




## Research Paper

# Water and sanitation influence on child health in Namibia: using demographic and health surveys

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## ABSTRACT

Important milestones in reducing child mortality rates have been achieved internationally and in Africa. With 76 deaths per 1,000 live births, sub-Saharan Africa (SSA) continues to have the world's highest under-five mortality (U5M) rate. In SSA, one child in every 13 dies from preventable causes before reaching their fifth birthday. This study sought to determine the impact of demographic, socio-economic, and environmental determinants on child health in Namibia, using the Namibian demographic and health surveys (NDHS) from 2006 and 2013. A logistic regression model was used to determine the association between improved sanitary facilities and water sources and U5M in Namibia. Improved access to sanitation facilities in Namibia is associated with a lower U5M rate, according to the 2013 survey. No significant association was observed between improved access to safe water and child death. In 2013, the greater the mother's level of education, the lower the chance of child death. Finally, the findings demonstrate that mothers who are HIV-positive are more likely to experience under-five death. Hence, the Namibian government should increase sanitation facilities and promote maternal healthcare services for less fortunate households to lower the U5M rate.

**Key words:** child health, demographic and health survey, Namibia, safe water, sanitation, under-five mortality

## HIGHLIGHTS

- Eighty-seven percent (87%) of households have access to safe water supply in Namibia.
- Children from the Zambezi region had  $\geq 50\%$  chance of under-five mortality (U5M) compared with children from the Otjozondjupa and Khomas regions ( $p < 0.05$ ).
- Mothers from the cities had 32% lower chance of experiencing U5M than mothers from villages.
- HIV-positive mothers had a 2.3 times higher chance of experiencing U5M than the HIV-negative mothers.

## INTRODUCTION

Child survival and health are high on the global agenda for long-term development. However, children in underdeveloped countries such as Namibia continue to die from preventable causes before reaching their fifth birthday. According to the World Health Organization (WHO), the African region has the highest child mortality rates, with around 74 fatalities per 1,000 live births, nine times greater than cases reported in the European area (WHO 2021). Furthermore, WHO estimates that roughly 28% of all fatalities in children under five are preventable and attributed to environmental factors (WHO 2016).

The global under-five mortality (U5M) has reduced by 60% from 1990 to 2020, currently at 5.2 million, equating to a daily death rate of 14,000 children (UNICEF 2020). Reaching the targets set by the Millennium Development Goals (MDGs), which expired in 2015, remains a far-fetched dream (Brault *et al.* 2020). Goal 3 of the Sustainable Development Goals (SDGs), which replaced the MDGs, is to 'reduce new-born mortality to at least 12 deaths per 1,000 live births and under-5 mortality to at least 25 per 1,000 live births' (United Nations 2017). According to the SDGs and current statistics, countries

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and global efforts must be coordinated and accelerated to prevent the expected deaths of 48 million children between 2020 and 2030 before they reach their fifth birthday (UNICEF 2020).

Namibia is a sub-Saharan African (SSA) country with the world's highest child mortality rate (UNICEF 2020). Despite this, there has been significant progress in the African region to lower child mortality rates in recent years. With 76 deaths per 1,000 live births, SSA continues to have the world's highest U5M rate. In SSA, one out of every 13 children dies before reaching their fifth birthday due to preventable causes (UNICEF 2015, 2020).

The current burden of a high mortality rate among children under five in the SSA is due to a high neonatal mortality rate. The first 30 days of an infant's existence are critical for survival and adaptability. As a result, newborn children at this age are vulnerable to a variety of environmental stressors that, if not addressed, can result in premature death. Furthermore, exposure to environmental factors during infancy causes health conditions that continue into adulthood, leading to a lower life expectancy (UNICEF 2020), reducing the human capital required to achieve global SDGs. Improving environmental conditions could prevent 47% of U5M in the newborn period and increase longevity (WHO 2021).

In Namibia, infant mortality has decreased dramatically over time. The country had the highest U5M rates in Southern Africa in the early 1990s and the early 2000s (62 deaths per 1,000 live births). Furthermore, the country's infant mortality rate fell from 36.3 deaths per 1,000 live births in 2013 to 30.7 deaths per 1,000 live births in 2019 (O'Neill 2021). Between 2015 and 2018, there was also a significant reduction in the neonatal mortality rate. Improved availability of sanitation facilities and health services at the home level and improved household indices, and breastfeeding initiation contributed to lowering infant mortality in the early 1990s and the early 2000s (Ndirangu *et al.* 2018; Headey & Palloni 2019).

Although the child mortality rate has decreased over time, particularly in the late 1990s and the early 2000s, the infant mortality rate in Namibia remains higher than the 3.9 targets set by the SDGs. Reaching the SDG 3.9 target is also threatened by the rising in HIV infections in Namibia. Namibia had an HIV prevalence rate of 913 per 10,000 people in 2020, with children occupying 4% of the infected population (UNAIDS 2021).

Namibia is a middle-income country, although with social inequalities between ethnic groups and uneven distribution of wealth across regions (MOHSS *et al.* 2014). Namibia's population grew by 13% between 2001 and 2011 (National Planning Commission 2011); however, the country remains one of the least densely populated, with a population density of 2.6 people per square kilometres (MOHSS *et al.* 2014). Topography/terrain, population density, and poor rainfall patterns, on the other hand, make it challenging to distribute piped water from safe sources and enhance sanitation facilities (MOHSS *et al.* 2014). Despite the above knowledge, it's worth noting that no study investigated the impacts of the interactions of the HIV/AIDS epidemic, migration from rural to urban regions, population growth, and economic inequality in Namibia's U5M rate using the national demographic and health data.

In 2011, 80 and 51% of Namibian homes had access to safe drinking water and improved toilet facilities, respectively (National Planning Commission 2011). The statistics above suggest that between 20 and 49% of households lack safe drinking water and improved sanitary facilities. Children in those households are more likely to suffer or die from diarrheal diseases before reaching their fifth birthday or are more likely to die from environmental causes within their first month due to their underdeveloped physiological systems (US EPA 2011). Evidence from 172 countries shows that improved water and sanitation infrastructure lowers the odds of child diarrhoea by 7 and 13%, respectively (Gunther *et al.* 2010), suggesting improvement in children's health.

Children's health is a sensitive indicator of the country's overall health and economic situation (Rayhan & Khan 2006). To our knowledge, no research has looked into the impact of water and sanitation on the health of Namibian children.

Different studies have found a link between demographic, socio-economic, environmental, cultural, and health-related factors and child health in other nations (Rayhan & Khan 2006; Abir *et al.* 2015). A study conducted using demographic and health data from 28 SSA countries reported a correlation between enhanced immunization coverage and ethnic homogeneity with lower child death odds (Boco 2010). A positive association exists between rurality, residence region, mother's education, marital status, religion, and ethnicity towards vulnerability and a weak survival rate of children under five in Cameroon (Defo 1993). The findings from a Ghanaian study imply that numerous social and environmental factors influence children's health and survival, and this study will examine the Namibian community (Kanmiki *et al.* 2014). It is worth noting that both the Cameroon and Ghanaian studies used data from national demographic and health surveys.

This study attempted to determine the impact of demographic, socio-economic, and environmental determinants on child health in Namibia, using the Namibian demographic and health surveys (NDHS) from 2006 to 2013. The study used the logistic regression model to investigate the influence of water sources and sanitation facilities on U5M in Namibia. Our goal was to

determine the impact of improved water sources and toilet facilities on U5M in Namibia, comparing variables from the NDHS, between 2006 and 2013. Secondly, the model compared the effects of improved toilet facilities and protected water sources on U5M in Namibia between 2006 and 2013 by region.

## METHODOLOGY

### Data sources and variables

The NDHS of 2006 and 2013 were the sources of data in this study. The NDHS is a cross-sectional survey that questioned mothers in Namibia between 15 and 49 years old to provide policymakers with demographic, socio-economic, and health data. The household survey gathered data on various home amenities, such as the source of drinking water and the type of toilet facilities available, and data on family factors, maternal education, child health, and dietary variables.

The 2006 NDHS is Namibia's third comprehensive survey, with the interviews conducted between November 2006 and March 2007. Additionally, the 2013 NDHS is the fourth DHS survey, and it collected data from May to September of that year. The Ministry of Health and Social Services (MOHSS) was in charge of both surveys. The data are representative of Namibian households by area and residence (rural and urban). In this study, the participants are *de jure* household members or regular residents. The sample size was 4,821 in 2006 and 4,768 in 2013. In 2006, there were five missing variables for a mother's marital status, while in 2013, there were 36 missing ones. Finally, concerning the measurement of HIV results, 2,873 observations were observed in 2013, while no participants answered the HIV questions in the 2006 survey.

During the interviews, mothers indicated whether their child was still alive or dead as well as their age when they died. As a result, we created a binary variable for U5M, which takes one if the child died before the age of 5 and zero if the child is still alive. This study applied the model with the main determinants of U5M risk in two categories, according to the Mosley and Chen framework for child survival in underdeveloped countries (Mosley & Chen 1984).

Table 1 shows the categorization of the explanatory variables. The environmental factors covered in the analysis are the source of drinking water and the type of toilet facilities. The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (WHO & UNICEF 2020) defines and classifies both variables. The source of drinking water is a good predictor of its fitness for use, which is essential in Namibia because waterborne infections like diarrhoea are common. Improved water supplies refer to water sources that are more likely to deliver adequate water. The options are a piped supply within the yard, the dwelling, or the plot; a tube well; protected well or protected spring; or bottled water.

Unprotected springs, wells, and tanker trucks/carts with drums are all considered unprotected drinking water sources since they likely contain disease-causing substances. The type of toilet facilities was improved and non-improved. Improved toilet facilities refer to flushing toilets into a piped sewer system, septic tank, or pit latrine, and pit latrines with a slab in a household. When toilets are pit latrines with no slab and open pit, a household has an unimproved toilet facility. Both factors have binary variables, with one indicating improved toilet facilities and zero indicating no improvement. In the same way, the protected water supply takes one and zero if not protected.

The study also includes information on the household's socio-economic and demographic features, such as education, wealth, age, and residence. Maternal education is a significant driver of health outcomes. The mother's education level ranged from no education, primary, secondary, and higher education. We ranked the mother's wealth into three categories: poor, moderate, and rich. However, because the NDHS does not collect direct information on family income, the wealth index is calculated using the household's assets. The presence of power, a car, a motorcycle, a refrigerator, a radio, a television, and the type of flooring were all considered assets (Rutstein & Johnson 2004). The NDHS divided the wealth index into five quintiles, from low to high. The poor and poorest were combined in this study to form the contemporary poor. Again, in this study, the rich group comprised of wealthy and most affluent merged. Four categories for the mother's age were: under 20, 20–29, 30–39, and 40–49. Types of marital status were: never married, married, living with a partner, widowed, divorced, and no longer living together/separated.

The total number of household members is a continuous variable that ranged from 1 to 33 in 2006 and to 25 in 2013. In both years, the number of children aged 5 or younger ranged from zero to eight. Other explanatory variables for the Namibian setting were locations (urban, rural) and geographical regions (Caprivi, Erongo region) as dummy variables. Because of the country's severely unequal distribution of resources, location issues are essential in Namibia (MOHSS *et al.* 2014).

Biological, maternal, and dietary aspects were also taken into account, as shown in Table 1. In the previous 5 years, the number of births was in three categories: one, two, and three or more. First, second, third, or higher were birth order

**Table 1** | Summary of study variables

Variable name	Variable description	Coding structure
Dependent variable		
U5M	Whether their child is still alive or dead at the time of the interview	Categorized, 0=No, 1=Yes
Environmental factors		
Source of drinking water	If piped into dwelling, to yard or plot, public tap, etc.	Categorized, 1=Protected, 2=Not protected
Type of toilet facility	If flush to a piped sewer system, septic tank, a pipe connected to groundwater, etc.	Categorized, 1=Improved, 2=Not improved
Socio-economic and demographic factors		
Mother's level of education	The highest level of education attained by the mother at the time of the interview	Categorized, 1=Higher, 2=Secondary, 3=Primary, 4=No education
Wealth status	Wealth index of the household	Categorized, 1=Poor, 2=Middle, 3=Rich
Maternal age	Maternal age in years	Categorized, 1=Less than 20, 2=20–29, 3=30–39, 4=40–49
Marital status	Current marital status	Categorized, 1=Never in union, 2=Married, 3=Living with partner, 4=Widowed, 5=Divorced, 6=No longer living together/separated
Place of residence	Type of location	Categorized, 1=Rural, 2=Urban
Region	The location of the region	Categorized, 1=Caprivi, 2=Erongo.
Number of households	The number of households	Continuous ranged from 1 to 33 in 2006 and from 1 to 25 in 2013
Five or under-five children in the household	The number of children under 5 or 5 in the household	Continuous ranged from 0 to 8 in 2006 and 2013
Biological, maternal, and nutritional factors		
Number of births in the last 5 years	The number of births the mother had in the last 5 years before the survey	Categorized, 1=Three or above, 2=two birth, 3=one birth
Birth order	The order of the birth	Categorized, 1=3rd or above 3rd, 2=2nd child, 3=1st child
Child gender	Gender of the birth	Categorized, 1=Male, 2=Female
Breastfeeding	If the child is ever breastfed	Categorized, 1=No, 2=Yes
HIV	Recent HIV test result	Categorized, 1=Negative, 2=Positive

categories in this study. In addition, the gender of a child and breastfeeding status also accounted for child mortality. Finally, the study added the HIV variable in the 2013 model.

### Statistical methods and analysis

This study estimated Equations (1) and (2) by applying a logistic regression model. The model investigated the association between access to different toilet facilities and water sources and U5M in Namibia as well as the association of socio-economic and proximate factors with child health in Namibia. The logistic regression model forecasts the likelihood of the child dying before reaching the age of 5. The dependent variable in the model is a binary outcome, with one indicating that the child died before the age of 5 and zero meaning that he is still alive. Odds ratios interpreted the findings of the logistic regression estimations.

$$CS = \beta_0 + \beta MC + \beta BMF + \beta EF + \beta NF + \varepsilon \quad (1)$$

The acronym CS stands for child survival, and it refers to whether or not the child was alive at the time of the survey. The answer to this question is either yes or no. Mother's qualities as MC include her age, education, wealth, and marital status.

Mother's age is in categories, and less than 20s is the reference group. The classes of mothers' education: uneducated, primary education, secondary, and higher education, as the reference group.

Similarly, the household's wealth was divided into three groups: poor (reference group), middle, and rich. BMF represents the biological and maternal factors, including the birth gender, males and females as the reference group. The number of births in the last five years is categorized into three groups, one birth, two births, and three or above births (reference group). Similarly, the birth order of the child is grouped into three groups, first child, second child, and third or above for the reference group. Covered environmental variables (EF) include access to safe water supply and the type of toilet facilities used at the household level. The reference groups are the protected water source and the improved toilet facility, respectively. Finally, NF stands for the child's nutritional factors, which takes one if the child is breastfeeding, while not breastfeeding is the reference group.

$$CS = \beta_0 + \beta_{MC} + \beta_{BMF} + \beta_{EF} + \beta_{NF} + \beta_{PR} + \beta_{HN} + \beta_{NC} + \varepsilon \quad (2)$$

The second model includes variables relevant to Namibia. The PR vector denotes the location of residence as well as geographical location, covering 14 political regions. The reference group used in this analysis is the Caprivi region. Additionally, it includes NH and NC vectors, which present the total number of household members and the total number of children under five, respectively, as continuous variables. Furthermore, in 2013, Model 2 added the mother's HIV results to determine the influence of a mother's HIV status on her child's health; the reference group is the negative results. Lastly, Models 1 and 2 are both estimated separately for 2006 and 2013.

## RESULTS AND DISCUSSION

We investigated the impact of drinking water sources, toilet facilities, mother's characteristics and socio-economic factors, and proximate factors on the health of children under the age of 5 in Namibia. Table 2 shows the descriptive statistics of the 2006 and 2013 surveys. The majority of residents had unimproved toilet facilities. In 2006, 65% of Namibian households had unimproved toilet facilities, and 61% in 2013. In both the 2006 and 2013 surveys, 87% of Namibian respondents had access to a protected water supply.

The proportion of uneducated mothers in Namibia was 12 and 8% in 2006 and 2013, respectively. The number of mothers who completed secondary education increased from 53% in 2006 to 63% in 2013. In both years, the percentage of mothers with a higher degree fell below 5%. In 2006, 40% of the population was impoverished compared with 44% in 2013. The wealthiest group accounted for 34% of all households in both years, while the rest were in the middle. Half of the mothers were between the ages of 20 and 29, with the lowest proportion between 20 and 40. The highest share of mothers in both surveys were never married, followed by married and living with a partner.

In terms of location, the vast majority of respondents lived in rural areas. In 2006, almost 63% of households lived in rural areas, and this percentage decreased to around 55% in 2013. The observed decrease in the percentage of rural households could be attributable to increased rural-urban migration observed in the country during the last two decades. Despite the observed increase in urbanization, Namibia is still mostly rural, with around four in ten residents living in urban regions (MOHSS *et al.* 2014).

Table 2 reveals that 60% of women had one child 5 years before the 2006 survey, whereas 34% had two children. Only 6% of mothers had three or more children in the last 5 years. In 2013, these percentages remained unchanged. Furthermore, a third of respondents had their first birth order at the time of the survey. In contrast, 44% of respondents have a birth order of three or higher. Males made up 51% of children under the age of 5 in 2006. In 2006, 41.5% of mothers were breastfeeding, compared with 38.8% in 2013. Finally, in 2006, households did not respond to the HIV status-related questions. In 2013, 2,873 participants responded to the inquiry about recent HIV results, with the majority of them having negative HIV results.

Table 3 illustrates the results of estimating model 1 for the years 2006 and 2013. In both years, the study discovered that the source of drinking water had no substantial impact on the child's health. The wide distribution of safe water supply and widespread usage of water treatment tablets in the country's households contributes to the insignificance of the drinking water source to child health (Kgabi *et al.* 2014).

Similar research in Egypt and 70 middle-income countries (Abou-ali 2003; Fink *et al.* 2011) corroborates our findings. According to the Egyptian study, lower childhood mortality did not statistically connect with access to municipal water, but it was significantly associated with lower infant mortality (Abou-ali 2003). Fink *et al.* (2011) confirmed the favourable

**Table 2** | Summary statistics for the respondents in NDHS 2006 and 2013

Year Variables	2006			2013		
	Frequency	%	Cumulative	Frequency	%	Cumulative
Source of drinking water						
Improved source	4,211	87.35	87.35	4,142	86.87	86.87
Unimproved source	610	12.65	100	626	13.13	100
Type of toilet facilities						
Improved sanitation	1,684	34.93	34.93	1,869	39.2	39.2
Unimproved sanitation	3,137	65.07	100	2,899	60.8	100
Highest educational level						
No education	586	12.16	12.16	397	8.33	8.33
Primary	1,483	30.76	42.92	1,129	23.68	32.01
Secondary	2,547	52.83	95.75	3,010	63.13	95.13
Higher	205	4.25	100	232	4.87	100
Wealth index						
Poor	2,001	41.51	41.51	2,202	43.64	43.64
Middle	1,203	24.95	66.46	1,121	22.22	65.85
Rich	1,617	33.54	100	1,723	34.15	100
Mother's age in groups						
Less than 20	309	6.41	6.41	304	6.38	6.38
20–29	2,402	49.82	56.23	2,420	50.76	57.13
30–39	1,681	34.87	91.1	1,606	33.68	90.81
40–49	429	8.9	100	438	9.19	100
Marital status						
Never in union	1,957	40.64	40.64	2,129	44.65	44.65
Married	1,333	27.68	68.31	1,094	22.94	67.6
Living with partner	1,262	26.2	94.52	1,294	27.14	94.74
Widowed	87	1.81	96.32	41	0.86	95.6
Divorced	27	0.56	96.89	37	0.78	96.37
No longer living together/separated	150	3.11	100	173	3.63	100
Type of location						
Rural	3,021	62.66	62.66	2,615	54.84	54.84
Urban	1,800	37.34	100	2,153	45.16	100
Births in last 5 years						
One birth	2,789	57.85	57.85	2,853	59.84	59.84
Two births	1,724	35.76	93.61	1,638	34.35	94.19
3–4 births	308	6.39	100	277	5.81	100
Birth order						
1st child	1,500	31.11	31.11	1,534	32.17	32.17
2nd child	1,179	24.46	55.57	1,159	24.31	56.48
Above 3	2,142	44.43	100	2,075	43.52	100
Currently breastfeeding						
No	2,819	58.47	58.47	2,918	61.2	61.2
Yes	2,002	41.53	100	1,850	38.8	100

*(Continued.)*

Table 2 | Continued

Year Variables	2006			2013		
	Frequency	%	Cumulative	Frequency	%	Cumulative
Sex of the child						
Male	2,479	51.42	51.42	2,369	49.69	49.69
Female	2,342	48.58	100	2,399	50.31	100
HIV						
No				2,484	86.46	86.46
Yes				389	13.54	100

Source: Author's Computation.

effect associated with access to safe water supply on children aged 1–12 months while adjusting parental and household variables. As a result, access to safe water during the weaning process of an infant could be a crucial determinant of child survival and health, significantly if socio-economic, biological, and maternal characteristics are not improved (Abou-ali 2003).

Furthermore, this study found a significant association between the type of toilet facilities and child health. The results of the 2013 survey revealed that children in homes with unimproved toilet facilities were 80% more likely to die than those with improved toilet facilities ( $p=0.011$ ). A study conducted using demographic and health data from 70 low and middle-income countries during 1986–2007 found that children who live in a home with improved toilet facilities were associated with a 23% lower risk of dying before reaching five (Fink *et al.* 2011). Namibia invested more resources into improving and expanding population access to safe drinking water than improved toilet facilities. By 2013, 61% of Namibian households did not have improved toilet facilities, and roughly 87% of Namibian households had access to safe water (MOHSS *et al.* 2014). These discrepancies could explain the results of this research.

In terms of a mother's socio-economic status, the study found that in 2013, a mother's education was crucial for her child's health. For example, compared with mothers with higher education, the probabilities of under-five children's deaths are 3.6 and 3.4 times higher for illiterate mothers and mothers with secondary education, respectively. Furthermore, mothers with primary education have a 4.4 times higher risk of having a child under the age of 5 die than mothers with a higher level of education. A study from Ghana supports our findings that women with a junior and secondary education were 45 and 76% less likely to experience child deaths, respectively (Kanmiki *et al.* 2014). In 2006, the mother's wealth was critical to the child's health. Rich mothers have a 45% lower risk of under-five child mortality than poor mothers, with a  $p$ -value of 0.023. Evidence from a study conducted in Namibia revealed that a unit increase in wealth was associated with a 0.052 and 0.301 increase in the mother's BMI in the 5th and 90th percentiles, respectively (Amugsi *et al.* 2016). Although this does not imply that educated mothers make better nutritional choices for their children, it suggests a greater chance of doing so. Finally, the mother's age and marital status are unimportant in the 2006 and 2013 analyses.

Breastfeeding is a crucial factor in determining a child's survival and health. According to our findings, if a mother is not breastfeeding, she is seven and five times more likely to have a child die before the age of 5 in 2006 and 2013, respectively. Furthermore, the number of births in the previous 5 years is a significant determinant for U5M. In 2006 and 2013, mothers who had only one child in the last 5 years had 84 and 91% less probability than mothers with three or four children. A positive association exists between multiple gestations with child mortality in low- and middle-income nations, especially during infancy (Owais *et al.* 2013; Kayode *et al.* 2015). Multiple pregnancies are commonly associated with poverty, contributing to stillbirths and premature deliveries, risk factors of under-five child mortality (Kayode *et al.* 2015). The rate of newborn fatalities in Bangladesh is 29 per 1,000 live births, with the leading causes being asphyxia (35%), sepsis (28%), and preterm births (19%) (Owais *et al.* 2013). In addition, contributing factors to infant mortality worth mentioning are hypoglycaemia and hypothermia, which are difficult to manage in low-resource settings (Kibria *et al.* 2018).

This study also revealed that inappropriate birth spacing and order are associated with the risk of child mortality. In Ghana, inadequate birth spacing negatively relates to child survival; children with insufficient spacing had 2.5 times the chance of dying during the newborn stage (Kayode *et al.* 2015). In addition, primigravida contributes to an increased risk of infancy mortality rate, which decreases over the second to fourth years of life (Kibria *et al.* 2018). Incredibly, the probability of

**Table 3** | Estimation results (implied odds ratio)

Variables	Odds ratio	p-value	Odd ratio	p-value
Source of drinking water				
Unprotected	0.85	0.408	0.68	0.105
Protected	R		R	
Toilet facilities				
Improved	R		R	
Not improved	0.85	0.482	1.8**	0.011
Mother's education				
No education	0.82	0.667	3.62*	0.096
Primary	1.88	0.115	4.44**	0.045
Secondary	1.44	0.345	3.44*	0.089
Higher	R		R	
Mother's age (years)				
Less than 20	R		R	
20–29	0.83	0.538	0.68	0.274
30–39	0.97	0.929	0.65	0.267
40–49	1.54	0.24	0.84	0.69
Marital status				
Married	0.85	0.294	0.79	0.217
Otherwise	R		R	
Child gender				
Male	1.39***	0.009	1.14	0.372
Female	R		R	
Breastfeeding				
Yes	R		R	
Not	7.15***	0.000	4.9***	0.000
Number of births in the last 5 years				
1 birth	0.16***	0.000	0.09***	0.000
2 births	0.33***	0.000	0.24***	0.000
3–4 births	R		R	
Wealth				
Rich	0.55**	0.023	1.28	0.337
Middle	1.01	0.93	0.98	0.918
Poor	R		R	
Birth order				
1st birth	1.17	0.44	0.92	0.726
2nd birth	1.17	0.381	0.84	0.413
3rd birth or above	R		R	
Constant	0.05***	0.000	0.02***	0.000
Year	2006		2013	

R refers to the reference group.

Source: Author's Computation.

\*Denotes the estimate is significant at 10%.

\*\*Denotes the estimate is significant at 5%.

\*\*\*Denotes the estimate is significant at 1%.



child mortality rises again from the fifth infant onwards; however, birth spacing and mother's education could significantly reduce these deaths (Kibria *et al.* 2018).

Table 4 shows the results of estimating model 2. Model 2 includes the household location, recent HIV results, the number of households, and children. The findings of model 2 reveal that the source of drinking water does not affect children's health. In 2013, the type of toilet facilities was still significant. The odds of U5M for women who do not have access to improved toilet facilities is 1.65, with a  $p$ -value of 0.041. The result predicts that children die more in households with unimproved toilet facilities than those with improved toilets.

In 2013, the impact of a mother's education on her child's health was significant. Compared with mothers with a higher level of education, the odds for uneducated and low-educated mothers is roughly four. A study from SSA confirms that children of mothers who received formal education had an 80% chance of surviving until the fifth birthday compared with those whose mothers have not been to school (Bado & Susuman 2016). This paper revealed that mothers between the ages of 20 and 29 have a 45% lower probability of under-five child death than mothers under 20. Furthermore, adolescent mothers (18) and mothers over 35 had a higher likelihood of U5M. However, there is no apparent danger associated with older mothers, especially with proper birth spacing patterns (Owais *et al.* 2013). Children born to older mothers with a 2-year gap between births were less likely to die (Kibria *et al.* 2018). Instead, children of grand multiparous mothers with poor health-seeking habits are more likely to die (Kayode *et al.* 2015). Throughout the study, the mother's marital status did not influence the child's health.

According to a 2006 model, male children have a 41% probability of dying before reaching 5 years compared with a female child ( $p=0.009$ ). Despite this, there is no evidence of child deaths in 2013 based on gender disparity. According to the study conducted in Afghanistan from the 2015 DHS data, 52% of 266 children that died were boys. The same study predicts boys neonates were 0.5% more likely to die than girls (Kibria *et al.* 2018). Breastfeeding is vital to a child's health, as previously stated. In 2006 and 2013, mothers who do not breastfeed had 5.2 and 3.7 increased chances of having a child die under the age of 5 than mothers who do. In addition, there is an association between breastfeeding and a mother's nutrition status. A study in Bangladesh found that proper nutrition for mothers during pregnancy or breastfeeding correlated with a 0.4 reduction in newborn deaths (Owais *et al.* 2013).

Table 4 shows a similar odds ratio of births in the previous 5 years in 2006 and 2013. Compared with mothers who had three or more babies in the last 5 years before the study, mothers who had only one birth had a 96% lower likelihood of experiencing U5M. At the same time, mothers have an 80% lower chance of U5M if they had two births in the last 5 years. Finally, in 2006 and 2013, the birth order had no significance.

Model 2 investigated the mother's region and the type of location (urban/rural) to child health. In Namibia, the mother's location (urban versus rural) was significantly ( $p=0.04$ ) linked to U5M rates. First, according to the 2013 model, mothers who reside in cities are 32% less likely to experience U5M than mothers who live in villages. Second, according to the 2006 model, mothers from the Khomas, Oshana, and Oshikoto regions have a lower risk of U5M than mothers from the Caprivi region (Zambezi Region). In addition, according to the 2013 model, mothers from the Hardap, Omusati, and Oshana regions were 50% less likely to experience U5M ( $p=0.05$ ) than mothers from the Zambezi region. Furthermore, with a  $p$ -value of 0.038, mothers in the Otjozondjupa region have a 58% lower risk of U5M.

Socio-economic inequalities between the Zambezi and Otjozondjupa, Hardap, Omusati, Oshana, Khomas, and Oshikoto regions could explain the observed differences in the risk of U5M rate. The Zambezi region is among the least developed in the country, with a low literacy rate. Seasonal flooding and high teenage pregnancies are also common in the region (Maemeko *et al.* 2018). Furthermore, a considerable proportion of the population in the Zambezi region has no access to protected water sources (26.8%) and improved toilet facilities (73.5%) (National Planning Commission 2011). In addition, the Zambezi region has one of the lowest poverty inequality indexes in the world (0.493) (Knoema 2011) and an HIV/AIDS prevalence rate of 237 per 1,000 people (MOHSS *et al.* 2014). The region's high-risk ratio of U5M is attributable to the interplay of factors mentioned above. Therefore, improving access to safe water sources and sanitation is necessary to reduce the risk factors of U5M in the Zambezi region.

Furthermore, the odds of children aged 5 and under 5 in homes show that every one-child increase in the household reduces the likelihood of U5M roughly by 64 and 61% in 2006 and 2013, respectively. Furthermore, the odds of under-five death increases with every one-member increase in the household by 14 and 13% in 2006 and 2013, respectively.

The result of the last column of the 2013 model demonstrate that HIV-positive mothers experience a 2.3 times higher probability of U5M than HIV-negative mothers. After adding HIV to the model, a mother's education is no longer significant, and

**Table 4** | Estimation results (implied odds ratio)

Variables	Odds ratios	p-value	Odds ratio	p-value	Odds ratio	p-value
Source of drinking water						
Unprotected	0.80	0.318	0.70	0.160	0.82	0.544
Protected	R		R			
Toilet facilities						
Improved	R		R		R	
Not improved	0.84	0.453	1.65**	0.041	1.63	0.118
Mother's education						
No education	0.92	0.856	4.40*	0.058	2.53	0.268
Primary	1.78	0.166	4.36**	0.049	2.65	0.208
Secondary	1.29	0.523	3.56*	0.082	2.19	0.295
Higher	R		R			
Mother's age (years)						
Less than 20	R		R		R	
20–29	0.79	0.428	0.55*	0.098	0.56	0.266
30–39	0.90	0.769	0.57	0.154	0.56	0.315
40–49	1.45	0.339	0.84	0.692	0.82	0.757
Marital status						
Never in union	R		R		R	
Married	0.97	0.860	0.84	0.452	0.76	0.363
Living with partner	1.10	0.594	1.34	0.134	1.19	0.494
Widowed	1.75	0.133	2.46	0.118	2.06	0.290
Divorced	1.43	0.654	0.87	0.851	0.89	0.888
No longer living together/separated	1.46	0.293	0.81	0.644	0.72	0.567
Child gender						
Male	1.41***	0.009	1.13	0.429	1.28	0.196
Female	R		R		R	
Breastfeeding						
Yes	R		R		R	
Not	5.24***	0.000	3.74***	0.000	2.58***	0.001
Number of births in the last 5 years						
1 birth	0.04***	0.000	0.04***	0.000	0.03***	0.000
2 births	0.14***	0.000	0.17***	0.000	0.15***	0.000
3–4 births	R		R		R	
Wealth						
Rich	0.49**	0.021	1.61*	0.093	1.69	0.150
Middle	0.97	0.884	1.10	0.652	0.98	0.941
Poor	R		R		R	
Birth order						
1st birth	1.16	0.474	0.94	0.806	0.78	0.460
2nd birth	1.28	0.188	0.89	0.581	0.82	0.472
3rd birth or above	R		R		R	

*(Continued.)*

Table 4 | Continued

Variables	Odds ratios	p-value	Odds ratio	p-value	Odds ratio	p-value
Place of residence						
Caprivi	R		R		R	
Erongo	0.65	0.234	0.70	0.368	0.83	0.708
Hardap	0.80	0.557	0.48*	0.088	0.37*	0.093
Karas	0.73	0.427	0.60	0.199	0.67	0.403
Kavango	0.91	0.762	0.78	0.468	0.80	0.590
Khomas	0.37***	0.005	0.54	0.135	0.81	0.669
Kunene	0.54	0.127	0.75	0.405	1.16	0.745
Ohangwena	0.60	0.089	0.81	0.531	0.45*	0.081
Omaheke	0.53	0.131	0.62	0.209	0.33*	0.068
Omusati	0.63	0.144	0.51*	0.099	0.35**	0.040
Oshana	0.48**	0.023	0.47*	0.097	0.41	0.120
Oshikoto	0.52**	0.037	0.66	0.256	1.12	0.787
Otjozondjupa	0.61	0.151	0.42**	0.038	0.54	0.238
Type of location						
Urban	1.07	0.697	0.68**	0.049	0.65*	0.090
Rural	R		R		R	
Number of children 5 and under in household	0.36***	0.000	0.39***	0.000	0.35***	0.000
Number of a household member	1.14***	0.000	1.13***	0.000	1.18***	0.000
Recent HIV test result						
Yes					2.30***	0.001
No					R	
Constant	0.53	0.376	0.18*	0.075	0.35	0.357
Year						
2006			2013		2013	
Number of observations	4,816		4,768		2,873	
Log-likelihood	-904.43		-720.80		-435.57	

R refers to the reference group.

Source: Author's Computation.

\*Denotes the estimate is significant at 10%.

\*\*Denotes the estimate is significant at 5%.

\*\*\*Denotes the estimate is significant at 1%.

there is no evidence of the impact of a mother's educational level on child health. However, other variables such as breastfeeding, number of children in the last 5 years, number of under-fives, and members in the household remained significant.

## CONCLUSION AND RECOMMENDATION

In summary, there is a need for health programmes that target health determinants connected to child health and survival in Namibia. As revealed by both models, increased access to improved toilet facilities is a crucial determinant of child survival in Namibia. In particular, to Namibia, access to safe drinking water has no impact on children's health. The Namibian government's efforts in enhancing access to safe water sources are praiseworthy, as the findings of this study illustrate. Generally, access to safe water is significant to child health. To accomplish the SDG's target of reducing under five-related death rates, the government must address health inequalities among the different regions in Namibia. Furthermore, we recommend strengthening health promotion and education programmes on breastfeeding, a suitable child spacing pattern, maternal age, and mother's education. Finally, HIV-positive, multiparous, adolescent, and older mothers should be encouraged to regularly seek health advice during the gestational and neonatal period to reduce the risk of under-five child mortality.

## ACKNOWLEDGEMENT

The authors express their gratitude to the MOHSS in Namibia for this study's demographic and health data.

## AUTHORS' CONTRIBUTIONS

M.A. conceptualized the idea, constructed the work's methodology and data analysis. The introduction, discussion, and conclusion of this paper were the work of A.A. and N.H. To finalize the manuscript, all authors contributed to the final manuscript's editing and revision. All authors read and approved the current version of the work.

## CONFLICTS OF INTEREST

The authors state that they have no conflicts of interest. This work received no financial support from any institution.

## DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

## REFERENCES

- Abir, T., Agho, K. E., Page, A. N., Milton, A. H. & Dibley, M. J. 2015 Risk factors for under-5 mortality: evidence from Bangladesh demographic and health survey, 2004–2011. *BMJ Open* 5 (8), 1–9. <https://doi.org/10.1136/bmjopen-2014-006722>.
- Abou-ali, H. 2003 The effect of water and sanitation on child mortality in Egypt. Rapport Nr.: Working Papers in Economics, 113 (46).
- Amugsi, D. A., Dimbuene, Z. T., Bakibinga, P., Kimani-Murage, E. W., Haregu, T. N. & Mberu, B. 2016 Dietary diversity, socioeconomic status and maternal body mass index (BMI): quantile regression analysis of nationally representative data from Ghana, Namibia and Sao Tome and Principe. *BMJ Open* 6 (9), e012615. <https://doi.org/10.1136/bmjopen-2016-012615>.
- Bado, A. R. & Susuman, A. S. 2016 Women's education and health inequalities in under-five mortality in selected Sub-Saharan African countries, 1990–2015. *PLoS ONE* 11 (7), 1–18. <https://doi.org/10.1371/journal.pone.0159186>.
- Boco, A. G. 2010 *Individual and Community Level Effects on Child Mortality: An Analysis of 28 Demographic and Health Surveys in Sub-Saharan Africa DHS Working Papers*. Calverton, Maryland, USA.
- Brault, M. A., Mwinga, K., Kipp, A. M., Kennedy, S. B., Maimbolwa, M., Moyo, P., Kenneth, N., Connie, A. H. & Vermund, S. H. 2020 Measuring child survival for the Millennium Development Goals in Africa: what have we learned and what more is needed to evaluate the Sustainable Development Goals? *Global Health Action* 13 (1), 1732668. <https://doi.org/10.1080/16549716.2020.1732668>.
- Defo, B. K. 1993 *Regional and Socioeconomic Differentials in Infant and Childhood Mortality in Cameroon*. Center for Demography and Ecology. University of Wisconsin, Madison.
- Fink, G., Günther, I. & Hill, K. 2011 The effect of water and sanitation on child health: evidence from the demographic and health surveys 1986–2007. *International Journal of Epidemiology* 40 (5), 1196–1204. <https://doi.org/10.1093/ije/dyr102>.
- Gunther, I., Fink, G. & Bank, T. W. 2010 *Water, Sanitation and Children's Health: Evidence from 172 DHS Surveys*. Policy Research Working Paper Series No. 5275. Available from: <http://econpapers.repec.org/RePEc:wbk:wbrwps:5275>.
- Headey, D. & Palloni, G. 2019 Water, sanitation, and child health: evidence from subnational panel data in 59 countries. *Demography* 56 (2), 729–752. <https://doi.org/10.1007/s13524-019-00760-y>.
- Kanmiki, E. W., Bawah, A. A., Agorinya, I., Achana, F. S., Awoonor-Williams, J. K., Oduro, A. R., Phillips, J. F. & Akazili, J. 2014 Socio-economic and demographic determinants of under-five mortality in rural northern Ghana. *BMC International Health and Human Rights* 14 (1), 1–10. <https://doi.org/10.1186/1472-698X-14-24>.
- Kayode, G. A., Ansah, E., Agyepong, I. A., Amoakoh-coleman, M., Grobbee, D. E. & Klipstein-grobusch, K. 2015 Individual and community determinants of neonatal mortality in Ghana: a multilevel analysis. *BMC Pregnancy and Childbirth* 14 (1), 1–12.
- Kgabi, N., Mashauri, D. & Hamatui, N. 2014 Utilisation of water purification 'tablets' at household level in Namibia and Tanzania. *Open Journal of Applied Sciences* 04 (14), 560–566. <https://doi.org/10.4236/ojapps.2014.414055>.
- Kibria, G. M. A., Burrowes, V., Choudhury, A., Sharmeen, A., Ghosh, S., Mahmud, A. & Angela, K. C. 2018 Determinants of early neonatal mortality in Afghanistan: an analysis of the Demographic and Health Survey 2015. *Globalization and Health* 14 (1), 1–12. <https://doi.org/10.1186/s12992-018-0363-8>.
- Knoema 2011 Zambezi. Available from: <https://knoema.com/atlas/Namibia/Zambezi>.
- Maemeko, E. L., Nkengbeza, D. & Chokomosi, T. M. 2018 The impact of teenage pregnancy on academic performance of grade 7 learners at a school in the Zambezi region. *Open Journal of Social Sciences* 06 (09), 88–100. <https://doi.org/10.4236/jss.2018.69006>.
- MOHSS, ICF International, & Namibia Statistics Agency 2014 *The Namibia Demographic and Health Survey 2013*. Available from: <https://dhsprogram.com/pubs/pdf/FR298/FR298.pdf>.
- Mosley, H. & Chen, L. C. 1984 An analytical framework for the study of child survival in developing countries. *Population and Development Review* 10 (1984), 25–45.
- National Planning Commission. 2011 *Namibia 2011 Population and Housing Census*. Available from: [https://www.ecb.org.na/images/docs/Investor\\_Portal/2011\\_Census\\_Report.pdf](https://www.ecb.org.na/images/docs/Investor_Portal/2011_Census_Report.pdf).

- Ndirangu, M. N., Gatimu, S. M., Mwinyi, H. M. & Kibiwott, D. C. 2018 Trends and factors associated with early initiation of breastfeeding in Namibia: analysis of the Demographic and Health Surveys 2000–2013. *BMC Pregnancy and Childbirth* **18** (1), 1–10. <https://doi.org/10.1186/s12884-018-1811-4>.
- O'Neill, A. 2021 *Infant Mortality Rate in Namibia 2019*. Available from: <https://www.statista.com/statistics/807052/infant-mortality-in-namibia/>.
- Owais, A., Faruque, A. S. G., Das, S. K., Ahmed, S., Rahman, S. & Stein, A. D. 2013 Maternal and antenatal risk factors for stillbirths and neonatal mortality in rural Bangladesh: a case-control study. *PLoS ONE* **8** (11), 1–8. <https://doi.org/10.1371/journal.pone.0080164>.
- Rayhan, M. I. & Khan, M. S. H. 2006 Factors causing malnutrition among under five children in Bangladesh. *Pakistan Journal of Nutrition* **5** (6), 558–562. <https://doi.org/10.3923/pjn.2006.558.562>.
- Rutstein, S. O. & Johnson, K. 2004 *The DHS Comparative Report: The DHS Wealth Index*. Available from: <https://dhsprogram.com/pubs/pdf/CR6/CR6.pdf>.
- UNAIDS 2021 *HIV and AIDS Estimates*. Available from: <https://www.unaids.org/en/regionscountries/countries/namibia> (accessed 20 August 2021).
- UNICEF 2015 The UN Inter-Agency Group for Child Mortality Estimation: Levels & Trends in Child Mortality. *Report 2015*.
- UNICEF 2020 *UN IGME Child Mortality Report 2020*. Available from: <https://www.unicef.org/media/60561/file/UN-IGME-child-mortality-report-2019.pdf>.
- United Nations 2017 *The Sustainable Development Goals Report*. United Nations Publications. <https://doi.org/10.18356/3405d09f-en>.
- US EPA 2011 *Exposure Factors Handbook: 2011 Edition*. US EPA, EPA/600/R-(September), 1–1466. <https://doi.org/EPA/600/R-090/052F>.
- WHO 2016 *Public Health and Environment*. Available from: <https://www.who.int/data/gho/data/themes/public-health-and-environment#:~:text=Mortality and burden of disease,to the environment is 23%25>.
- WHO 2021 *Resolution Adopted by the General Assembly on 25 September 2015*. Available from: <https://undocs.org/A/RES/70/1>.
- WHO and UNICEF 2020 *Water Supply, Sanitation and Hygiene Guidance Note to Facilitate for Drinking Water, Sanitation and Hygiene in Households*. Available from: <file:///C:/Users/aalfeus/Downloads/jmp-2020-households-country-consultation.pdf>.

First received 30 September 2021; accepted in revised form 15 December 2021. Available online 24 December 2021