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Socio-economic and geographical inequalities in infant mortality rates in Sierra Leone, 2008–2019

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Abstract

Background The death of a child before their first birthday remains a significant global challenge, particularly in sub-Saharan Africa. This study examined the socio-economic and geographical inequalities in infant mortality in Sierra Leone between 2008 and 2019, utilising data from the Sierra Leone demographic and health surveys.

Methods Three Sierra Leone demographic health survey rounds (2008, 2013, 2019) were analysed. Simple [difference and ratio] and complex [population attributable risk and fraction] measures of inequality in the infant mortality rates were calculated using the World Health Organization's health equity assessment toolkit software.

Results The national infant mortality rate dropped from 111.1/1,000 live births (LBs) in 2008 to 77.4/1,000 LBs in 2019. Inequality for age decreased from 20.1 (2008) to 14.7/1,000 LBs (2019); economic inequality from 54.9 (2008) to 30.4/1,000 LBs (2019); and inequality due to maternal education fell from 28.9 (2008) to 9.7/1,000 LBs (2019). However, inequality by urban/rural residence increased from 7.4 (2008) to 13.8/1,000 LBs (2019). The population attributable risk revealed that addressing place of residence inequality would reduce the infant mortality rate -5.4 /1,000 LBs, -5.3/1,000 LBs, and -9.1 /1,000 LBs points in 2008, 2013 and 2019 respectively. Inequality associated with the child's sex decreased from -12.8/1,000 LBs in 2008 to -17.0 in 2019. The population attributable fraction and risk were zero in all survey years, indicating that female and male children had statistically equivalent mortality rates. Provincial inequality increased (2008: 26.9/1,000 LBs; 2019: 47.0/1,000 LBs). The population attributable risk suggests if provincial inequality were eliminated the infant mortality rate would have been -15.7/1,000 LBs, -19.0 /1,000 LBs, and -23.5/1,000 LBs lower in 2008, 2013 and 2019 respectively.

Conclusion Low socio-economic status, limited maternal education, adolescent motherhood, and residence in rural areas and Northwestern province were associated with higher infant mortality rate. Tailored interventions that target vulnerable populations, like adolescent mothers, families living in poverty, and Northwestern province, are essential to improving child health outcomes in Sierra Leone.

Keywords Infant, Mortality, Global Health, Inequality, Sierra Leone

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Introduction

The Infant mortality rate (IMR), which is the probability of babies dying between birth and their first birthday, expressed per 1,000 live births [1–3], is a key indicator of a population's socioeconomic development. High rates are usually indicative of unmet health and social needs [4, 5]. Despite improvements in most global regions in achieving set targets [6] many children in vulnerable

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-Sahara 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 designed to assess health inequalities within and among countries, focusing on health and socio-economic indicators, including child, maternal, and reproductive health [22, 23].

This study analyzed four inequality indicators:

1. Difference (D): An absolute measure of the disparity in mortality rates among different groups. D is calculated as the difference in mortality rates between the highest and lowest risk groups. A value of zero indicates no inequality, while higher values signify greater inequality in mortality rates.
2. Ratio (R): A relative measure comparing mortality rates of two groups. A value of 1 indicates no inequality, and values greater than 1 indicate increasing inequality. The ratio was determined by dividing the mortality rate of the higher-risk group by that of the lower-risk group. An R equal to 1 denotes no inequality, while values exceeding 1 indicate increasing levels of inequality.
3. Population-Attributable Fraction (PAF): This measure reflects the proportion of a health outcome that can be attributed to a specific risk factor or condition.
4. Population-Attributable Risk (PAR): This measure quantifies the risk of a health outcome associated with a particular exposure or characteristic.

   Both the PAF and PAR were calculated to assess the impact of socio-economic factors on infant mortality. Positive values for the PAF and PAR indicate favorable conditions, while negative values denote

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

Dimension	2008(111.1/1,000 live births)				2013 (109.9/1,000 live births)				2019 (77.4/1,000 live births)			
	Sample	IMR	Lower Bound	Upper Bound	Sample	IMR	Lower Bound	Upper Bound	Sample	IMR	Lower Bound	Upper Bound
Age												
15–19 years	2216	125.4	108.3	142.4	4412	125.9	112.5	139.4	3666	89.4	78.4	100.3
20–49 years	9486	105.2	93.6	116.8	20,055	105.2	98.2	112.2	16,054	74.7	68.0	81.3
Economic status												
Quintile 1 (poorest)	2712	147.9	124.5	171.3	5806	115.6	104.3	126.8	4716	90.7	77.7	103.7
Quintile 2	2590	101.0	81.0	121.1	5426	109.9	97.3	122.5	4458	78.2	67.1	89.2
Quintile 3	2641	105.4	89.0	121.7	5343	116.9	105.2	128.6	4048	77.3	67.1	87.5
Quintile 4	2286	99.2	82.5	115.8	4692	102.5	91.8	113.2	3519	73.3	62.1	84.5
Quintile 5 (richest)	1701	92.9	72.9	113.0	3595	100.1	83.7	116.4	2978	60.2	46.9	73.6
Education												
No education	9369	114.0	101.0	126.9	18,460	112.0	104.7	119.3	11,940	78.9	71.6	86.2
Primary education	1353	113.7	89.9	137.4	3137	104.4	90.7	118.1	2787	85.1	70.7	99.4
Secondary or higher education	1209	85.0	67.1	103.0	3266	102.4	88.9	115.8	4992	69.1	59.5	78.7
Place of residence												
Rural	8767	113.1	100.0	126.1	18,639	111.7	104.2	119.2	12,970	82.1	74.0	90.3
Urban	3165	105.6	86.2	124.9	6224	104.6	91.6	117.6	6750	68.3	59.4	77.1
Sex of child												
Female	5964	104.6	93.1	116.2	12,231	102.4	95.2	109.7	9718	68.8	61.9	75.7
Male	5968	117.5	104.3	130.7	12,632	117.2	108.6	125.8	10,002	85.8	78.1	93.5
Province												
Eastern	2288	95.2	81.4	109.1	6083	127.0	112.7	141.3	4299	85.4	73.7	97.1
Northern	5521	113.2	93.4	132.9	9824	95.5	86.0	105.0	4012	53.9	44.0	63.9
Northwestern	NA	NA	NA	NA	NA	NA	NA	NA	3747	101.0	85.7	116.4
Southern	2528	122.2	102.4	142.0	5881	117.9	106.5	129.4	4163	79.5	65.3	93.8
Western	1593	108.6	84.3	132.9	3075	106.7	87.0	126.5	3499	67.0	53.1	80.9

IMR infant mortality rate, *NA* Data not available from 2008 and 2013, Sierra Leone had four province

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

	2008			2013			2019		
Dimension	**Estimate**	**Lower Bound**	**Upper Bound**	**Estimate**	**Lower Bound**	**Upper Bound**	**Estimate**	**Lower Bound**	**Upper Bound**
Age									
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
Economic status									
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
Education									
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
Place of residence									
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
Sex of child									
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	−3.8	3.8	0	−3.6	3.6
R	0.8	0.7	1.0	0.8	0.7	0.9	0.8	0.7	0.9
Province									
D	26.9	3.1	50.8	31.4	14.4	48.4	47.0	29.0	65.1
PAF	−14.2	−14.3	−14.1	−13.0	−13.1	−13.0	−30.3	−30.4	−30.2
PAR	−15.7	−26.7	−4.8	−14.3	−19.0	−9.7	−23.5	−30.0	−17.0
R	1.2	1.0	1.5	1.3	1.1	1.5	1.8	1.4	2.3

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 (20,190. 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

improvement would be expected, implying that the risk to male children was statistically equivalent to that of female children.

Provincial inequalities

There were significant inequalities in the IMR in Sierra Leone among the regions which worsened over time. The D, increased from 26.9/1,000 LBs in 2008 to 31.4/1,000 LBs in 2013, and sharply rose to 47.0/1,000 LBs in 2019, indicating more pronounced provincial inequalities in infant mortality rates over time. It should however be noted that data were missing for the two earlier observation periods for the Northwestern, the province with the highest rate in 2019. The PAF, which estimates the proportion of infant mortality that could be reduced if inequalities were eliminated, worsened from −14.2/1,000 LBs in 2008 to −30.3/1,000 LBs in 2019. This suggests that provincial inequalities are responsible for a growing share of the infant mortality rates documented in 2019.

The PAR, which reflects the absolute reduction in infant mortality rates that could occur if inequalities were eliminated, also worsened over time, increasing from −15.7/1,000 live births in 2008 to −23.5/1,000 live births in 2019. Furthermore, the R, comparing the likelihood of infant mortality between the worst- and best-performing provinces, rose from 1.2/1,000 live births in 2008 to 1.8/1,000 live births in 2019. Thus by 2019, infants in provinces with the highest mortality rates were 80% more likely to die compared to those in provinces with the lowest rates.

Discussion

This study explored the association of socio-economic and geographic inequalities with infant mortality in Sierra Leone from 2008 to 2019. While the infant mortality rate declined from 111.1/1,000 LBs in 2008 to 77.4/1,000 LBs in 2019, little or no change occurred between 2008 and 2013. Most of the improvement occurring between 2013 and 2019, possibly due to the FHCI, implemented in 2010 [12], which has contributed to their increased healthcare utilization, positively impacting the IMR [13]. Despite these gains, Sierra Leone's IMR remains substantially higher than the under-5 mortality rate target of 25 per 1,000 live births by 2030 [24]. Continued efforts are needed to align with these international benchmarks. Comparatively, other countries in the region, such as Liberia, 63 deaths per 1,000 LBs and Nigeria, 67 deaths per 1,000 LBs, reported substantial reductions, albeit similar, IMR [25, 26].

Improvements in the IMR in Sierra Leone may be attributed to improved nutrition, increased access to healthcare services, vaccination coverage and enhanced maternal literacy which increased from 35% in 2008 t0 52% in 2019 [9, 12]. Investments in healthcare infrastructure, enhanced education and health literacy, alongside community-based development programs, can enable Sierra Leone to make substantial progress toward reducing IMR and improving health outcomes for infants, ultimately contributing to the broader goals of sustainable development. Socio-economic factors such as adolescent pregnancy and poverty increase mortality risk, consistent with the experience of other LMICs [27–30]. These disparities are further exacerbated by cultural norms, and social stigma [31–33]. Mothers with no formal education lack awareness about essential health practices and the value of accessing preventive healthcare services [34–42]. Addressing these challenges requires comprehensive strategies that enhance access to reproductive health education, affordable healthcare, and nutritional support while promoting educational opportunities and economic empowerment for women [12, 34, 38–41, 43–45]. By integrating maternal health services with educational and economic initiatives, we can improve health outcomes for mothers and their children, ultimately reducing infant mortality rates [34, 45].

The urban–rural and provincial IMR divide in Sierra Leone aligns with studies in Gambia [46] and Nigeria [47]. Geographic disparities in healthcare infrastructure, essential services and socioeconomic conditions are exacerbated by transportation barriers and inadequate road networks [48]. Such limitations contribute to higher levels of poverty, lower educational attainment, and limited access to resources, which collectively impact health outcomes [49, 50]. Additionally, selected traditional practices that are more prevalent in rural communities can negatively influence maternal health-seeking behaviors [51]. Provincial inequalities underscored the uneven progress in reducing infant mortality across the country. Provinces, such as the Northwestern, have lagged behind the national progress, exacerbating health inequities. The significant lowering of IMR in the Northern compared to the Northwestern can be attributed to targeted investments in the Northern in healthcare infrastructure enabling improved access to skilled birth attendants, antenatal care, immunization, and postnatal services, which are critical for reducing infant mortality. Additionally, the North may have seen improvements in socio-economic conditions, such as education and income levels, and community-level health promotion initiatives. In contrast, provinces like the Northwestern continue to have higher IMR, due to persistent limitations in healthcare infrastructure, inadequate distribution of skilled healthcare providers, and poor transportation networks as well as higher levels of poverty and lower levels of maternal education. These factors, combined with gaps in the implementation and reach of health programs, could

explain why the Northwestern has not experienced the same level of improvement as the Northern. To effectively address these inequalities and reduce IMR in regions with the highest mortality rates, targeted interventions must be implemented to address the unique challenges faced by these areas [52]. Addressing socio-economic determinants, such as maternal education and reducing poverty, will also be essential for achieving more equitable progress in reducing IMR across all provinces. In addition, to effectively reduce inequaliities associated with place of residence, targeted interventions to improve healthcare access in rural communities should include enhancing transportation options for mothers, and training of rural community health workers to provide essential education on maternal and child health [52].

Although the study does not directly measure access to health services, the observed provincial inequalities in infant mortality rates suggest significant variations in access to healthcare across regions. The rising disparity index and worsening PAF indicate that some regions are likely to have poorer access to critical services such as antenatal care, skilled birth attendants, or post-natal care, which are vital for reducing infant mortality. The increase in relative risk from 1.2/1,000 live births in 2008 to 1.8/1,000 live births in 2019 further highlights the widening gap between provinces with the best and worst health outcomes, likely to reflect unequal distribution of health resources and services.

Provincial inequalities may also be compounded by other dimensions, such as economic status, education, and place of residence, which influence access to health services. Residents of rural or economically disadvantaged provinces may be less likely to utilize the available services given the limited health infrastructure and fewer healthcare providers. The worsening PAF and PAR over time suggest these inequalities have deepened, with underserved provinces bearing a disproportionate burden of infant mortality.

IMR variations by sex of the infant, with males consistently exhibiting higher mortality rates, aligns with global trends of higher male risk of mortality during infancy [27, 28]. To reduce any excess risk associated with gender, targeted interventions need to address underlying cultural and social factors that contribute to disparities. Community awareness campaigns and healthcare provider training regarding specific health needs of male and female infants will ensure equitable access to healthcare resources for all infants [53].

Strength and limitations

Using demographic health surveys (DHS) data to investigate risk factors for infant mortality in Sierra Leone offers several strengths. The data are population-based and nationally representative and provide a comprehensive view of the health status and behaviors of the population. The large sample size enhances statistical power to detect significant effects. The standardized methodology enables comparability across regions and time periods. Additionally, the diverse data collected on demographic characteristics, health behaviors, and health outcomes allow for exploration of various potential risk factors for infant mortality.

The limitations of using DHS data to investigate infant mortality risk factors in Sierra Leone include the cross-sectional nature of DHS surveys which limits the capacity to establish causal relationships between risk factors and infant death. Further, the lack of detailed information on certain risk or contextual factors may limit the depth of analysis that can be undertaken.

Conclusion

This study examined the association of socio-economic and geographic factors with infant mortality in Sierra Leone. The findings suggest that low socio-economic status, lack of maternal education, adolescent childbearing, rural residence, and living in the Northwestern province in the country were associated with higher IMR. Efforts to reduce the IMR were enhanced by the introduction of the FHCI which improved equitable access to healthcare services. Other initiatives will be required to promote female education, address poverty, and strengthen health systems across different provinces of the country. Tailored interventions that target vulnerable populations, such as adolescent mothers, families living in poverty, and rural residents, are essential to improve child health outcomes in Sierra Leone.

Abbreviations

D	Difference
HEAT	Health Equity Assessment Toolkit
PAF	Population Attributable Fraction
PAR	Population Attributable Risk
R	Ratio
SDG	Sustainable Development Goal
SLDHS	Sierra Leone Demographic and Health Survey
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
WHO	World Health Organization

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Authors' contributions

AO, HK, CB, and AJB conceived the study, performed the data analysis, and wrote the initial draft of the manuscript. All the authors reviewed and approved the final version of the manuscript.

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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 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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