	-14.7	-25.9	-3.5	-17.0	-27.3	-6.7
PAF	0	-0.0	0.0	0	-0.0	0.0	0	-0.0	0.0
PAR	0	-5.6	5.6	0.0	0.0	0.0	0.0	0.0	0.0

D Difference, NA Not Available, PAF Population Attributable Fraction, PAR Population Attributable Risk, R Ratio

eliminating the socio-economic disparity between children of the richest and poorest mothers, the IMR would have been -18.1/1,000 LBs in 2008, -18.9/1,000 LBs in 2013, and -17.1/1,000 LBs in 2019 lower.

**Maternal education status**

Inequality in IMR between the least and most educated participants decreased from 28.9/1,000 LBs (2008) to 9.7/1,000 LBs (2019). The PAF and PAR for maternal education suggests that closing this disparity would reduce the IMR by -23.3/1,000 LBs and -25.9/1,000 LBs in 2008, -6.7/1,000 LBs and -7.4/1,000 LBs in 2013, and -10.5/1,000 LBs and -8.1/1,000 LBs in 2019 respectively.

**Place of residence**

Inequality between children born to mothers in urban versus rural areas increased from 7.4/1,000 LBs in 2008 to 13.8/1,000 LBs in 2019. The PAR for place of residence suggests that addressing disparity between urban and rural children would lessen the IMR by -5.4/1,000 LBs in 2008, -5.3/1,000 LBs in 2013, and -9.1/1,000 LBs in 2019.

**Child's sex**

The inequality between male and female children decreased from -12.8/1,000 LBs in 2008 to -17.0/1,000 LBs in 2019. The PAF and PAR however had zero values in all survey years, indicating that no further







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