REVIEW ARTICLE

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

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Abstract

Although South Africa is among the countries with lower under-five mortality rates in sub-Saharan Africa, the country has failed to meet the national targets set to achieve the Millennium Development Goals. The study aimed to examine multilevel determinants of deaths of children under five in South Africa. Secondary data from the 2016 South Africa Demographic Health Survey was used to conduct bivariate and multilevel logistic regression analyses. The under-five mortality rate was estimated at 42.1 deaths per 1000 live births. The under-five mortality rates were highest in Mpumalanga and lowest in Western Cape. The findings showed that several factors were associated with under-five deaths, namely the sex of the child, population group, mother's level of education, household wealth, type of toilet facility, source of drinking water, and province. The findings call for targeted interventions aimed at reducing under-five deaths among vulnerable groups, i.e., those from a low socioeconomic background, from the black population group, as well as male children. *(Afr J Reprod Health 2024; 28 [11]: 181-195).*

Keywords: Multilevel analysis, determinants, under-five deaths, under-five mortality, SDG 3, South Africa

Résumé

Bien que l'Afrique du Sud fasse partie des pays ayant les taux de mortalité des moins de cinq ans les plus faibles en Afrique subsaharienne, le pays n'a pas réussi à atteindre les objectifs nationaux fixés pour atteindre les objectifs du Millénaire pour le développement. L'étude visait à examiner les déterminants à plusieurs niveaux des décès d'enfants de moins de cinq ans en Afrique du Sud. Les données secondaires de l'Enquête démographique et de santé de 2016 en Afrique du Sud ont été utilisées pour mener des analyses de régression logistique bivariées et multiniveaux. Le taux de mortalité des moins de cinq ans était estimé à 42,1 décès pour 1 000 naissances vivantes. Les taux de mortalité des moins de cinq ans étaient les plus élevés à Mpumalanga et les plus faibles au Cap-Occidental. Les résultats ont montré que plusieurs facteurs étaient associés aux décès des moins de cinq ans, à savoir le sexe de l'enfant, le groupe de population, le niveau d'éducation de la mère, la richesse du ménage, le type d'installations sanitaires, la source d'eau potable et la province. Les résultats appellent à des interventions ciblées visant à réduire les décès des enfants de moins de cinq ans parmi les groupes vulnérables, c'est-à-dire ceux issus d'un milieu socio-économique défavorisé, du groupe de la population noire, ainsi que les enfants de sexe masculin. *(Afr J Reprod Health 2024; 28 [11]:181-195).*

Mots-clés: Analyse multiniveau, déterminants, décès des moins de cinq ans, mortalité des moins de cinq ans, ODD 3, Afrique du Sud

Introduction

Since 1990, there has been substantial global progress in the reduction of child mortality rates. This fact is supported by multiple scholars[1-3], who present compelling evidence that the number of deaths among children under the age of five years has significantly decreased. Specifically, between

1990 and 2022, the global under-five mortality rates dropped from 12.8 million to 4.9 million[4]. 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[5]. Studies 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[6,7]. The average rate of child mortality in sub-Saharan Africa in 2018 was reported to be 78 deaths per 1000 live births[8]. Another study[9] 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 developing regions[4,10,11].

Rural areas in South Africa account for 49 deaths per 1000 live births, while urban areas account for 38 deaths per 1000 live births[12]. Unfortunately, rural areas in South Africa face a shortage of adequate child healthcare facilities compared to urban areas[13]. A study[14] uncovered an association between under-five deaths and the place of delivery. Furthermore, research[15] 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 in South Africa concerning children under the age of five years. Consequently, the necessity for additional interventions aimed at reducing the rate of under-five deaths in public health facilities is emphasized[15,16].

Evidence from the household census conducted in 2011 revealed a total of 54,580 reported deaths of children under the age of five years[17]. Additionally, a study[15] highlighted variations in under-five mortality rates within different South African provinces in 2015. 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[15]. These findings indicate significant differences in the rates of child deaths among provinces within South Africa. In terms of the provincial distribution, Free State (68.4 deaths per 1000 live births) and KwaZulu-Natal (62.6 deaths per 1000 live births) reported the highest under-five mortality rates; however, the under-five mortality rates were lower in Western Cape (24.5 deaths per 1000 live births) and Gauteng (34.3 deaths per 1000 live births)[17].

Furthermore, additional studies 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 years in East African countries[9,18]. Moreover, a study[19] demonstrated that under-five mortality serves as an indicator of the overall socioeconomic status of a country.

A range of policies, programmes, and strategies[20] have been established to fulfil both national and international objectives. Despite South Africa's failure to achieve the Millennium Development Goals (MDGs) target of 20 deaths per 1000 live births by 2015[21], there is little likelihood of meeting the Sustainable Development Goals (SDGs). SDG 3, Target 3.1, aims to eradicate preventable deaths among children under five years of age by 2030. This goal can be attained by reducing under-five mortality to below 25 deaths per 1,000 live births[22,23]. According to recent statistics, South Africa currently has an under-five mortality rate of 42 deaths per 1000 live births in the five years preceding the survey[12]. 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, the black population group experiences a higher under-five mortality rate compared to other population groups[19]. When examining provincial data, it is evident that Mpumalanga, North West, Eastern Cape, and Free State have the highest under-five mortality rates, ranging from 63 to 70 deaths per 1000 live births over the ten years preceding the survey[12]. 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 SDGs. In alignment with the SDGs' objectives, South Africa is actively engaged

in efforts to decrease the under-five mortality rate[24]. 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 programmes 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[25-27]. Consequently, South Africa must 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 MDG 4. 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. Therefore, the main objective of the study is to examine the multilevel determinants of under-five deaths in South Africa.

Methods

Data source

Secondary data from the South African Demographic and Health Survey (SADHS) conducted in 2016 was used for the study. The SADHS is a nationally representative survey that collects comprehensive information on various health and population issues[12]. The survey employed a two-stage stratified sample design for data collection[12]. In the first stage, primary sampling units (PSUs) were selected, while in the second stage, dwelling units (DUs) were chosen through systematic sampling[12]. The study focused on a weighted sample of 13,856 children under the age of five years.

Outcome variable

Under-five death was the outcome variable in the study with the focus on child survival status (alive or dead). The variable was coded as 1 = not alive (dead), otherwise 0.

Explanatory variables

For this study, several explanatory variables were chosen, these variables include the sex of the child, birth size below 2.5 kg, 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. These variables are described briefly in Table 1. These variables were included based on statistical associations with under-five deaths established in previous studies[28-30].

Statistical analysis

The analysis in this study was conducted using Stata version 14[31]. To achieve the study objective, various analyses were employed, including computing the under-five mortality rates (U5MR), univariate analysis, bivariate analysis, and multivariate multilevel logistic regression. Firstly, under-five mortality rates were computed using the *syncmrates* user-written command in Stata[32]. *syncmrates* is a user-written command which calculates the child mortality rates, on Demographic and Health Survey (DHS) data, using the synthetic cohort probabilities[32]. This command can be downloaded onto Stata using the command "*ssc install syncmrates*"[32]. The command allows researchers to automate the calculation of various child mortality rates using DHS data. Secondly, univariate analysis was utilized to provide a descriptive overview of the study sample.

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 2.5 kg	Reported whether the birth weight of the child was below 2.5 kg or not.	0=No 1=Yes
Age at birth (years)	Respondents were asked about their age at the time of birth.	0=<20 1=20–29 2=30–39 3=40–49
Population group	The population group (i.e., race) of the respondents. The classifications are based on the official racial classifications for South Africa. The category, 'Other' includes the White, Indian/Asian, and Other population groups; these populations are combined due to having small cases.	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	This variable is based on the DHS wealth index – (derived using principal components analysis). For more information about the DHS wealth index, see here: https://dhsprogram.com/topics/wealth-index/	1=Poor 2=Average 3=Rich
Type of toilet facility	The type of toilet facility of the respondent. 'Other' includes pit latrines, composting toilets, bucket toilets, chemical toilets, and other types of toilet facilities.	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

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-level factors influencing under-five deaths in South Africa. Multilevel logistic regression was employed in this study to account for the hierarchical nature of the data.

A two-level model was used, 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} represents 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 and community-level factors. The study employed various statistical measures to measure the random effects and model fitness. The Intra-Class Correlation (ICC) was used to estimate the percentage of variation attributed to community-level variables. The Median Odds Ratio (MOR) describes 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) was used to compare different models. Moreover, we used the Variance Inflation Factor (VIF) to assess multicollinearity between the factors we included in the study. The findings indicated no multicollinearity 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

The dataset used was obtained, with permission, from the DHSProgram. For all the countries where DHS data is collected, the DHSProgram follows all the necessary ethical procedures before collecting data from the participants. Detailed information about the DHS ethics processes can be found here: https://dhsprogram.com/methodology/Protecting-the-Privacy-of-DHS-Survey-Respondents.cfm.

Results

Socio-demographic characteristics

Table 2 presents the background characteristics of the study population. 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 2.5 kg, whereas only 3.3% reported a birth weight below 2.5 kg. 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 years, while the majority (55.7%) had their first child between the ages of 20–29 years. Moreover, 19.7% of women experienced their first birth between the ages of 30 and 39 years, with only 1.4% having their first child in their late forties.

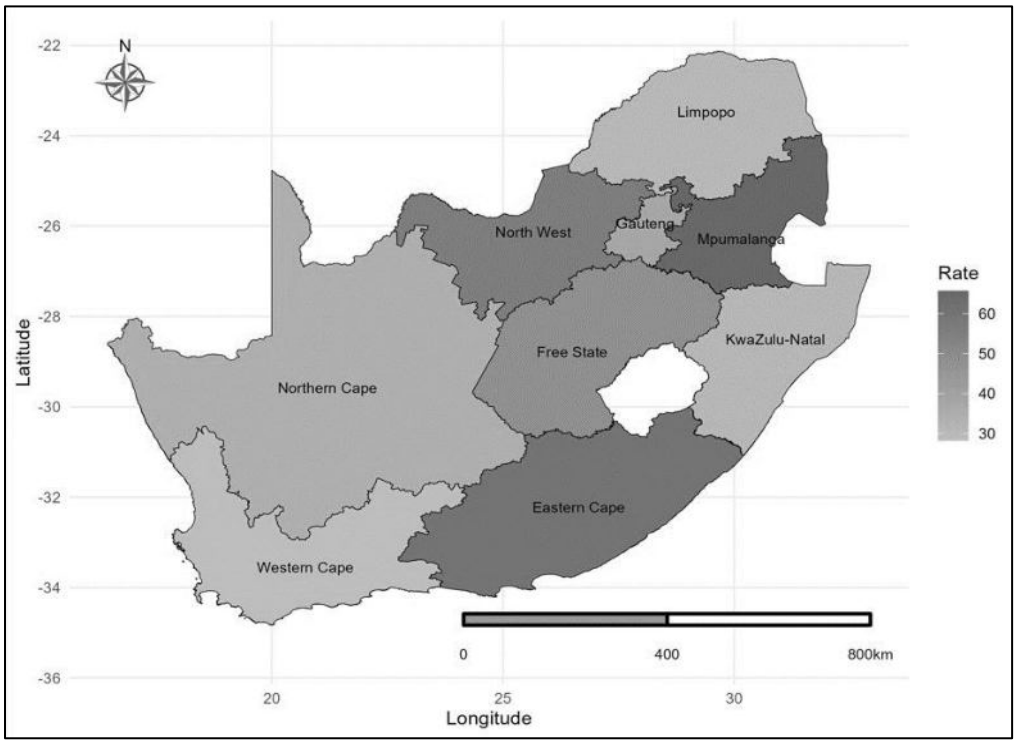
The majority of the study population (87.9%) belonged to the black population group, while 8.6% were from the coloured population group. The remaining 3.4% represented 'other' population groups, including whites and Indians/Asians. Regarding the mothers' level of education, the findings indicated that only 3.6% of mothers had no education, 14.0% had primary education, and the majority (82.4%) had secondary education or higher.

Concerning household wealth, 43.9% of women were from poor households, while 22.3% were from average-wealth households.

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

Characteristics	**Under-five death**				**N (%)**	**χ^2 value**	**p-value**
	No		**Yes**				
	%	**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)		
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



Note: The overall U5MR is 42.1 deaths per 1000 live births

Figure 1: Under-five mortality rate (U5MR) by province in South Africa

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 toilet 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 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 the Free State (4.8%) and Northern Cape (2.0%).

Under-five mortality rate

Figure 1 shows the under-five mortality rates (U5MR) across the provinces of South Africa. 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, South Africa's U5MR stood at 42.1 deaths per 1000 live births.

Prevalence of under-five deaths

Table 2 provides a bivariate analysis of the factors associated with under-five deaths. The results revealed that various factors have an association with under-five deaths; these factors included individual/household-level factors (sex of child, population group, level of education, household wealth, and type of toilet facility) and community-level factors (place of residence and province). The findings also showed that 5.6% of male children and 4.4% of female children experienced death before reaching the age of five years. Children whose weight at birth was above 2.5 kg had a higher prevalence (5.1%) of under-five deaths. Children whose mother's age at birth was 30–39 years had a higher prevalence (5.3%) of under-five death; the prevalence of under-five deaths was higher among children whose mother's age at birth was 20–29 years (5.0%) and less than 20 years (4.9%). Moreover, the findings showed that children from the black population group had a higher prevalence (5.3%) of under-five deaths, while it was lower for those from the coloured population group (3.4%) and the 'other' population group (1.2%).

Additionally, children whose mothers had primary education (7.4%) and those whose mothers had no education (6.0%) had a higher prevalence of under-five deaths. Moreover, the findings showed that the prevalence of under-five deaths decreased with household wealth status. Children from poor households had a higher prevalence (6.0%) of under-five deaths, while it was lowest (3.4%) among those from rich households. There was also some variation in the prevalence of under-five deaths by type of toilet facility. Children whose households used 'other' (i.e., pit latrine, composting toilet, bucket toilet, chemical toilet, and other types of toilet facilities) toilet facilities had a higher prevalence (6.0%) of under-five deaths; the prevalence was also high (5.8%) among those whose households did not have any toilet facilities, and it was lower (4.1%) among children from households which had access to flush toilets. In addition, children from households which did not have access to piped water for drinking had a higher prevalence (5.6%) of under-five deaths. Regarding the place of residence, children from rural areas had a higher prevalence (5.9%) of under-five deaths than children from urban areas (4.5%). Furthermore, the prevalence of under-five deaths was higher among children from Mpumalanga (7.7%), Eastern Cape (7.2%), and North West (6.9%); it was lowest among children from Limpopo (3.0%).

Determinants of under-five deaths

Table 3 presents the multilevel model for the determinants of under-five deaths in South Africa. The null model (Model 0) reveals some variations in the factors determining under-five deaths across the various clusters (variance = 0.423 [95% CI 0.29–0.62]). This is 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 zero to 6.32% in model three. Model three accounted for approximately 48% (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 three, characterized by the lowest deviance (-2LL) and AIC values, demonstrated the best-fit model among the models considered. Therefore, the findings are interpreted from model three. The findings revealed that female children had lower odds [AOR: 0.77, 95% CI: 0.66–0.89] of under-five deaths compared to male children. In terms of population group, children from the black population group had higher odds [AOR: 1.72, 95% CI: 1.13–2.60] of under-five deaths compared to children from the coloured population group. In terms of mother's level of education, children whose mothers had secondary or higher education had lower odds [AOR: 0.68, 95% CI: 0.56–0.82] of under-five deaths compared to children whose mothers had primary education.

Furthermore, the findings showed that children from poor households had higher odds [AOR: 1.46, 95% CI: 1.12–1.92] of under-five deaths compared to children from rich households.

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

Variable	Model 0 AOR [95% CI]	Model 1 AOR [95% CI]	Model 2 AOR [95% CI]	Model 3 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 2.5 kg				
No®		1		1
Yes		0.65 [0.39–1.09]		0.64 [0.39–1.08]
Age at birth (years)				
<20		0.99 [0.82–1.19]		0.97 [0.81–1.17]
20–29®		1		1
30–39		1.10 [0.90–1.33]		1.11 [0.91–1.34]
40–49		0.90 [0.46–1.73]		0.91 [0.47–1.77]
Population group				
Black		1.73** [1.20–2.50]		1.72* [1.13–2.60]
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]		1.20 [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]
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

In addition, children from households with 'other' toilet facilities had higher odds [AOR: 1.63, 95% CI: 1.04–2.55] of under-five deaths compared to children from households with no toilet facility. Children from households with no piped water for drinking had lower odds [AOR: 0.90, 95% CI: 0.71–1.13] of under-five deaths compared to children from households with piped water for drinking. Though not significant, the findings for the place of residence showed that children from rural areas had higher odds of under-five deaths compared to those from urban areas. Although the finding for place of residence is not significant, it is important in the context of the province. Children from Mpumalanga [AOR: 1.85, 95% CI: 1.26–2.71], North West [AOR: 1.70, 95% CI: 1.15–2.51], and the Eastern Cape [AOR: 1.63, 95% CI: 1.10–2.41], had higher odds of under-five deaths compared to children from the Gauteng province. However, children from the Limpopo province had lower odds [AOR: 0.63, 95% CI: 0.40–0.99] of under-five deaths compared to children from the Gauteng province.

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 findings showed some substantial between-cluster variation in under-five deaths, thus supporting the use of multilevel modelling in explaining under-five deaths in South Africa. This finding is in line with findings from other similar studies in sub-Saharan Africa, as well as other developing regions[33,34]. The results also indicated that various factors (such as the sex of the child, population group, educational level, household wealth, type of toilet facility, place of residence, and province) were statistically associated with under-five deaths. These findings align with similar studies conducted in other developing nations, where some of these factors were also found to be associated with child mortality[35-38]. A study by[39] observed differences in child survival based on the sex of the child. The findings showed that female children had lower odds of under-five deaths[39]. However, another study[40] found that males under the age of five years had a greater risk of death compared to females. One reason why more males die than females could be that females have stronger immune systems and are better at fighting off infections and respiratory illnesses than males[41].

Moreover, children from the black population group had higher odds of under-five deaths than children from the coloured population group. Research conducted in sub-Saharan Africa has consistently demonstrated that ethnicity plays a significant role in under-five deaths[19,42,43]. A similar study, conducted in Brazil[44], found that inequalities in racial groups contribute to childhood mortality. This finding 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 a limited ability to make informed decisions regarding children's health compared to other racial groups such as whites, Indians/Asians, and coloureds.

Children whose mothers had secondary or higher education had lower odds of under-five deaths than children whose mothers had primary

education. This finding is similar to findings from other studies[45,46]. Education plays a crucial role in the health and well-being of children. 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 issues and can make informed decisions regarding their children's healthcare. Additionally, mothers with higher levels of education exhibit greater attentiveness to their children's hygiene practices[47].

Maternal educational level increases, there is an increase in women's engagement in family decision-making and their active participation in fulfilling the requirements of child healthcare[47]. Children from poor households had higher odds of under-five deaths than children from rich households. This observation supported the findings of previous studies[48-50], which identified that household wealth is a key 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 a better diet; these factors have been shown to reduce the occurrence of prevalent childhood illnesses[51].

Additionally, children from households with 'other' (mostly unimproved) toilet facilities had higher odds of under-five deaths than children from households with no toilet facility. This finding aligns with a study[52], which 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 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[53,54]. Moreover, children from households with no piped water for drinking had lower odds of under-five deaths than children from households with piped water for drinking. This finding is unexpected. A study conducted in Zimbabwe found similar results where children from households with unimproved water had a lower risk of mortality[55]. However, this finding is different from studies which have found that access to improved sources of water, including piped water, tends to improve the risk of under-five deaths[56,57]. Disparities in the quality of water could explain these unexpected findings. While urban areas have better access to piped water, many rural areas still face water challenges[58]. These rural areas tend to rely on alternative sources of water, such as boreholes and rainwater catchments, which may provide 'safer' water that is properly managed[59]. Additionally, households with no piped water may engage in stricter water purification practices, such as boiling the water, which can assist in reducing the risk of related diseases. It is important to exercise caution when interpreting the results for piped water — the reasons for this caution are provided elsewhere[55].

Furthermore, children from Mpumalanga, North West, and the Eastern Cape, had higher odds of under-five deaths than children from the Gauteng province. These provinces also had higher U5MR compared to other provinces.

These findings align with other studies conducted in South Africa, which also found provincial variations in under-five deaths[60,61]. 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 and thus affects the healthcare provision.

Strength and limitations

The main limitation of this study is that analysis of cross-sectional data does not allow one to establish causation between the variables. For instance, it is not possible to conclude that inadequate sanitation causes under-five mortality. Moreover, 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 SDG 3, which aims to reduce child mortality rates. The findings from this study may

serve as a foundation for further research into 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. Selected factors, including the sex of the child, population group, level of education, household wealth, type of toilet facility, place of residence, and province, were found to be associated with under-five deaths. It is crucial to reduce the under-five mortality rate to achieve the objectives of SDG 3. The results showed a higher prevalence of under-five deaths among children born to women with a lower socioeconomic status in South Africa. Furthermore, children born to black women have higher odds of under-five deaths compared to children born to women of other racial groups. Furthermore, children from provinces such as Mpumalanga, North West, and the Eastern Cape, had higher rates of under-five deaths than those from other provinces. Based on the study's findings, several recommendations for policymakers and other relevant stakeholders emerge. There is a need for targeted interventions that will aim to reduce under-five deaths among the at-risk groups (i.e., children from low socioeconomic backgrounds, children from the black population group, as well as male children). Moreover, there is a need to have a closer look at the factors influencing under-five deaths in certain provinces (i.e., Mpumalanga, North West, and the Eastern Cape); a better understanding of these factors can bring about solutions to lowering the higher prevalence of under-five deaths.

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Contribution of authors

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

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