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ORIGINAL ARTICLE

Socio-economic differentials of under-five mortality in Botswana: an application of the indirect estimation method

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Abstract

Background Socio-economic differentials in infant and under-five mortality exist in all countries worldwide, but the extent of differentials varies across countries. This study aimed to examine the socio-economic differentials of under-five mortality in Botswana within the framework of equality and equity.

Methods and findings The analysis for this paper was based on the data from 2001 and 2011 Botswana Population and Housing Censuses and the 2017 Botswana Demographic Survey. One census method was used to indirectly estimate under-five mortality for different socio-economic groups using Princeton west model life tables. Results from this study revealed that socio-economic disparities in under-five mortality disfavouring the worse-off exist in all the selected socio-economic variables. The variations of socio-economic groups by mother's place of residence and employment status have been narrowing over time, whereas the differences of socio-economic groups by mother's level of education and marital status have been widening over time.

Conclusions The findings of this study show that policies and interventions targeted at reducing inequalities should reach all socioeconomic groups across the country. Differences of each society and localities should be considered while designing and implementing policies and interventions.

Keywords Socio-economic · Differentials · Under-five · Mortality · Botswana

Introduction

The under-five mortality rate (U5MR), the probability of dying before 5 years of age (per 1000 live births), is a key global indicator of child health and one of the most important measures of global health. Unfortunately, due to inadequacy of vital registration systems, estimation of under-five mortality, which includes infant (less than one year) and childhood (between one year and 5 years), in most sub-Saharan countries still relies on indirect estimation procedures (Adedini and Odimegwu 2011). Reducing under-five mortality represents an important health predictor and societal goal at national and global levels. For instance, Sustainable Development Goal (SDG) 3 calls for an 'end to preventable deaths of new-born and children under-five' and further demands 'a reduction of under-5 mortality to less than 25 deaths per 1000 live births by 2030' (Statistics Botswana and UNFPA 2018). Botswana reported an under-five mortality rate of 48 deaths per 1000 live births in 2017 against 152 deaths per 1000 live births in 1971. This was an accomplishment. However, given the current country situation, the country stills lags behind reducing under-five mortality to less than 25 deaths per 1000 live births by 2030. Botswana, like other countries in sub-Saharan Africa, is committed to reducing under-five mortality rates in line with the SDG targets. As such, policymakers and healthcare service managers require accurate and complete data on the number and causes of child deaths to plan and monitor healthcare service delivery and health outcomes (Tables 1, 2, 3, 4, and 5).

Malderen et al. (2019) argues that socioeconomic inequalities in U5MR exist in all countries, but the socioeconomic dimensions may differ across countries. The SDG 5 (achieve gender equality and empower all women and girls) indicators track key elements of women's social, economic and political participation and guide the building of gender-equitable societies (Statistics Botswana and UNFPA 2018). Gender equality is essential to the achievement of

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Table 1 Sample of the study in the 2001 and 2011 PHC and BDS 2017

	2001 PHC sample	2011 PHC sample	2017 BDS Sample (not weighted)
Total no. of women aged 15–49 years	454,863	563,408	563,398
Total no. of children ever born to women aged 15–49 years	921,470	941,131	1,010,645
Total no. of children dead to women aged 15–49 years	67,607	68,939	40,539

Table 2 Estimates of infant and under-five mortality by mother's level of education

2001 PHC			2011 PHC			2017 BDS		
Primary or less	q(1)	q(5)		q(1)	q(5)		q(1)	q(5)
2000	76.6	105.8	2010	57.4	79.9	2014	32.9	46.2
1999	67.5	93.6	2009	66.6	92.4	2012	31.4	44.2
1997	59.9	83.3	2007	57.5	80.1	2009	47.8	66.8
1994	46.1	64.5	2005	50.0	69.9	2006	31.3	44.0
1992	38.1	53.5	2003	54.5	76.1	2004	53.3	74.3
1989	40.0	56.1	2000	55.3	77.0	2001	35.6	50.1
1986	47.1	65.9	1997	59.3	82.6			
Secondary								
2000	45.1	63.1	2009	39.1	54.9	2015	6.6	9.4
1999	45.7	64.0	2007	68.0	94.3	2013	18.0	25.5
1997	44.5	62.3	2005	63.9	88.7	2011	22.9	32.3
1994	30.8	43.4	2003	63.5	88.1	2008	25.3	35.7
1991	24.9	35.2	2001	58.5	81.4	2005	27.2	38.3
1988	24.7	34.8	1998	47.5	66.4	2002	14.5	20.6
1985	27.6	38.9	1996	42.5	59.5			
Tertiary or higher								
2000	31.7	44.6	2010	34.3	48.2	2014	8.0	12.3
1998	44.3	62.1	2009	48.4	67.6	2013	8.0	11.4
1997	38.4	53.9	2006	50.4	70.4	2011	5.0	7.1
1995	31.4	44.1	2003	49.5	69.2	2010	17.2	24.3
1993	27.4	38.7	2000	46.3	64.7	2007	9.1	13.0
1991	20.3	28.8	1997	38.9	54.6	2005	22.2	31.3
1988	34.2	48.0	1994	36.1	50.7	2003	17.2	24.4

better health. Girls' education is critically linked to self-determination, improved health, social and economic status, as well as positive outcomes for the mother and the child (John and Singh 2017). The WHO Commission on Social Determinants of Health called for closing the health gap in a generation in the year 2005. The Commission aimed to (1) improve daily living conditions by improving the well-being of girls and women and the circumstances in which their children are born, putting major emphasis on early child development and education for girls and boys, improving living and working conditions and create social protection policy supportive of all, and create conditions for a flourishing older life. Policies to achieve these goals were aimed at involving civil society, governments and global institutions; (2) tackle the inequitable distribution of power, money and resources and; (3) measure and understand the problem and assess the impact of action (WHO 2008). Consistent with the recommendations of WHO commission on Social Determinants of Health, developing countries such as Botswana need to explore if there is progress in reducing the gap of under-five mortality. Population-based surveys provide insights into the existence of differences by demographic and socioeconomic characteristics and a special section of equity; hence, this study employs the use of data from the Botswana Population and Housing Censuses and Demographic surveys.

Table 3 Estimates of infant and under-five mortality by mother's employment status

2001 PHC			2011 PHC			2017 BDS		
Employed	q(1)	q(5)		q(1)	q(5)		q(1)	q(5)
2000	39.0	54.7	2009	39.7	55.7	2013	15.2	21.5
1999	46.7	65.3	2007	61.5	85.5	2012	28.0	39.5
1997	47.4	66.2	2006	53.9	75.2	2010	21.8	30.8
1994	38.8	54.4	2004	49.2	68.8	2008	28.3	39.9
1992	35.6	50.0	2002	46.2	64.6	2006	33.2	46.6
1989	40.2	56.4	2000	42.9	60.1	2004	24.5	34.6
1986	49.4	69.1	1997	47.2	66.0			
Not employed								
2000	53.0	73.9	2010	58.6	81.6	2015	6.4	9.1
1999	55.2	76.9	2009	53.6	74.6	2013	15.3	21.7
1997	58.6	81.5	2007	52.8	73.6	2011	38.9	54.5
1994	51.8	72.4	2005	51.5	71.9	2008	28.1	39.6
1991	48.5	67.8	2002	51.7	72.2	2005	39.0	54.7
1988	53.2	74.2	1999	49.0	68.5	2002	28.8	40.6
1985	60.5	84.5	1996	47.6	66.6			

Table 4 Estimates of infant and under-five mortality by mother's marital status

2001 PHC			2011 PHC			2017 BDS		
Married	q(1)	q(5)		q(1)	q(5)		q(1)	q(5)
2000	9.9	14.0	2009	16.8	23.9	2013	24.1	34.0
1999	35.5	49.9	2007	42.3	59.2	2012	17.9	25.4
1997	37.6	52.8	2006	50.3	70.5	2011	16.5	23.4
1994	35.0	49.2	2004	47.1	65.9	2010	44.1	61.8
1992	34.7	48.8	2002	47.2	66.0	2008	24.1	34.1
1989	42.0	58.9	2000	44.1	61.8			
1986	49.8	69.5	1997	44.1	61.7			
Living together								
2000	52.0	72.5	2010	59.5	82.8	2015	11.1	15.8
1999	53.2	74.2	2009	56.7	79.0	2013	15.1	21.5
1997	56.5	78.7	2007	55.1	76.8	2011	25.8	36.4
1994	46.5	65.1	2005	55.4	77.2	2009	28.0	39.5
1991	43.2	60.5	2002	53.6	74.7	2006	25.0	36.4
1988	46.1	64.5	1999	50.5	70.6	2003	32.4	45.7
1985	55.8	77.7	1996	53.5	74.6			

Macassa et al. (2011) acknowledges that the social context plays an important role for inequalities in children's chances of survival. Thus, it is important to examine how different levels of socio-economic factors affect the level of under-five mortality and to understand the gap between socioeconomic groups. Previous studies that examined children under-five mortality in Botswana found that places of residence and the sex of a child were linked with under-five mortalities. A study by Majelantle (2014) addressed the levels and trends of infant and child mortality by places of residence only without going into other socio-economic differentials. The current study goes further to explore socio-economic differentials of under-five mortality in Botswana (sex, mother's level of education, mother's occupation, mother's marital status and mother's place of residence). The findings of this study will help policymakers to plan and monitor healthcare services and delivery outcomes based on empirical data.

Materials and methods

Study design, setting and sampling

The analysis for this paper is based on the data from the 2001 and 2011 Botswana Population and Housing

Table 5 Estimates of infant and under-five mortality by mother's place of residence

2001 PHC			2011 PHC			2017 BDS		
Cities and towns	q(1)	q(5)		q(1)	q(5)		q(1)	q(5)
2000	65.8	91.4	2010	62.1	86.3	2013	20.4	28.8
1999	52.8	73.6	2009	64.9	90.1	2012	27.5	38.8
1997	45.1	63.1	2007	52.6	73.4	2010	15.4	21.8
1994	34.5	48.5	2005	43.6	61.1	2008	26.1	36.8
1992	29.2	41.2	2003	38.2	53.6	2005	21.1	29.8
1989	34.2	48.1	2000	34.2	48.0			
1986	42.4	59.4	1997	34.5	48.6			
Urban villages								
2000	51.9	72.5	2010	63.6	88.4	2015	12.2	17.3
1999	53.4	74.5	2009	54.5	76.0	2013	20.2	28.5
1997	55.8	77.8	2007	48.6	67.9	2011	28.0	39.4
1994	47.5	66.4	2004	37.6	52.8	2008	31.2	44.0
1991	44.2	61.9	2001	43.9	61.4	2005	37.2	52.6
1988	48.8	68.3	1998	40.5	56.8	2002	26.6	37.5
1985	56.7	79.0	1995	38.5	54.0			
Rural areas								
2000	65.1	90.4	2010	61.1	84.9	2014	8.4	11.9
1998	67.2	93.2	2009	58.6	81.6	2013	28.1	39.7
1996	64.9	90.1	2006	59.1	82.3	2011	19.9	28.1
1994	60.4	84.0	2003	61.4	85.4	2010	30.8	43.3
1991	57.4	79.9	2000	57.6	80.2	2007	40.0	56.3
1988	63.4	88.1	1997	52.7	73.6	2005	26.3	37.2
1985	77.0	106.4	1994	51.1	71.4			

Censuses (PHC) and the 2017 Botswana Demographic Survey (BDS).

A population census in Botswana is carried out after every 10 years. The 2001 PHC is the fourth and the 2011 PHC is the fifth of the national censuses to be conducted in Botswana. The primary objective of the Population and Housing Census is to provide up-to-date information for policymakers, planners, researchers and programme managers that would allow guidance in the development, monitoring and evaluation of policies in Botswana. The data in the census contains a wealth of information on the socio-economic demographics of the population. The number of enumeration areas were 4165 in 2001 and 4861 in 2011. There were 2,038,228 persons enumerated in Botswana during the 2011 Population and Housing census, compared with 1,680,863 enumerated in 2001 (Statistics Botswana 2011). The persons were enumerated where they were found during the enumeration period. The specific questions asked on the censuses to derive the under-five mortality estimates were how many children have been born alive? And how many of the children have died?

The Botswana Demographic Survey 2017 is an intercensal survey held every 10 years with the main aim of updating the census figures. This is the fourth to have been conducted in Botswana. The survey involves collecting information on population or demographic characteristics and statistics on fertility and mortality. The sample for the Botswana Demographic Survey 2017 constituted and covered the entire population residing in non-institutional dwelling units. A stratified two stage probability sampling design was used. A totla of 478 enumeration areas were drawn from the 2011 census sampling frame in the first stage. One hundred and twenty-two enumeration areas were selected in cities & towns, 187 in urban villages and 169 in rural areas. In the second stage, a complete listing of households was carried out in all selected enumeration areas. Twenty households were then systematically selected for interviews from a listing of households in the selected EAs and there were 9560 households in the sample (Statistics Botswana 2017). The specific questions asked on the survey to derive the infant and child mortality estimates were how many children have been born alive? And how many of the children have died?

The sample of this study was restricted to women aged 15–49 years old in all three datasets.

Measurement of socio-economic variables

Population-based surveys provide insights into the existence of differences by demographic and socioeconomic characteristics of a population. A special section of equity; estimates of the socio-economic variables as identified in the frameworks were derived directly using the Statistical Package for the Social Sciences (SPSS) in the Botswana censuses and survey datasets. The variables were selected because they are the most important structural stratifiers or societal hierarchies. These variables include the following and are categorized into levels indicated below; Mothers' level of education (tertiary or higher education, secondary education & primary or less education); Mothers' employment status (employed & not employed); Mothers' marital status (married & living together, those who were single, separated and widowed were excluded because the aim was to understand the differential between two groups who lived as couples); Mothers' place of residence (cities and towns, urban villages & rural areas).

Method

This study uses indirect estimation because the method gives estimates of infant and under-five mortality up to the year preceding a census or survey. Also, because data on child mortality differentials in most developing countries are usually drawn from censuses or surveys. Death registration is unreliable in many developing countries (Botswana included), and even when reliable, death registration records include very little information on characteristics of decedents and their households (Bainame and Letamo 2014). Censuses and surveys can readily and inexpensively include retrospective questions on mortality of children of respondents which can be analysed in light of questions on individual and household characteristics that are included in surveys. The most widely available type of data on child mortality, therefore, is reports by mothers on the numbers of children ever born to them and children still surviving.

Indirect methods

Brass and Coale (1968) pioneered indirect methods of estimating child mortality, the method uses information on total numbers of children ever born and children still alive (or dead) reported by women classified by age group (or grouped by time since first birth or marital duration).

The information in the indirect method is described as a summary birth history (SBH). The amount of information collected varies, from just two questions (number of children ever born and number of children still alive) to the most detailed summary birth history asking separately about boys and girls and enquiring separately about surviving children living at home versus those living elsewhere. The proportion dead of children born to women by age (or alternatively by time since first birth, or duration of marriage) reflects the level of child mortality. Young mothers normally have young children, who have been exposed to the risk of death for short or recent periods; the proportion dead for such mothers thus reflects child mortality risks to an early age. On the contrary, older mothers have a mix of young and older children exposed to the risk of dying for longer periods on average further in the past. Through models of fertility and child mortality, the proportions dead are converted into probabilities of dying by exact ages of childhood, ${}_nq_0$. The older the women, the greater the value of n (Moultrie et al. 2013).

If mortality has changed over time, the estimated probabilities of dying reflect the mortality rates that have prevailed at a range of ages and dates. Fortunately, a 'time location' method has been developed that estimates how many years previously each proportion dead approximates period probabilities of dying. These intervals increase with the age of respondents. Therefore, if the probabilities of dying estimated from the reports of different age groups of women are integrated into a common index of mortality, these statistics will refer to different dates and can be used to infer the broad trend in mortality over time (Moultrie et al. 2013).

Data requirements and assumptions as explained by Moultrie et al. (2013)

Tabulations of data required for the indirect method

Number of women grouped by five-year age; number of children ever born alive by women by relevant five-year group; number of children dead before (or are still alive at) the time of the survey, by relevant five-year group; and number of births in the year before the survey by five-year age group (optional).

Assumptions of the study

Population age patterns of fertility and child mortality are adequately represented by the model patterns used in developing the method.

In any period, mortality of children does not vary by five-year grouping of mothers.

No relationship exists between mortality risks of children and survival of mothers (by mortality or migration) in the population.

Any changes in child mortality in the recent past have been gradual and unidirectional.

Cross-sectional average numbers of children ever born by age (or by duration of marriage or time since first birth) adequately reflect the appropriately defined cohort patterns of childbearing (Moultrie et al. 2013).

Ward and Zaba (2008) concluded that estimates derived from reports of women aged 25–29 concerning their children ever born and surviving will not be greatly affected by even a generalized HIV epidemic.

Data analysis

One census method was used to indirectly estimate under-five mortality in Botswana using Princeton west model life tables. Estimates of infant and under-five mortality in Botswana using the Brass variant, age of the mothers, were calculated by the Child Mortality (CM) Indirect spreadsheet developed by Moultrie et al. (2013). Data on number and mean of children ever born, children surviving (or dead) grouped by age group of mothers were derived from the Botswana 2001 and 2011 PHC and BDS 2017 using SPSS version 22. The means were used to derive the estimates of infant and under-five mortality for each age group of mothers estimated to a reference time t(x). Summary tables in appendix 1–4 showing estimated IMR and U5MR by age group of mothers estimated to a reference time t(x) were presented for the datasets. The estimates for both females and males were also presented on the tables. Graphs were generated that show trend-lines in the general direction and levels of infant and under-five mortality that each socio-economic factor produces in all three datasets.

Trend in socio-economic differentials have been analysed for the period given below:

- 1987–1999 estimates based on the 2001 PHC
- 2000–2007 estimates based on the 2011 PHC
- 2008–2013 estimates based on the 2017 BDS

Results

Sex differentials of under-five mortality in Botswana

The study observed that important differences exist between boys and girls with respect to survival of under-fives. Figure 1 shows that the sex ratio of male to female mortality of under-fives is greater than 100 from the year 1988 to the year 2009. From the year 2009 the sex ratio increased from less than 100 to higher levels in 2013, thus the sex ratios of under-five mortality have been widening in the recent past. Improvements in obstetric practices and neonatal care may have been the main factors in the fall of excess male infant mortality.

Socio-economic differentials of infant and under-five mortality in Botswana

Under-five mortality differential by level of education

The results below in Fig. 2 indicate that the level of under-five mortality is lower among mothers who had tertiary

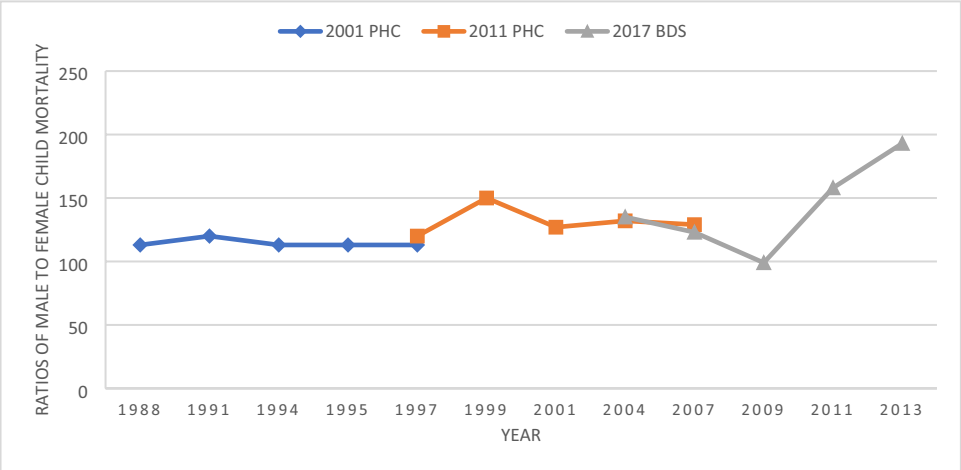

Fig. 1 Trend in sex ratios (M/F) of under-five mortality over time

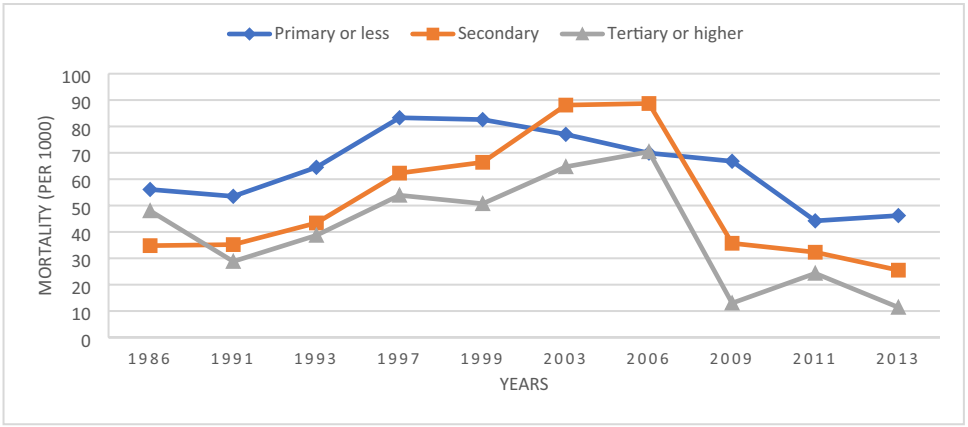

Fig. 2 Trend of under-five mortality by mother's level of education

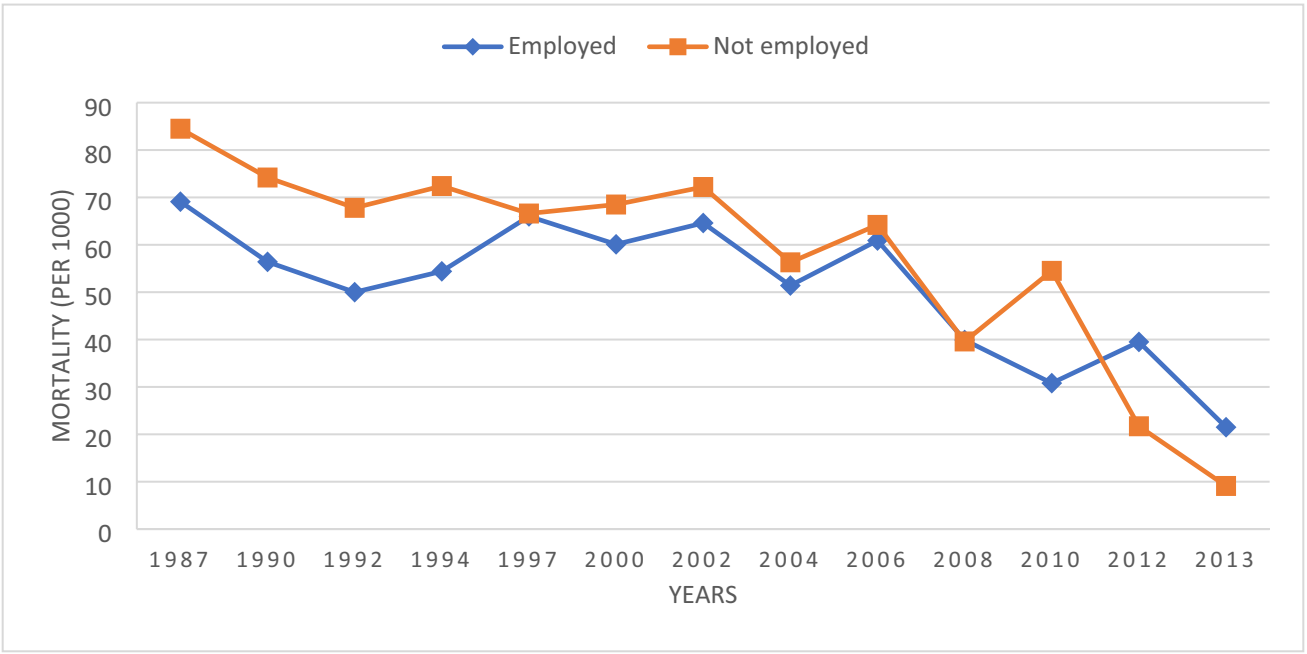

Fig. 3 Trend of under-five mortality by mother's employment status over time

education compared to those who had primary or less and secondary education from 1991 to 2013. The level of under-five mortality is higher among mothers who had primary education between 1986 and 2000 and 2008 to 2011 compared to those who had secondary and tertiary education. From 2002 to 2007, the level of under-five mortality was higher among mothers with secondary education compared to those who had primary or less and tertiary education. Mothers who had secondary and tertiary education then experienced a rapid decrease of under-five mortality rate from 2006 to 2009. The level of under-five mortality decreased from high rates in 1986 to lower rates in 2013 and the differentials had widened in the recent past.

Under-five mortality differential by mother's employment status

Figure 3 depicts the trend of under-five mortality by mother's employment status over time. The graphs show that the level of under-five mortality was higher among unemployed mothers compared to those who were employed between 1987 and 2010 and was lower

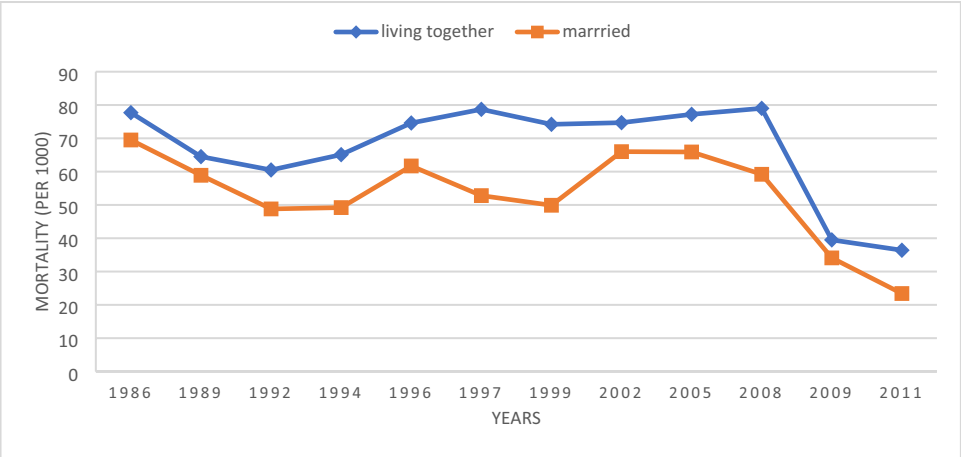

Fig. 4 Trend of under-five mortality by marital status over time

among unemployed mothers than those who were employed from 2011 to 2013. The higher mortality of under-fives if mothers work could be that employment for women is in addition to their traditionally ascribed roles, hence they reduce the availability of their time and increase the inability to provide personal and timely care for their children. Recommendations are that gender roles and gender relations should be renegotiated to better help infants. The results also show that under-five mortality among employed and not employed mothers declined from higher levels in 1987 to lower level in 2013. The gap of under-five mortality between employed and unemployed women narrowed over time.

Under-five mortality differential by mother's marital status

Under-five mortality rates for married and the living together mothers decreased from higher levels in 1986 to lower levels in the year 2011 (Fig. 4). Under-five mortality for the married and the living together mothers showed a sudden decline from the year 2008 to 2011. The ratio of under-five mortality among mothers living together to married mothers was low between 1986 and 1989, and then it widened between 1990 and 2008, and narrowed further from 2008–2009 before widening again from 2009 up to 2011.

Under-five mortality differential by mother's place of residence

Figure 5 below depicts the trends of under-five mortality by mother's place of residence. The graphs show that from 1986 to 2013, the level of under-five mortality was higher among mothers living in rural areas compared to those who lived in cities and towns and urban villages. Mothers who lived in urban villages experienced the second highest level of under-five mortality from 1986 to 2003. In the year 2007, there was a peak of under-five mortality for mothers residing in

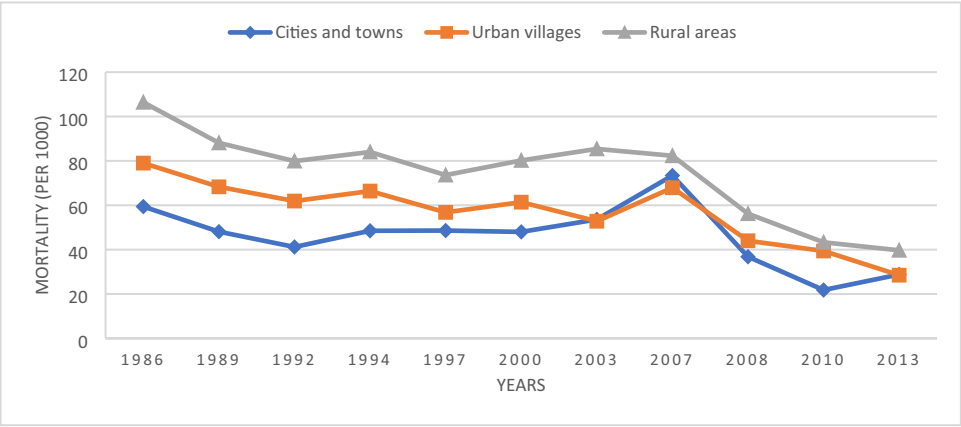

Fig. 5 Trend of under-five mortality by mother's place of residence

urban villages and cities and towns, with mothers who resided in cities and towns experiencing the second highest level of mortality after those who resided in rural areas. The level of under-five mortality decreased from higher levels in the year 1986 to lower levels in the year 2013 for all the mothers residing in the listed places of residence and the differential seems to be narrowing over time.

Discussion

Our study found that under-five mortality was higher among male under-fives than females from the year 1988 up to 2013. This is consistent with previous findings which link sex differences in under-five mortality to sex differences in genetic and biological make up, with boys being biologically weaker and more susceptible to diseases and premature death (Thurstans et al. 2022). The biological advantage that women have is taken as a certainty, because the mortality of males is higher than that of females from the very outset of life: during the first year of life, in the absence of any outside influence which could differentiate mortality between the sexes, male mortality is greater than female mortality (Majelantle 2014; Pongou 2013). More generally, the genetic difference between the sexes is associated with a better resistance to biological aging. Female hormones and the role of women in reproduction have been linked to greater longevity (Johnson and Lachance 2012). The sex ratios of under-five mortality seem to be increasing in the recent past. In this context, it is difficult to explain the widening sex differential because the health inequalities are related to biological variations and the external environment and conditions mainly outside the control of the individual's concerns.

One of the socioeconomic variables found to be linked to under-five mortality is the mother's education level, with mothers with high education level experiencing low under-five mortality compared to those with low education level. This is consistent with some studies which show that mothers with higher education experience low infant and child mortality than those with lower education (Yaya et al. 2018; Wegbom et al. 2019). Maternal education offers mothers more connections with resources for infant health and an awareness of healthy behaviors (including exercise and not smoking). It can also refine the skills needed to access and effectively use the health care system. Providing a basic education, especially to girls, will be very important to building on the gains of the recent past. Education also helps build the kind of behaviours and habits that have a positive impact on an individual's health.

Findings indicate that under-five mortality was higher among mothers who were unemployed compared to those who were employed. Mothers who are dissatisfied with their employment status enjoy their children less, are less confident as parents, and have more difficulty controlling their children (Teng et al. 2018). Factors such as stress, economic hardship and lack of social support could have been important in accounting for increased risks of infant and child mortality among unemployed mothers. The WHO (2010) framework explains that it is the conversion of money and assets into health enhancing commodities and services via expenditure that may be a more relevant concept for interpreting how income affects health. Being unemployed may decrease economic access to antibiotics and other drugs from private venders, where an employed mother would often have a better access in addition to improved housing and better nutrition since access to antibiotics plays a significant role in the survival of newborns. However, these benefits of women's employment are likely to depend critically on the type of employment in which women are engaged. Malderen et al. (2019) and Chao et al. (2018) prove that parental income has been negatively associated with inequalities in child mortality in most sub-Saharan countries and low-income and middle-income countries.

The infant and child mortality gap has been narrowing over time perhaps because of the social assistance programmes that help the vulnerable groups. Botswana has ten main state-run social assistance programmes and one of these programmes is the Vulnerable Groups Feeding Programme. The programme provides take-home food rations via clinics to all children aged 6–60 months, with ration packages designed separately for 6–18, 19–36 and 37–60 month age groups with the aim of reducing hunger and malnutrition (Regional Hunger and Vulnerability Programme 2011). Botswana also has an immunization programme where vaccines are provided free of charge to all children through the public sector at health posts throughout the country.

The results of this study show that mothers who are cohabiting experience higher under-five mortality compared to married mothers. Cohabitation causes more negative communication (Cohan and Kleinbaum 2002), it brings more conflicts between partners (Thomson and Collela 1992), it brings about more physical violence (Brownridge and Halli 2000)

and higher rates of infidelity for female partners (Forste and Tanfer 1996). All these cohabitation effects between partners can lead to an emotional strain which often can lead to neglect of infants and children. The gap in under-five mortality among married and cohabitating women seem to be widening consistently over time and this could be that Botswana still does not recognize the cohabitation union.

We found that mothers living in rural areas experienced higher under-five mortality compared to those living in urban villages and cities and towns. Evidence from Yaya et al. (2019) show that child mortality is generally higher in rural areas than in urban areas in today's middle- and low-income countries. Izugbara (2014) argues that cities and towns tend to have lower mortality rates than rural areas, possibly because people residing in rural areas are less educated than their urban counterparts and the distribution of amenities favours the urban areas. In addition, a shortage of drinkable water in the rural areas and absence of health-care services by members of the community could also increase risks of infant and child mortality in such localities.

The health gap has narrowed in the recent past with respect to the mother's place of residence. Reasons may be that, by 2006, 90% of the rural and 100% of the urban population, respectively, had access to a safe water supply, while only 30% and 60% had improved toilet facilities and sanitation, respectively (Ministry of Health 2011). In Botswana, 95% of the total population (89% of the rural population) lives within eight kilometers of a health facility (CSO 2007). The public sector is the prominent provider of health care services in Botswana, with more than 80% of people receiving care from public facilities and programmes (CSO 2006). Availability and access to drinkable water within the community could be a leading factor to prevent children from contracting water-borne diseases and avoidable infections. As an upper middle-income country, Botswana has made significant achievements towards universal health access for women and children. Most of the population (85%) lives within a 5 km radius of a health facility and most pregnant women (73%) access antenatal care services at least four times (WHO 2015). In addition, almost 100% of births occur in health facilities (WHO 2015). Furthermore, child welfare clinic attendance is estimated at 85%. This proves the CSDH framework by acknowledging the health system itself as a social determinant of health (SDH).

The nationally representative data gives us a whole general picture, but interventions should consider the differences of each society and localities while designing and implementing interventions. This study had strengths that are worth mentioning. This was the first study to our knowledge that examined the socio-economic differentials of under-five mortality in Botswana using indirect estimation methods, and it therefore provides novel information for policy and programme intervention. Meanwhile, this study has the following limitations. Several studies have investigated the impact of HIV on indirect estimates of child mortality. Moultrie et al. (2013) argued that HIV will affect the accuracy of indirect estimates not only because of the relationship between mortality of children and that of their mothers but also because of the effects of HIV on age patterns of child mortality, and its implications for approaches that infer fertility patterns from observed parity ratios. In addition, they also explained that child mortality risks can also no longer be assumed to be independent of the age of the mother. However, in one respect, indirect estimates may be less affected by selection for maternal survival than direct estimates because the analysis is carried out by age group. Mothers under the age of 25 are unlikely to have died from HIV/AIDS; therefore, reports of child survival based on age groups 15–19 and 20–24, and even 25–29, may be a little biased by HIV (Ward and Zaba 2008). However, it is the age groups 15–19 and 20–24 that are most biased by other selection effects, so this may not be a huge help. Estimates based on women aged less than 20 are also likely to be very seriously biased because of differential infant mortality by age of mother at birth (Feeney 1980).

Conclusion

Results from this study show that some socio-economic differentials in under-five mortality have been narrowing overtime from the year 1988 to 2013. We have found socio-economic differentials still exist in Botswana but narrowed over time with respect to mother's place of residence and mother's employment status. As a result, an improvement in socio-economic status of women would lead to a decrease in infant and under-five mortality. Strengthening maternal and child health (MCH) programmes, specifically in rural areas and improving health care services would help to ensure overall child survival and expanding programmes in immunization should pay attention to all the above-mentioned socioeconomic factors of under-five mortality along with the preventive and curative healthcare interventions.

Appendices

Appendix 1

Table 6 Estimates of infant and under-five mortality by mother's level of education

2001 PHC			2011 PHC			2017 BDS		
Primary or less	q(1)	q(5)		q(1)	q(5)		q(1)	q(5)
2000	76.6	105.8	2010	57.4	79.9	2014	32.9	46.2
1999	67.5	93.6	2009	66.6	92.4	2012	31.4	44.2
1997	59.9	83.3	2007	57.5	80.1	2009	47.8	66.8
1994	46.1	64.5	2005	50.0	69.9	2006	31.3	44.0
1992	38.1	53.5	2003	54.5	76.1	2004	53.3	74.3
1989	40.0	56.1	2000	55.3	77.0	2001	35.6	50.1
1986	47.1	65.9	1997	59.3	82.6			
Secondary								
2000	45.1	63.1	2009	39.1	54.9	2015	6.6	9.4
1999	45.7	64.0	2007	68.0	94.3	2013	18.0	25.5
1997	44.5	62.3	2005	63.9	88.7	2011	22.9	32.3
1994	30.8	43.4	2003	63.5	88.1	2008	25.3	35.7
1991	24.9	35.2	2001	58.5	81.4	2005	27.2	38.3
1988	24.7	34.8	1998	47.5	66.4	2002	14.5	20.6
1985	27.6	38.9	1996	42.5	59.5			
Tertiary or higher								
2000	31.7	44.6	2010	34.3	48.2	2014	8.0	12.3
1998	44.3	62.1	2009	48.4	67.6	2013	8.0	11.4
1997	38.4	53.9	2006	50.4	70.4	2011	5.0	7.1
1995	31.4	44.1	2003	49.5	69.2	2010	17.2	24.3
1993	27.4	38.7	2000	46.3	64.7	2007	9.1	13.0
1991	20.3	28.8	1997	38.9	54.6	2005	22.2	31.3
1988	34.2	48.0	1994	36.1	50.7	2003	17.2	24.4

Appendix 2

Table 7 Estimates of infant and under-five mortality by mother's employment status

2001 PHC			2011 PHC			2017 BDS		
Employed	q(1)	q(5)		q(1)	q(5)		q(1)	q(5)
2000	39.0	54.7	2009	39.7	55.7	2013	15.2	21.5
1999	46.7	65.3	2007	61.5	85.5	2012	28.0	39.5
1997	47.4	66.2	2006	53.9	75.2	2010	21.8	30.8
1994	38.8	54.4	2004	49.2	68.8	2008	28.3	39.9
1992	35.6	50.0	2002	46.2	64.6	2006	33.2	46.6
1989	40.2	56.4	2000	42.9	60.1	2004	24.5	34.6
1986	49.4	69.1	1997	47.2	66.0			
Not employed								
2000	53.0	73.9	2010	58.6	81.6	2015	6.4	9.1
1999	55.2	76.9	2009	53.6	74.6	2013	15.3	21.7
1997	58.6	81.5	2007	52.8	73.6	2011	38.9	54.5
1994	51.8	72.4	2005	51.5	71.9	2008	28.1	39.6
1991	48.5	67.8	2002	51.7	72.2	2005	39.0	54.7
1988	53.2	74.2	1999	49.0	68.5	2002	28.8	40.6
1985	60.5	84.5	1996	47.6	66.6			

Appendix 3

Table 8 Estimates of infant and under-five mortality by mother's marital status

2001 PHC			2011 PHC			2017 BDS		
Married	q(1)	q(5)		q(1)	q(5)		q(1)	q(5)
2000	9.9	14.0	2009	16.8	23.9	2013	24.1	34.0
1999	35.5	49.9	2007	42.3	59.2	2012	17.9	25.4
1997	37.6	52.8	2006	50.3	70.5	2011	16.5	23.4
1994	35.0	49.2	2004	47.1	65.9	2010	44.1	61.8
1992	34.7	48.8	2002	47.2	66.0	2008	24.1	34.1
1989	42.0	58.9	2000	44.1	61.8			
1986	49.8	69.5	1997	44.1	61.7			
Living together								
2000	52.0	72.5	2010	59.5	82.8	2015	11.1	15.8
1999	53.2	74.2	2009	56.7	79.0	2013	15.1	21.5
1997	56.5	78.7	2007	55.1	76.8	2011	25.8	36.4
1994	46.5	65.1	2005	55.4	77.2	2009	28.0	39.5
1991	43.2	60.5	2002	53.6	74.7	2006	25.0	36.4
1988	46.1	64.5	1999	50.5	70.6	2003	32.4	45.7
1985	55.8	77.7	1996	53.5	74.6			

Appendix 4

Table 9 Estimates of infant and under-five mortality by mother's places of residence

2001 PHC			2011 PHC			2017 BDS		
Cities and towns	q(1)	q(5)		q(1)	q(5)		q(1)	q(5)
2000	65.8	91.4	2010	62.1	86.3	2013	20.4	28.8
1999	52.8	73.6	2009	64.9	90.1	2012	27.5	38.8
1997	45.1	63.1	2007	52.6	73.4	2010	15.4	21.8
1994	34.5	48.5	2005	43.6	61.1	2008	26.1	36.8
1992	29.2	41.2	2003	38.2	53.6	2005	21.1	29.8
1989	34.2	48.1	2000	34.2	48.0			
1986	42.4	59.4	1997	34.5	48.6			
Urban villages								
2000	51.9	72.5	2010	63.6	88.4	2015	12.2	17.3
1999	53.4	74.5	2009	54.5	76.0	2013	20.2	28.5
1997	55.8	77.8	2007	48.6	67.9	2011	28.0	39.4
1994	47.5	66.4	2004	37.6	52.8	2008	31.2	44.0
1991	44.2	61.9	2001	43.9	61.4	2005	37.2	52.6
1988	48.8	68.3	1998	40.5	56.8	2002	26.6	37.5
1985	56.7	79.0	1995	38.5	54.0			
Rural areas								
2000	65.1	90.4	2010	61.1	84.9	2014	8.4	11.9
1998	67.2	93.2	2009	58.6	81.6	2013	28.1	39.7
1996	64.9	90.1	2006	59.1	82.3	2011	19.9	28.1
1994	60.4	84.0	2003	61.4	85.4	2010	30.8	43.3
1991	57.4	79.9	2000	57.6	80.2	2007	40.0	56.3
1988	63.4	88.1	1997	52.7	73.6	2005	26.3	37.2
1985	77.0	106.4	1994	51.1	71.4			

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Declarations

Ethical considerations This paper is based on the analysis of secondary data. All ethical issues were addressed at the time of data collection during the survey and censuses by Statistics Botswana.

Conflict of interest The authors declare that they have no conflict of interest.

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