Original Research Article

Multilevel modelling of the determinants of under-five deaths in South Africa: Evidence from 2016 Demographic Health Survey

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Abstract

Background: The world has made significant progress in reducing under-five mortality rates (U5MR). However, the U5MR remains high in sub-Saharan Africa. Although South Africa has among the lowest U5MR in the region, the country has failed to meet the national targets of reducing U5MR. Therefore, we aim to examine multilevel determinants of deaths of children under-five years in South Africa.
Methods: We used secondary data from the 2016 South Africa Demographic Health Survey. We conducted bivariate and multivariate (multilevel logistic regression) analyses to meet the study's objective.
Results: The findings show that the sex of a child, population group, level of education, household wealth, type of toilet facility, place of residence and province were associated with under-five deaths. The U5MR was highest in Mpumalanga and lowest in Western Cape. Furthermore, children who used toilet facilities were more likely to die before the age of five compared to children with no toilet facilities. Under-five mortality rate showed variations at the provincial level. Children from the Eastern Cape province as well as from the North West province were more likely to die under the age of five years compared to children from the Gauteng province.
Conclusions: The study identified various factors associated with under-five the deaths. The results demonstrated that there is a slow progress in reducing under-five mortality rate. The study calls for the improvement of child health services in rural areas, further improvement in ambulance services, and a functional rapid response system for emergencies in remote rural areas.

Keywords: multilevel analysis, determinants, under-five deaths, under-five mortality, children under-five, South Africa

Introduction

Since 1990 there has been substantial global progress in the reduction of child mortality rates. This fact is supported by multiple scholars (Sanyang, 2019; Word Health Organization, 2020; Worku *et al.*, 2021), which present compelling evidence that the number of deaths among children under the age of five has significantly decreased. Specifically, between 1990 and 2020 the global under-five mortality rates dropped from 12.6 million to 5.0 million. Despite global efforts and advancements in reducing child mortality, the sub-Saharan Africa region has experienced slower progress and continues to bear the highest under-five mortality rates. Numerous studies (Aheto, 2019; Hug *et al.*, 2019) have highlighted that the under-five mortality rate in sub-Saharan Africa is 16 times higher than the average rate of child deaths in Europe and North America. According to a study by Tadesse (2021), the average rate of child mortality in sub-Saharan Africa in 2018 stood at 78 deaths per 1000 live births. Another study by Mathews *et al.* (2016) revealed that the global distribution of child deaths under the age of five is imbalanced, with a significant concentration in the sub-Saharan Africa region. Moreover, a large proportion of these deaths occur in rural areas within that region. According to a report by the National Department of Health *et al.* (2019), rural areas in South Africa account for 49% of under-five deaths, while urban areas make up only 38%. Unfortunately, rural areas in South Africa face a shortage of adequate child healthcare facilities compared to urban areas, as noted by de Villiers (2021). Additionally, Yaya *et al.* (2018) have argued that children born in non-public health institutions in South Africa are 17% more likely to die before reaching the age of five, compared to children of the same age born in public health institutions. A study conducted in Nigeria by Adeyinka *et al.* (2020) uncovered a significant correlation between under-five deaths and the place of delivery. Furthermore, research conducted by Bamford *et al.* (2018) revealed that over 50% of all under-five deaths in South Africa occurred within health facilities in 2015. This alarming finding has raised concerns regarding health practices concerning children under the age of five in South Africa. Consequently, both Bamford *et al.* (2018) and Guta *et al.* (2018). emphasized the necessity for additional interventions aimed at reducing the rate of under-five deaths in public health facilities. These interventions should prioritize the implementation of cautious measures and the presence of highly skilled health workers.

Additionally, a study by Bamford *et al.* (2018) highlighted variations in under-five mortality rates within different South African provinces. They reported that the under-five mortality rate in health facilities ranged from 43.5% in the Eastern Cape to 67.7% in the Northern Cape. These findings indicate significant differences in the rates of child deaths among provinces within South Africa. Supporting this, evidence from the household census conducted in 2011, as reported by Statistics South Africa (2019), revealed a total of 54,580 reported deaths of children under the age of five. In terms of regional distribution, KwaZulu-Natal reported the highest number of deaths among children under 5 years, accounting for 27.19% of the total. It was followed by Gauteng (15.74%), Eastern Cape (14%), Limpopo (10%), Mpumalanga (9%), and North West (9%). Conversely, the provinces with the lowest under-five mortality rates were the Free State (7%), Western Cape (4%), and Northern Cape (2%) (Statistics South Africa, 2019). Furthermore, additional studies conducted by Mathews *et al.* (2016) and Tesfa *et al.* (2021)

provided evidence suggesting that various factors, including environmental and behavioural factors, maternal and child factors, as well as socio-demographic factors, exert significant influence on the survival of children under the age of five in East African countries such as Burundi, Rwanda, and Tanzania. Moreover, a study by Rademeyer (2017) demonstrated that under-five mortality serves as an indicator for the overall socioeconomic status of a country.

A range of policies, programs, and strategies(Goga *et al.*, 2019) have been established to fulfil both national and international objectives. Despite South Africa's failure to achieve the Millennium Development Goals (MDGs), there is little likelihood of meeting the Sustainable Development Goals (SDGs) without intervention. Among the SDGs is the aim to eradicate preventable deaths among children under five years of age by 2030, as outlined in target 3. This goal can be attained by reducing under-five mortality to below 25 deaths per 1,000 live births (Ayele *et al.*, 2021). According to recent statistics, South Africa currently exhibits an under-five mortality rate of 42 deaths per 1000 live births in the five-year period preceding the survey (National Department of Health *et al.*, 2019). This can be attributed to inadequate healthcare services and prevalent poverty. Disparities in under-five mortality rates exist across provinces and population groups within South Africa. Notably, black population experiences a higher under-five mortality rate compared to other groups (Rademeyer, 2017). When examining provincial data, it is evident that Mpumalanga, North West, Eastern Cape, and Free State exhibit the highest under-five mortality rates, ranging from 63 to 70 deaths per 1000 live births over the ten-year period preceding the survey (National Department of Health *et al.*, 2019). South Africa is tasked with reducing its under-five mortality rate by at least 17 deaths per 1000 live births by 2030. Consequently, comprehending the intricate factors influencing under-five deaths becomes crucial for key stakeholders involved in child health interventions. This understanding will enable role-players to effectively devise strategies aimed at achieving the targets outlined in the Sustainable Development Goals (SDGs).

In alignment with the SDGs' objectives, South Africa is actively engaged in efforts to decrease the under-five mortality rate (Ajulor, 2018). In order to effectively plan and assess the healthcare system's performance in terms of health services and overall outcomes, accurate and comprehensive data on the number and causes of children's deaths are crucial for healthcare practitioners and policymakers. The objective of this study is to examine the influence of social and economic factors in reducing under-five mortality. The study's findings can offer valuable insights to programs dedicated to addressing under-five mortality, informing their strategies and interventions. Previous studies have established that child health serves as a reliable indicator and measure of a country's overall health status, extending beyond the well-being of children alone (Boerma *et al.*, 2018; Organisation for Economic Co-operation and Development, 2021; Prada & Sanchez-Fernandez, 2021). Consequently, it is imperative for South Africa to enhance the performance of its healthcare system and meet the child health targets outlined in SDG 3, as a means to address the shortcomings of not achieving Millennium Development Goal 4 (Statistics South Africa, 2015). Thus, conducting the present study becomes necessary, as it aims to provide credible and timely estimates of childhood mortality essential for monitoring progress towards South Africa's SDG 3 target. Additionally, under-five mortality rates serve as vital indicators for assessing changes in child survival and

evaluating the quality of healthcare services delivered to children across different communities and stages of their lives.

The main objective of the study is to examine the multilevel determinants of under-five deaths in South Africa.

Methods

Data source

The present study utilized secondary data obtained from the South African Demographic and Health Survey (SADHS) conducted in 2016. The SADHS is a nationwide representative survey that collects comprehensive information on health and population (National Department of Health et al., 2019). The survey employed a two-stage stratified sample design for data collection (National Department of Health et al., 2019). In the first stage, primary sampling units (PSUs) were selected, while in the second stage, dwelling units (DUs) were chosen through systematic sampling, where the target population was ordered according to a specific scheme, and elements were selected at regular intervals from the ordered list (Jang et al., 2020). The study focused on a weighted sample of 13,856 children who died before reaching 60 months of age.

Outcome variable

We use under-five deaths as our outcome variable in the study. The outcome variable for this study is whether the child is alive or dead at the time of survey. This variable is based on children whose month at death is 0-59 months and variable B5 is coded as 1=Dead and 0=Alive. If the child is aged 0-59 months at the time of the survey, and B5 is no, then they are coded as not alive (dead) or 1 otherwise.

Explanatory variables

For this study, several explanatory variables were chosen, these variables include the child's sex, birth size below 2.5kg, the mother's age at birth, population group, mother's education, household wealth, household toilet facility, source of drinking water, place of residence, and province. We briefly describe these variables in Table 1. These variables were included on the basis of their previous statistical associations with under-five deaths use in previous studies (Donald *et al.*, 2019; Hidalgo-Lopezosa *et al.*, 2019; O'Shea *et al.*, 2023).

Table 1: Description of the study variables

Independent variable	**Description**	**Coding**
Individual/household-level factors		
Sex of child	Reported sex of the child	1=Male 2=Female
Child's size at birth below 2.5kg	Reported whether the birth weight of the child was below 2.5kg	0=No 1=Yes
Age at birth	Respondents were asked about their age at the time of birth	0=<20

Independent variable	Description	Coding
		1=20-29
		2=30-39
		3=40-49
Population group	The population group (i.e., race) of the respondents	1=Black 2=Coloured 3=Other
Level of education	The highest level of education attained by the respondent	0=No education 1=Primary 2=Secondary+
Household wealth	Respondent's household wealth status	1=Poor 2=Average 3=Rich
Type of toilet facility	The type of toilet facility of respondent, based on Principal Factor Analysis.	0=None 1=Flush 2=Other
Source of drinking water	Respondent's type of drinking water	1=Piped 2=Not piped
Community-level factors		
Place of residence	Respondent's place of residence	1=Urban 2=Rural
Province	Respondent's province of residence	1=Western Cape 2=Eastern Cape 3=Northern Cape 4=Free State 5=KwaZulu-Natal 6=North West 7=Gauteng 8=Mpumalanga 9=Limpopo

Statistical analysis

The analysis in this study was conducted using Stata version 14 software package. The study specifically focuses on children aged 0–59 months during the survey period. To achieve the study objectives, various analyses were employed, including rates, univariate analysis, bivariate analysis, and multivariate multilevel logistic regression. Firstly, under-five mortality rates were computed using the *syncmrates* user-written command in Stata. Secondly, univariate analysis was utilized to provide a descriptive overview of the study sample. Thirdly, bivariate analysis involving a chi-square test (χ^2) was conducted to assess the prevalence of under-five deaths in South Africa. Lastly, multivariate multilevel logistic regression was employed to investigate the individual/household-level and community factors influencing under-five deaths in South Africa. To account for the hierarchical structure of the SADHS data, the study applied multilevel analysis methods. Multilevel logistic regression is employed in this study to acknowledge the hierarchical nature of the data by incorporating residual components at each level of the hierarchy. In this particular study, a two-level model was utilized, with individuals/households (level 1) nested within communities (level 2). The level 1 model focuses

on exploring the associations between individual/household-level variables and under-five deaths, while the level 2 model examines the impact of community-level factors on under-five deaths. To conduct the multivariate multilevel logistic regression analysis, the Stata *melogit* command was utilized.

The formula for the two-level model is shown as:

$$logit\left(\pi_{ij}\right) = log\left[\frac{\pi_{ij}}{1-\pi_{ij}}\right] = \beta_0 + \beta_1 x_{ij} + \beta_2 x_{ij} \ldots + u_{0j} + e_{0ij}$$

Where π_{ij} is the probability of an *ith* child in the *jth* community dying before the age of five, β_0 is the intercept, β_n is the regression coefficient, x_{ij} is the independent variables, u_{0j} is the community level errors and e_{0ij} denotes the individual-level errors. This study fits four models. Model 0 is the null model, which was used to test for variability among the communities without any independent variable. Model 1 fits the individual/household-level factors. Model 2 was adjusted for the community-level factors. Model 3 was adjusted for both individual/household-level or community-level factors. The study employed various statistical measures to analyze the results. The Intra-Class Correlation (ICC) was used to estimate the percentage of variation attributed to community-level variables. The Median Odds Ratio (MOR) described the variance as an odds ratio (OR), representing the median value obtained from two different levels. The Proportional Change in Variance (PCV) measured the proportional change in the community-level variance. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were utilized to compare different models. Multicollinearlity was assessed using the Variance Inflation Factor (VIF). The findings indicated no collinearlity issues between the independent variables (VIF<10). The minimum VIF observed was 1.00, the maximum was 1.81, and the mean VIF was 1.27.

Ethical consideration

This study relies on secondary data rather than conducting primary data collection. The dataset used was obtained with permission from the SADHS program, exclusively for academic purposes, and was not shared with individuals who did not apply for access. Prior to commencing the study, the researcher sought ethical clearance from the Basic and Social Sciences Research Ethics Committee (BaSSREC) at North-West University. The study received clearance (ethics number NWU-01058-22-A7) following the ethical review process.

Results

Socio-demographic characteristics

Table 2 presents the background characteristics of the study population, providing valuable insights into their demographics. The results indicate that 52.3% of the children included in the study were male, while 47.7% were female. Furthermore, the results reveal that approximately 96.7% of the women reported that their children's size at birth exceeded 2.5kg, whereas only

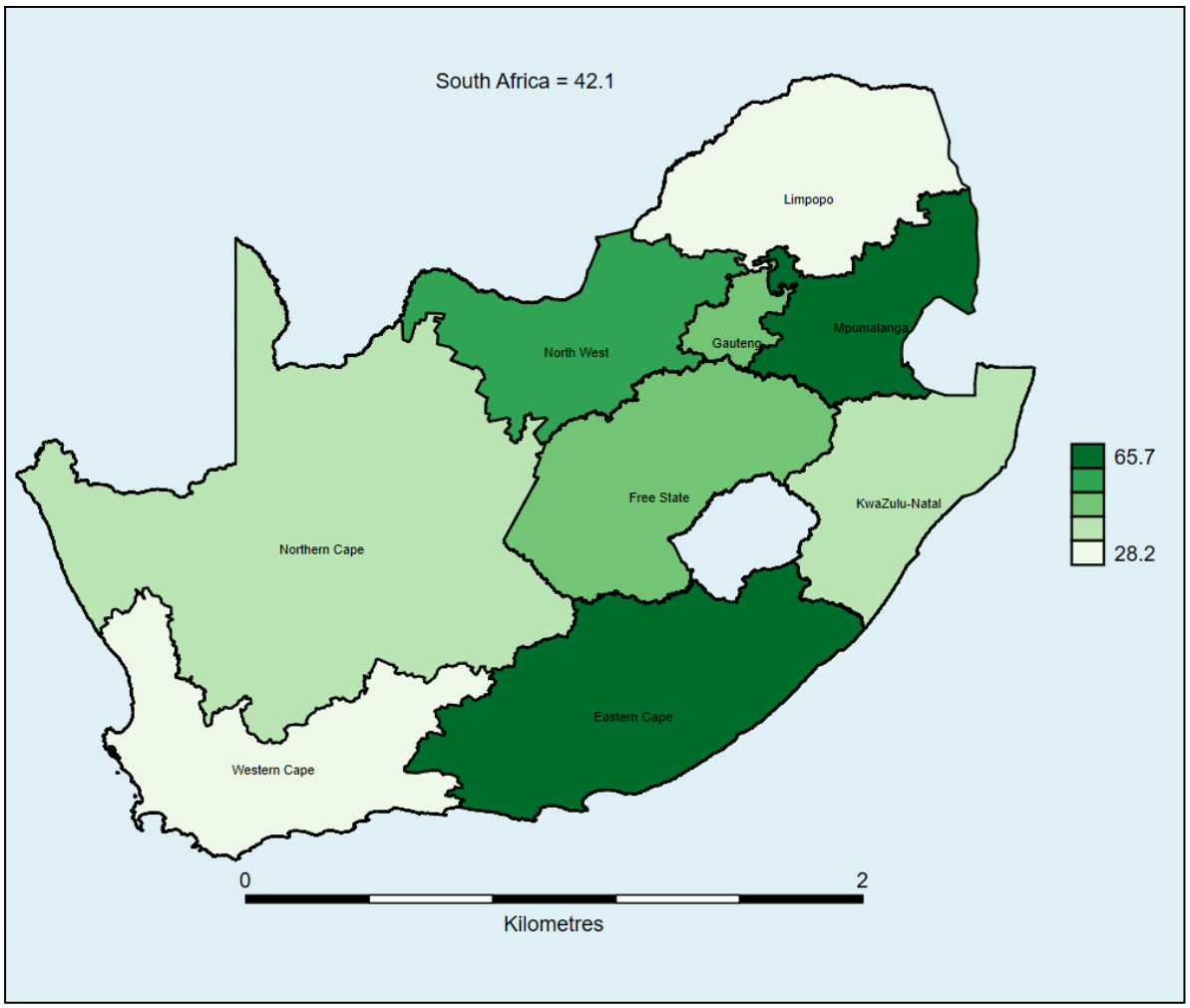
3.3% reported a birth weight below 2.5kg. The findings also shed light on the mother's age at the time of their first child's birth. Specifically, 23.3% of women had their first child before the age of 20, while the majority (55.7%) had their first child in their thirties. Interestingly, the number of first births decreased as maternal age increased. For instance, 19.7% of women experienced their first birth between the ages of 30 and 39, with only 1.4% having their first child in their late forties. The majority of the study population (87.9%) belonged to the black population group, while 8.6% were classified as colored. The remaining 3.4% represented other population groups, including whites and Indians. Regarding the mothers' level of education, the evidence indicates that only 3.6% of mothers had no formal education, 14.0% had completed primary education, and the majority (82.4%) had attained secondary education or higher levels of education. These findings provide important contextual information about the study population, contributing to a comprehensive understanding of their background characteristics.

In relation to the socioeconomic status of households, it was found that 43.9% of women belonged to poor households, while 22.3% came from households considered average in wealth. Additionally, 33.8% of women were identified as belonging to rich households. In terms of toilet facilities, a small proportion of women (2.9%) came from households without such facilities, while the majority (52.5%) were from households equipped with flush toilets. The remaining 44.5% of women resided in households with other types of toilet facilities. Regarding the source of drinking water, the data showed that 84.1% of the study population had access to piped water, while 15.9% did not have piped water access. The respondents were found to be unevenly distributed across different residential areas, with 63.8% of women residing in urban areas and 36.2% in rural areas. Examining the geographical distribution, the majority of women in the study were from Gauteng province (26.1%), followed by KwaZulu Natal (18.1%), Eastern Cape (11.6%), Western Cape (10.9%), Limpopo (10.3%), Mpumalanga (8.7%), and North West (7.5%). In contrast, fewer women were from Free State (4.8%) and Northern Cape (2.0%).

Under-five mortality rates

Figure 1 illustrates the under-five mortality rates (U5MR) across the provinces of South Africa (refer to Figure A3 in the appendices). The province with the lowest U5MR was Western Cape, with a rate of 28.2 deaths per 1000 live births. Limpopo and KwaZulu-Natal also exhibited relatively low U5MRs, reporting rates of 30.7 and 31.2 deaths per 1000 live births, respectively. On the other hand, Mpumalanga recorded the highest U5MR at 65.7 deaths per 1000 live births, followed by Eastern Cape with a rate of 60.2 deaths per 1000 live births and North West with 55.7 deaths per 1000 live births. Free State reported a U5MR of 48.1 deaths per 1000 live births. Additionally, Gauteng province had a rate of 38.0 deaths per 1000 live births, while Northern Cape recorded 34.3 deaths per 1000 live births. Overall, the study findings indicated that South Africa's U5MR stood at 42.1 deaths per 1000 live births.

Figure 1: Under-five mortality rate by province in South Africa



Prevalence of modern contraceptive use

Table 2 provides a bivariate analysis of the factors linked to under-five deaths. The results reveal that various factors exhibit associations with under-five deaths. The study demonstrates that both individual/household-level factors (including child's sex, population group, level of education, household wealth, and type of toilet facility) and community-level factors (such as place of residence and province) exhibit significant associations with under-five deaths. The findings indicate that 5.6% of male children and 4.4% of female children experienced death before reaching the age of five. Furthermore, the study highlights that 5.3% of black women reported the death of their children before the age of five, while 3.4% of colored women reported under-five deaths. In comparison, only 1.2% of mothers from the white and Indian population groups had children who passed away before the age of five. The results also reveal an association between maternal education and the mortality rate of children under the age of five.

Child death under the age of 5 years was reported by 6.0% of mothers with no education, 7.4% of mothers with primary education, and 4.6% of mothers with secondary education. The results indicate that there was no significant association between the child's size at birth or the mother's age and under-five deaths. However, household status and child health were found to be associated factors. Among poor households, 6.0% experienced under-five deaths, whereas among households with average income, 5.5% reported such deaths. In contrast, among rich households, 3.3% reported the deaths of children aged 0-59 months. Child deaths under the age of five were observed in 5.8% of women who lacked access to toilet facilities, while only 4.1% of women with flush toilet facilities reported such deaths. Additionally, a higher proportion of women (6.0%) who used other types of toilet facilities, such as pit toilets, bush toilets, composting toilets, bucket toilets, or chemical toilets, reported experiencing under-five deaths among their children. Regarding the place of residence, 5.9% of women residing in rural areas reported the death of their children before their fifth birthday, compared to 4.5% of women living in urban areas who reported under-five deaths. There are vatiations in the rates of under-five deaths across South African provinces (refer to the visual representation of these variations in Figure A2 in the appendix). The highest percentages of under-five deaths were reported in Mpumalanga (7.7%), Eastern Cape (7.2%), North West (6.9%), Free State (5.3%), KwaZulu-Natal (4.8%), Northern Cape (4.6%), and Gauteng (4.1%). On the other hand, lower percentages of child deaths were recorded in Western Cape (3.6%) and Limpopo province (3.0%).

Table 2: Distribution of respondents and prevalence of under-five deaths by explanatory factors

Characteristics	**Under-five death**				**N (%)**	χ^2	
	No		**Yes**			**value**	**p-value**
	%	**CI**	**%**	**CI**			
Individual/household level factors							
Sex of child						11.7	0.001
Male	94.4	[93.6-95.1]	5.6	[4.9-6.4]	7248 (52.3)		
Female	95.6	[94.9-96.2]	4.4	[3.8-5.1]	6608 (47.7)		
Child's size at birth below 2.5kg						3.4	0.064
No	94.9	[94.3-95.5]	5.1	[4.5-5.7]	13397 (96.7)		
Yes	97.3	[95.1-98.5]	2.7	[1.5-4.9]	459 (3.3)		
Age at birth						1.1	0.768
<20	95.1	[94.2-95.9]	4.9	[4.1-5.8]	3228 (23.3)		
20–29	95.0	[94.2-95.7]	5.0	[4.3-5.8]	7713 (55.7)		
30–39	94.7	[93.5-95.7]	5.3	[4.3-6.5]	2726 (19.7)		
40–49	96.2	[92.7-98.0]	3.8	[2.0-7.3]	188 (1.4)		
Population group						30.2	0.000
Black	94.7	[94.0-95.3]	5.3	[4.7-6.0]	12184 (87.9)		
Coloured	96.6	[94.0-98.1]	3.4	[1.9-6.0]	1198 (8.6)		
Other	98.8	[97.1-99.5]	1.2	[0.5-2.9]	474 (3.4)		
Level of education						41.1	0.000
No education	94.0	[91.1-96.0]	6.0	[4.0-8.9]	499 (3.6)		
Primary	92.6	[90.7-94.1]	7.4	[5.9-9.3]	1945 (14.0)		
Secondary+	95.4	[94.8-96.0]	4.6	[4.0-5.2]	11412 (82.4)		
Household wealth						43.6	0.000
Poor	94.0	[93.1-94.8]	6.0	[5.2-6.9]	6085 (43.9)		
Average	94.5	[93.0-95.7]	5.5	[4.3-7.0]	3090 (22.3)		

Characteristics	Under-five death				N (%)	χ^2	
	No		Yes			value	p-value
	%	CI	%	CI			
Rich	96.6	[95.6-97.4]	3.4	[2.6-4.4]	4680 (33.8)		
Type of toilet facility						36.0	0.000
None	94.2	[91.0-96.3]	5.8	[3.7-9.0]	404 (2.9)		
Flush toilet	95.9	[95.0-96.6]	4.1	[3.4-5.0]	7280 (52.5)		
Other	94.0	[93.2-94.7]	6.0	[5.3-6.8]	6171 (44.5)		
Source of drinking water						1.8	0.183
Piped	95.1	[94.4-95.7]	4.9	[4.3-5.6]	11655 (84.1)		
Not piped	94.4	[93.2-95.5]	5.6	[4.5-6.8]	2201 (15.9)		
Community level factors							
Place of residence						19.2	0.000
Urban	95.5	[94.7-96.2]	4.5	[3.8-5.3]	8837 (63.8)		
Rural	94.1	[93.3-94.7]	5.9	[5.3-6.7]	5018 (36.2)		
Province						84.7	0.000
Western Cape	96.4	[94.1-97.8]	3.6	[2.2-5.9]	1514 (10.9)		
Eastern Cape	92.8	[91.3-94.1]	7.2	[5.9-8.7]	1610 (11.6)		
Northern Cape	95.4	[93.3-96.8]	4.6	[3.2-6.7]	284 (2.0)		
Free State	94.7	[93.2-96.0]	5.3	[4.0-6.8]	665 (4.8)		
KwaZulu-Natal	95.2	[93.9-96.3]	4.8	[3.7-6.1]	2502 (18.1)		
North West	93.1	[91.6-94.4]	6.9	[5.6-8.4]	1036 (7.5)		
Gauteng	95.9	[94.0-97.2]	4.1	[2.8-6.0]	3612 (26.1)		
Mpumalanga	92.3	[90.8-93.6]	7.7	[6.4-9.2]	1207 (8.7)		
Limpopo	97.0	[96.0-97.8]	3.0	[2.2-4.0]	1425 (10.3)		
Total	**95.0**	**[94.4-95.5]**	**5.0**	**[4.5-5.6]**	**13856 (100.0)**		

Note: CI = confidence interval

Determinants of modern contraceptive use

Table 3 presents the multilevel model for the determinants of under-fived deaths in South Africa. The null model (Model 0) reveals some differences in the factors determining under-five deaths (ages 0-59 months) across the various clusters (variance = 0.423 [95% CI 0.29 to 0.62]). This primarily due to variations between-clusters, as indicated by an intra-cluster correlation coefficient (ICC 11.40%). However, the between-cluster variations decreased from 11.40% in Model 0 to 6.32% in Model 3. Model 3 accounted for approximately forty-eight percent (PCV 47.52%) of the variation in under-five deaths. The results from the MOR analysis confirmed that community factors played a role in shaping the odds of under-five deaths. Model 3, characterized by the lowest deviance (-2LL) and AIC values, demonstrated the best fit among the models considered. The interpretation of the findings from Model 3 in this study reveals that the rate of female children dying under the age of five years was less 0.77 [95% CI: 0.66-0.89], in comparison to male children. The occurrence of children dying under the age of five years from the black population group was 1.72 [95% CI: 1.13-2.6] times more compared to the coloured population group. The rate of under-five deaths among children born to mothers with secondary education was 0.68 [95% CI: 0.56-0.82] times less compared to children born to mothers with primary education. Furthermore, the results indicated that the under-five mortality rate decreased as the household wealth status improved. Children from poor

households had a rate that was 1.46 [95% CI: 1.12-1.92] times more compared to children from wealthy households.

Furthermore, the findings indicate that children who utilized other toilet facilities had a mortality rate that was 1.63 [95% CI: 1.04-2.55] times more compared to children who had no toilet facilities. Moreover, the occurrence of under-five deaths among children residing in households without piped water was 0.90 [95% CI: 0.71-1.13] times less in comparison to children from households that had piped water. The study findings indicated that geographical area was a contributing factor to under-five deaths. Specifically, the rate of child mortality in the Eastern Cape was 1.63 [95% CI: 1.10-2.41] times more than in the Gauteng province. Children under the age of five from the North West province had an incidence of deaths that was 1.70 [95% CI: 1.15-2.51] times more compared to children from the Gauteng province. Additionally, children under the age of five from Mpumalanga had an incidence of deaths that was 1.85 [95% CI: 1.26-2.71] times more compared to children from the Gauteng province.

Table 3: Multilevel determinants of under-five deaths in South Africa

Variable	**Model 0**	**Model 1**	**Model 2**	**Model 3**
	AOR [95% CI]	**AOR [95% CI]**	**AOR [95% CI]**	**AOR [95% CI]**
Individual/household level factors				
Sex of child				
Male®		1		1
Female		0.77*** [0.66-0.89]		0.77*** [0.66-0.89]
Child's size at birth below 2.5kg				
No®		1		1
Yes		0.65 [0.39-1.09]		0.64 [0.39-1.08]
Age at birth				
<20		0.99 [0.82-1.19]		0.97 [0.81-1.17]
20–29®		1		1
30–39		1.1 [0.90-1.33]		1.11 [0.91-1.34]
40–49		0.9 [0.46-1.73]		0.91 [0.47-1.77]
Population group				
Black		1.73** [1.20-2.50]		1.72* [1.13-2.6]
Coloured®		1		1
Other		0.84 [0.38-1.88]		0.85 [0.37-1.93]
Level of education				
No education		0.69 [0.46-1.02]		0.69 [0.46-1.02]
Primary®		1		1
Secondary+		0.64*** [0.53-0.77]		0.68*** [0.56-0.82]
Household wealth				
Poor		1.43* [1.09-1.88]		1.46** [1.12-1.92]
Average		1.24 [0.96-1.60]		1.2 [0.93-1.55]
Rich®		1		1
Type of toilet facility				
None®		1		1
Flush toilet		1.38* [0.84-2.26]		1.38 [0.84-2.29]
Other		1.58 [1.01-2.48]		1.63* [1.04-2.55]
Source of drinking water				
Piped®		1		1
Not piped		0.89 [0.71-1.11]		0.90* [0.71-1.13]

Variable	Model 0	Model 1	Model 2	Model 3
	AOR [95% CI]	AOR [95% CI]	AOR [95% CI]	AOR [95% CI]
Community level factors				
Place of residence				
Urban®			1	1
Rural			1.38** [1.13-1.70]	1.01 [0.79-1.30]
Province				
Western Cape			0.82 [0.51-1.34]	1.23 [0.73-2.07]
Eastern Cape			1.56* [1.05-2.32]	1.63* [1.10-2.41]
Northern Cape			0.98 [0.63-1.54]	1.27 [0.80-2.03]
Free State			1.35 [0.89-2.05]	1.42 [0.94-2.14]
KwaZulu-Natal			1.01 [0.67-1.50]	1.03 [0.70-1.54]
North West			1.64* [1.10-2.45]	1.70** [1.15-2.51]
Gauteng®			1	1
Mpumalanga			1.74** [1.18-2.58]	1.85** [1.26-2.71]
Limpopo			0.59* [0.38-0.93]	0.63* [0.40-0.99]
Random effects result				
PSU variance (95% CI)	0.423 [0.29-0.62]	0.337 [0.22-0.53]	0.287 [0.18-0.47]	0.222 [0.12-0.40]
ICC %	11.4	9.3	8.0	6.3
MOR	1.9	1.7	1.7	1.6
PCV %	®	20.3	32.2	47.5
Model fitness				
-2LL	5820	5734	5754	5683
AIC	5824	5766	5776	5733
PSU	714	714	714	714

Note: * = *p<0.05*; ** = *p<0.01*; *** = *p<0.001*; ® = reference category; AOR = adjusted odds ratio; CI = confidence interval; ICC = intra-cluster correlation coefficient; MOR = median odds ratio; PCV = proportional change in variance; -2LL = deviance [-2 log-likelihood]; AIC = Akaike Information Criterion; PSU = Primary Sampling Unit

Discussion

The study aimed to examine the multilevel factors determining under-five deaths in South Africa. This section discusses the findings from the bivariate and the multivariate analyses. The results indicated that various factors such as the sex of the child, population group, education of level, household wealth, type of toilet facility, place of residence, and province were linked to deaths of children under the age of five. These findings align with similar discoveries made in other developing nations, where these factors were also found to be associated with child mortality (Agho *et al.*, 2020; Doku *et al.*, 2020; Liang *et al.*, 2018; Makgolane, 2022). The findings showed that female children had lower odds of under-five deaths. A study by (Berelie *et al.*, 2019) also observed differences in child survival based on sex. Additionally, in low-income countries, female girls face a higher risk of mortality due to gender inequalities within these countires.; this was evident in the study of (Ng *et al.*, 2017) conducted in Zimbabwe.the findings from (Kumar *et al.*, 2021) further supported the notion that males under the age of five had a greater risk of death compared to females. Furthermore, the study highlighted variations in under-five deaths among different population groups, with Black women reporting a higher number of child deaths. Research conducted in sub-Saharan Africa has consistently demonstrated that ethnicity plays a significant role in under-five deaths (Ahinkorah *et al.*, 2020; Rademeyer, 2017; Victora *et al.*, 2020). This observation can be attributed to the historical socio-economic context of the country, where the black population group has faced

disadvantages in accessing quality healthcare and higher incomes, resulting in limited ability to make informed decisions regarding children's health compared to other racial groups such as whites, Indians/Asians, and coloureds. A similar study, conducted in Brazil by (Rebouças *et al.*, 2022), found that inequalities in racial groups contribute to childhood mortality.

Education plays a crucial role in both overall health and the well-being of children. The study found that children who were born to mothers with secondary education or higher had higher odds of under-five deaths. This finding is similar to other findings (Kiross *et al.*, 2019; Woldeamanuel & Aga, 2021). Children whose mothers have a higher level of education face a reduced risk of mortality before the age of five because their mothers possess a better understanding of health matters and can make informed decisions regarding their children's healthcare. Additionally, they exhibit greater attentiveness to their child's hygiene practices (Mandal *et al.*, 2021). Additionally, (Mandal *et al.*, 2021) observed that as maternal education level rises, there is an increase in women's engagement in family decision-making and their active participation in fulfilling the requirements of child healthcare. The results indicated that children born to women from rich households were less likely to die before age five. This observation is supported by previous studies conducted by (Biradar *et al.*, 2019; Chao *et al.*, 2018; Ekholuenetale *et al.*, 2020) which also identified household wealth as a significant factor influencing under-five deaths. Rich households possess several characteristics that contribute to improved child survival, including the ability to afford necessary medications for children and better diet. These factors have been shown to reduce the occurrence of prevalent illnesses such as malnutrition (Ward & Viner, 2017).

The results indicate a higher occurrence of under-five deaths among children whose mothers lack access to proper toilet facilities. This finding aligns with a study conducted by (Tagoe *et al.*, 2020), who discovered a correlation between inadequate toilet facilities for women and unhygienic conditions that can impact child health and contribute to child death. Child deaths, in these circumstances, can possibly be explained by unhygienic toilet conditions where the children reside. Pit toilets, bush ablutions, composting toilets, bucket toilets, and chemical toilets have all been associated with unhygienic conditions, which can have a detrimental effect on child health by spreading diarrheal pathogens, these findings have been highlighted in previous studies by (Adane *et al.*, 2017; Liu *et al.*, 2016). The findings indicated that rural areas exhibited a higher incidence of under-five deaths in comparison to urban areas. This disparity can be attributed to limited healthcare facilities and the distance residents have to travel to clinics and hospitals in order to address child health complications and receive necessary medical attention in a timely manner (Ahinkorah *et al.*, 2020). Additionally, the results revealed that Mpumalanga, Eastern Cape, and North West provinces had a higher prevalence of under-five deaths. These findings align with a study conducted by (Ntsimane, 2019) which also demonstrated provincial variations within South Africa concerning the occurrence of under-five deaths. One potential explanation for the elevated under-five mortality rates in these provinces is the economic status, which affects the healthcare system in each province.

Strengths and limitations of the study

The primary limitation of utilizing cross-sectional data is the inability to establish causation. For instance, it is not possible to conclude that inadequate sanitation directly causes under-five mortality. Moreover, cultural and religious beliefs may have led to the underreporting of certain under-five deaths. There is also a possibility of inconsistencies in the reporting of data related to the age of first childbirth, potentially resulting in over or under reporting. Furthermore, it is important to note that the findings regarding under-five mortality from the study may not be directly applicable to the present situation, as the data was collected during the 2016 Demographic Health Survey. Additionally, the researcher's analysis was limited to the variables available in the SADHS dataset. However, the study contributes to the global effort to achieve Sustainable Development Goal 3, which aims to reduce child mortality rates. Understanding the determinants of under-five deaths in South Africa adds to the collective knowledge base and informs global strategies for improving child health outcomes. The findings from this study can serve as a foundation for further research of the complex factors influencing under-five deaths.

Conclusion

The purpose of this study was to identify the factors associated with under-five mortality in South Africa. The selected factors, including the child's gender, population group, level of education, household wealth, type of toilet facility, place of residence, and province, were found to be risk factors for under-five deaths. Despite efforts of the country to reduce the under-five mortality rate, the study revealed that the rate remained unchanged. In 2018, the rate stood at 42 deaths per 1000 live births, and the study's findings indicate that it has remained constant. It is crucial to reduce the under-five mortality rate to achieve the objectives of Sustainable Development Goal 3. In conclusion, the results demonstrate a higher incidence of under-five deaths among children born to women with low levels of education and poor wealth status in South Africa. Furthermore, children born to black women have a higher mortality rate before reaching the age of five compared to children born to women of other racial groups. Based on the study's findings, several recommendations can be proposed for policymakers and the general population. It is essential to enhance child healthcare services in rural areas, including improving access to ambulance services and establishing functional rapid response systems for emergencies in remote rural regions.

When planning and formulating policies aimed at reducing the mortality rate of children under five, factors such as birth weight, toilet facilities, place of residence, province, wealth status, and maternal education should be taken into account. By considering these factors, efforts can be made to effectively contribute to achieving the Sustainable Development Goal target 3 by 2030. Health organizations and the Department of Health should actively promote child health education among women of reproductive age by implementing appropriate policies aimed at reducing the risk of child deaths. Given that this study identified the factors influencing under-five mortality throughout South Africa, in order to make meaningful improvement in reducing

the under-five mortality rate, future studies should focus on examining childhood mortality at the provincial level rather than the national level. This approach will provide more detailed insights and enable targeted interventions to be developed to address specific provincial challenges.

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Authors' contributions

TVB and MT conceptualised the study. TVB and MT worked on the draft of this paper. TVB contributed to the data analysis and interpretations. TVB worked on the discussions. MT supervised this study. All authors read and approved the final draft of this paper.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest concerning the research, authorship, as well as the publication of this article.

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