Trends and distribution patterns of infant mortality and maternal HIV positivity in South Africa: A decade review (2007 - 2016)

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Background. The infant mortality rate (IMR) (24 per 1 000 live births) remains high in South Africa (SA), well above the recommended sustainable development goal (SDG) 3 of 12 deaths per 1 000 live births. High infant mortality is a poor indicator of the health of a population and will hamper attainment of the SDGs.
Objectives. To investigate the trends and distribution patterns of IMR between 2007 and 2016 and its association with HIV-positive pregnant mothers in SA.
Methods. This study used a cross-sectional study design by analysing secondary data on infant mortality from the 2007 and 2016 Statistics South Africa Community Surveys (CSs), as well as data from the 2007 National Antenatal Sentinel HIV and Syphilis Prevalence Survey. (Antenatal HIV Sentinel Survey – ANCHSS). Line charts with descriptive statistics were used to detail trends in IMRs, and multiple logistic regression models were used to identify risk factors for infant mortality in the 2007 and 2016 CS datasets. Spearman's rank-order correlation (rho) was used to correlate infant mortality with data from the 2007 ANCHSS. All analyses were performed with Stata version 16.0.
Results. A total sample of 87 805, comprising 43 922 males and 43 883 females, was included in the analysis. The results revealed a decline in IMR from 55 deaths per 1 000 live births in 2007 to 32 in 2016. Overall, there was a significant decrease in the mortality rate from 2007 to 2016. The infant mortality proportions by province showed KwaZulu-Natal Province having the highest IMR (17.5 deaths per 1 000 live births in 2007 and 6.3 in 2016). Males had a higher IMR (28 deaths per 1 000 live births in 2007 and 17.7 in 2016) compared with females at 26.7 deaths per 1 000 live births in 2007 and 13.8 in 2016. IMR data from the 2007 CS was correlated with the 2007 ANCHSS (28% HIV prevalence in 2007), using Spearman's rank-order correlation, which showed a moderate correlation of 0.58 (p<0.001).
Conclusions. The study findings showed a reduction in the trends of infant mortality between 2007 and 2016 in SA; despite the reduction, health inequalities persist. There is a correlation evident between maternal HIV prevalence and IMR in SA. We recommend the use of disability-adjusted life expectancy in SA to measure population health and introduce robust data sets that can better inform policy.

S Afr Med J 2024;114(6b):e1337. https://doi.org/10.7196/SAMJ.2024.v114i6b.1337

Low- and middle-income countries (LMICs), including countries in sub-Saharan Africa (SSA), face persistent and high levels of child mortality as a result of a myriad of biological and social determinants.[1] Sustainable Development Goal 3.2.1 (SDG 3), which is an evolution of one of the millennium development goals adopted in 2000 by 189 countries of the United Nations (UN),[2] calls for an end to preventable deaths of children <5 years of age and specifies a reduction in the neonatal mortality rate to <12 per 1 000 live births in all countries by 2030.[3]

The monitoring of childhood mortality, including infant mortality, remains a major challenge in LMICs. However, much progress has been made to overcome this issue with implementation of strategies to ascertain that countries have fully functional civil registration and vital statistics (CRVS) systems to ensure accurate and timely record-keeping of births and deaths.[4]

South Africa (SA) is no exception to the countries challenged globally to reduce IMRs to UN standards. IMR is defined as the number of deaths in children <1 year of age per 1 000 live births in the same year.

The IMR is set as a sensitive measure of the health of a population and allows comparison of health systems and indicates countries or populations that may need to address these challenges.[5,6] The IMR is very important in determining the health status of a population over time. Mosley and Chen[7] propose a framework that categorises the determinants of IMR into proximal determinants, which assess not only biological determinants but also social and economic determinants that influence infant morbidity and mortality in developing countries. Infant mortality is influenced by various factors such as socioeconomic status, income inequality, race/ethnicity, family living conditions, disease rates in the family or community, and the environment.[8]

Over time the global IMR has been declining, with progress being made to eliminate the high infant mortality in different countries. High-income countries seemed to be making progress in this regard; however LMICs struggled to meet the millennium development goals and are still lagging with the SDGs, with unaddressed disparities such as the HIV/AIDS epidemic and poverty being the main contributors to the high infant mortality in Africa and Asia.[9]

To address the high infant mortality in SA, the National Department of Health (NDoH) has devised various strategies to mitigate infant mortality.[10] The NDoH adopted the World Health Organization (WHO)'s strategy of prevention of mother-to-child-transmission (PMTCT) as the HIV incidence among pregnant women was increasing in the early 2000s,[11] and this led to a marked reduction in infant mortality.

The PMTCT strategy has complemented the Perinatal Problem Identification Programme (PPIP), which was introduced in 1999 and has since contributed greatly to the reduction in infant mortality through quality improvement and audit on infant deaths to assess shortcomings and areas of improvement.[12] Although numerous strategies have been implemented to reduce infant mortality, there is room for zero infant mortality in SA and zero transmission of HIV through MTCT by HIV-positive mothers. This study investigated the trends and distribution patterns of IMR and its association with maternal HIV-positive status in SA between 2007 and 2016.

Methods

Study design

The study employed a cross-sectional study design through analysis of secondary data.

Study setting

SA occupies the southernmost part of Africa and had an estimated population of 56.5 million people[13] in 2017, distributed throughout its 9 provinces with 52 districts and 278 municipalities. The vital registration of live births in 2017 was 1 198 481.

In the Community Survey (CS) questionnaires, the sampled households responded to questions on mortality (2007 and 2016). The survey enumerator posed questions of mortality as the study was looking into infant mortality trends in SA as a whole, through secondary data analysis.[14]

Study sample

The study sample included a total of 59 280 (30 551 male and 28 729 female) infants from the 2007 Community Survey[15] and 28 525 (13 371 male and 15 154 female) infants from the 2016 Community Survey conducted by Statistics South Africa (Stats SA),[14] as well as data from the 2007 National Antenatal Sentinel HIV and Syphilis Prevalence Survey (Antenatal HIV Sentinel Survey – ANCHSS).[16]

Data collection

The study inclusion criteria were: (*i*) infants aged between 0 to 1 year at the time of death; (*ii*) infant deaths recorded in the CSs of 2007 and 2016; (*iii*) infants born in SA between 2007 and 2016; (*iv*) infants who died in SA between 2007 and 2016; and (*v*) HIV-positive pregnant women. The exclusion criteria were: (*i*) infants ≥1 year at time of death, and (*ii*) infants born in an institutional setting, such as a prison.

The demographic data for the study were derived from the infant mortality data extracted from the CSs of 2007 and 2016. Datasets were extracted from the StatsSA database and entered into MS Excel (Microsoft, USA) and Stata version 16.0 (StataCorp, USA) for analysis. To ensure robust trend analysis, missing data from the CSs between 2007 and 2016 were complemented with infant mortality data from UN Inter-agency Group for Child Mortality Estimation (UN IGME) (2008 - 2015). The data for HIV prevalence in pregnant mothers were extracted from the national ANCHSS of 2007.

Statistical analysis

All CS datasets were retrieved from Stats SA and exported to Stata version 16.0 for analysis. A *svyset* command was used in the analysis of all the variables after the weighting was applied to the datasets.

Line charts with descriptive statistics were used to detail the trends of IMRs for the period 2007 to 2016. They were further used to detail trends in IMRs per province for the same period.

Multiple logistic regression models were used to determine risk factors for infant mortality in the 2007 and 2016 CS datasets. The level of significance was set at a *p*-value <0.05. Adjusted odds ratios (AORs) and their 95% confidence intervals (CIs) were tabulated.

IMRs data from the 2007 CS were correlated with the national 2007 ANCHSS, using Spearman's rank-order correlation (rho).

Results

A total of 59 280 (30 551 male and 28 729 female) infants from the 2007 CS and 28 525 (13 371 male and 15 154 female) infants from the 2016 CS, as well as data from the 2007 ANCHSS were included in the analysis.

Trends of infant mortality rate from 2007 to 2016

Fig. 1 shows a decade review of IMRs of SA during the period 2007 to 2016. Overall, there is a notable decline in IMR from 55 deaths per 1 000 live births to 32 deaths per 1 000 live births.

The IMR proportions by province and year of occurrence indicate the trends of IMR, which show a downward trajectory (Fig. 1). This observation is similar to the UN data reporting of IMR in SA, which shows a decline in this decade reviewed.

In Fig. 2, analysis of the IMR by province shows a non-linear trend across the nine provinces, with KwaZulu-Natal having the highest IMRs in CS 2007 (17.5%) and CS 2016 (6.3%), and Northern Cape having the lowest IMRs in both CS 2007 (0.9%) and CS 2016 (0.9%). All provinces in this study show a significant decline in IMR between 2007 and 2016. Of note are the IMRs of KwaZulu-Natal and Eastern Cape provinces that were reduced by more than 50%.

Determinants of infant mortality

The Spearman's rank-order correlation (rho) (Fig. 3) showed a moderate positive correlation of 0.58 (p<0.001) because as the prevalence of HIV increased, the IMR also increased. Socioeconomic characteristics associated with infant mortality

Community Survey 2007

The results from the multivariable logistic regression analysis in Table 1 showed that, after adjusting for other variables, the odds of infant mortality were associated with: not having a cell phone in the household (AOR = 0.75; 95% CI 0.59 - 0.95; *p*=0.018); not having a refuse dump (AOR = 0.70; 95% CI 0.56 - 0.88; *p*=0.002); using wood for heating (AOR = 1.40; 95% CI 1.60 - 1.85; *p*=0.016); and no toilet facility (AOR = 0.73; 95% CI 0.55 - 0.98; *p*=0.037).

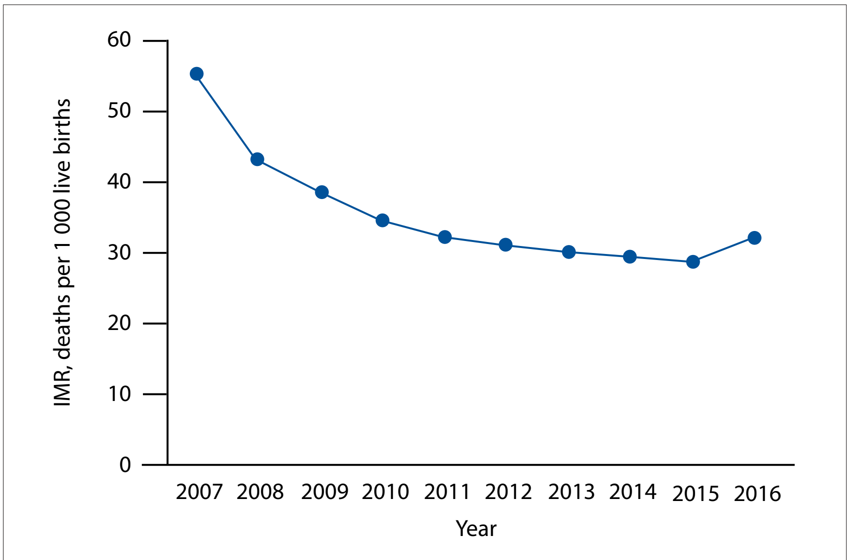

Fig. 1. IMR trend in SA between 2007 and 2016.

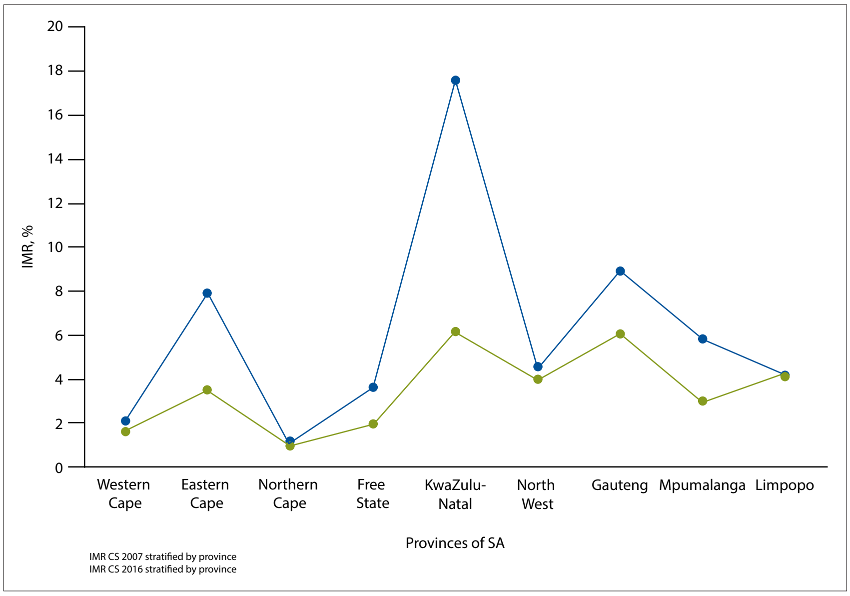

Fig. 2. IMR trends per province in SA from CS 2007 and CS 2016.

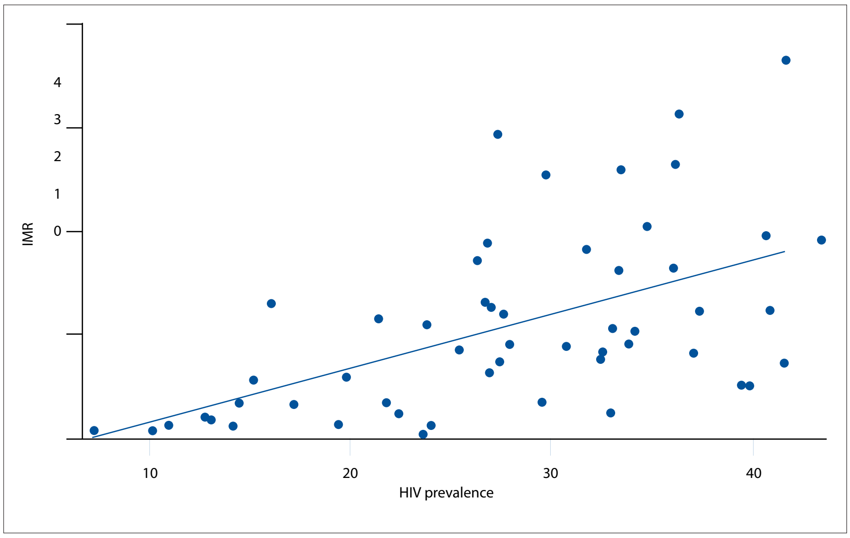

Fig. 3. Spearman's rank-order correlation (rho) applied to IMRs and HIV prevalence in pregnant mothers from 2007 ANCHSS and CS 2007.

Community Survey 2016

The results from the multivariable logistic regression analysis in Table 2 showed that, after adjusting for other variables, the odds of infant mortality were associated with: age of the household head ≥60 years (AOR = 0.70; 95% CI 0.56 - 087; *p*=0.002); and electricity access which the household is not paying for (AOR = 5.98; 95% CI 1.13 - 31.6; *p*=0.04).

Discussion

The study investigated the trends and distribution patterns of IMR by determining the proportion of the IMR attributable to the provinces and districts and its correlation with maternal HIV positivity in SA over a decade (2007 - 2016).

The findings show a significant decline in the IMR from 55 deaths per 1 000 live births in 2007 to 32 per 1 000 live births in 2016. The IMR decline in our study is in keeping with the global statistics that have shown a downward trajectory of IMR over time, from 5 million in 1990 to 2.4 million in 2020, a similar occurrence in SSA.

In the multiple logistic regression analysis of this study, the socioeconomic determinants of health, such as dwelling type and use of cell phone in that household, are some of the determinants of health that are found in SA. These data were collected in the CSs. Socioeconomic factors such as using wood for heating, having no toilet facility, head of household ≥60 years, and having electricity access which the household is not paying for were predictors of infant mortality.

The above socioeconomic determinants of health, which correlate to poor social status, a prevailing circumstance in LMICs, can be compared with a study conducted in Nepal that explored distal socioeconomic and related proximate determinants of infant mortality. This revealed commonalities with a poor socioeconomic background being a contributor to IMR.[4]

Spearman's correlation of the IMR and the maternal HIV prevalence of 28.0% (CI 26.9% – 29.1%) from the 2007 ANCHSS suggests that a high maternal HIV prevalence contributes to a high IMR. Prior to the SA NDoH's introduction of strategies to reduce HIV prevalence, IMR in SA was alarmingly high. An SA study by Pillay-van Wyk *et al.*[17] reported HIV/AIDS as the leading cause of infant mortality.

The above findings correlate with a study conducted by Adetunji,[18] where a high HIV prevalence was a contributor towards child and infant mortality. The study investigated trends in 25 SSA countries, with some critical observations being made. The results of the study are limited and not able to encapsulate the indirect effects of HIV prevalence on child and infant mortality. Adetunji argued that other socioeconomic determinants, besides the direct effects like transmission of the virus to the baby, could contribute towards child mortality.[18]

The current study investigated HIV prevalence in HIV-positive pregnant women as a predictor of infant mortality, and the correlation was positive. This is evident in similar studies looking into HIV as a predictor of infant mortality in African countries. Rahman *et al.*[9]in their study on socioeconomic determinants of infant mortality, particularly HIV, found that HIV was indeed a determinant of infant mortality in most African countries.

As evidenced in the trends from 2007 to 2016, the decline in IMR reflects major progress towards achieving SDG 3, which aims to ensure healthy lives and promote well-being for all, including reducing the global maternal mortality ratio and ending preventable deaths of newborns and children <5 years of age. Furthermore, the study's focus on socioeconomic determinants of health aligns with the broader agenda of addressing inequalities (SDG 10) and ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all (SDG 4).

The study's findings on correlation between maternal HIV positivity and IMR underscore the importance of addressing HIV/AIDS in maternal and child health programmes. Achieving the targets of the 95-95-95 strategy, which focuses on ensuring that 95% of people living with HIV know their status, are on treatment, and have suppressed viral loads, can contribute

Table 1. Multiple logistic regression of socioeconomic factors associated with IMR from CS 2007

Infant mortality	AOR	SE	*t*	*p*-value	95% CI	
Cell phone						
No	0.75	0.09	-2.36	0.02	0.59	0.95
Dwelling type						
Flat in block of flats	0.61	0.24	-1.24	0.21	0.28	1.33
Informal dwelling/shack in backyard	1.56	0.46	1.52	0.13	0.88	2.78
Room/flatlet NOT in backyard but on a shared property	4.48	4.58	1.47	0.14	0.61	33.2
Fridge						
No	1.04	0.13	0.34	0.74	0.82	1.33
Cooking						
Gas	1.67	0.73	1.18	0.24	0.71	3.92
Refuse						
Own refuse dump	0.70	0.081	-3.08	0.00	0.56	0.88
Radio						
No	0.72	0.09	-2.7	0.00	0.57	0.91
Household Income						
R38 401 - R76 800	0.76	0.13	-1.61	0.12	0.55	1.06
R153 601 - R307 200	1.67	0.84	1.02	0.31	0.62	4.49
Heating						
Paraffin	1.29	0.22	1.49	0.14	0.92	1.81
Wood	1.40	0.20	2.41	0.02	1.07	1.85
Animal dung	2.26	1.46	1.26	0.21	0.64	8.01
Other	2.27	0.77	2.43	0.02	1.17	4.41
Water access						
Dam/pool	2.63	1.46	1.74	0.08	0.89	7.81
Water distance						
Between 500 m and 1 km	0.76	0.13	-1.66	0.10	0.55	1.05
Toilet facility						
None	0.73	0.11	-2.09	0.04	0.55	0.98
Water service provider						
Unspecified	0.61	0.25	-1.19	0.23	0.27	1.38
_cons	2.43	0.26	8.32	0	1.97	2.99

SE = standard error.

Table 2. Multiple logistic regression of socioeconomic factors associated with IMR from CS 2016

Infant mortality	AOR	SE	*t*	*p*-value	95% CI	
Head of household gender						
Female	1.05	0.10	0.5	0.62	0.86	1.28
Age category						
≥60 years	0.70	0.08	-3.15	0.00	0.56	0.88
Refuse						
Dump or leave rubbish anywhere (no rubbish disposal)	0.79	0.15	-1.27	0.21	0.55	1.14
Electricity access						
Connected to other source which household is not paying for	5.98	5.06	2.11	0.04	1.13	31.6
Solar home system	1.65	1.33	0.62	0.54	0.34	8.06
No access to electricity	1.67	0.47	1.84	0.07	0.97	2.88
Dwelling type						
Flat or apartment in a block of flats	0.31	0.10	-3.81	0	0.17	0.56
Informal dwelling/shack in backyard	0.68	0.15	-1.77	0.08	0.44	1.04
Informal dwelling/shack not in backyard (e.g. in an informal settlement)	0.80	0.18	-0.96	0.34	0.51	1.26
Other	2.53	1.69	1.39	0.16	0.69	9.34
Water access						
No	1.12	0.13	0.98	0.33	0.89	1.41

...continued

Table 2. (continued) Multiple logistic regression of socioeconomic factors associated with IMR from CS 2016

Infant mortality	AOR	SE	*t*	*p*-value	95% CI	
Energy for light						
Candles	0.72	0.19	-1.28	0.2	0.43	1.19
Solar	0.46	0.25	-1.43	0.15	0.16	1.34
Head of household race						
White	0.48	0.19	-1.85	0.06	0.22	1.04
Skip meal						
Do not know	0.82	0.58	-0.28	0.78	0.20	3.32
Water source						
Rain-water tank in yard	0.61	0.22	-1.35	0.18	0.30	1.25
Household internet service						
No	0.89	0.15	-0.69	0.49	0.63	1.25
Energy source for cooking						
Paraffin	0.68	0.17	-1.55	0.12	0.41	1.11
Toilet						
Chemical toilet	0.72	0.13	-1.77	0.08	0.50	1.04
Toilet location						
Outside the yard	1.31	0.34	1.06	0.29	0.80	2.17
_cons	3.12	0.57	6.28	0	2.19	4.46

significantly to reducing IMRs associated with maternal HIV positivity in SA and regionally, where the problem is still prevalent.

The study's identification of socioeconomic health determinants that contribute to IMR is consistent with the African Union (AU)'s broader goal of addressing poverty and promoting economic development as pathways to improved health outcomes, and with the AU 2026 agenda to improve health outcomes across the African continent. The study's findings on the relationship between maternal HIV prevalence and IMR are relevant to this agenda, as addressing HIV/AIDS is a key component of efforts to improve maternal and child health in Africa.

Conclusion

The study showed a significant decline in the SA IMR over a 10-year period (2007 - 2016), both nationally and provincially. Provincial data showed a varied decline in IMR of all provinces during the study period. There is a correlation evident between maternal HIV prevalence and IMR in SA. More investment is needed in vital registrations and mortality reporting systems.[19]

Globally, IMR continues to be used as a measure of population health, but as the world evolves, so should the methods used to measure population health. We recommend the use of disability-adjusted life expectancy (DALE) in SA and developing countries to introduce robust datasets, the use of disability weights that can compare the burden of different health conditions and better inform policies that are inclusive of all population groups, assess the burden of different health conditions and prioritise interventions accordingly.

Declaration. Ethical approval to conduct the study was obtained from the Faculty of Health Sciences Research Ethics Committee at the University of Pretoria (ref no. 475/2022). All study methods were in compliance with relevant ethical guidelines.

Acknowledgements. None.

Author contributions. Both the first and the second authors (MM and NL) contributed to the idealisation of the study, the protocol, the study design, data analysis and draft manuscript. HR and AM contributed to the data analysis. All four authors contributed to the final write-up of the manuscript.

Funding. None.

Conflicts of interest. None.

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Accepted 7 April 2024.