The influence of maternal HIV status on mortality in children under the age of five years

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ABSTRACT

Child mortality can be used to measure the level of social development as well as the health status of children (Hill 1991). By world regions, sub-Saharan Africa maintains the highest rates of under-five mortality. Current under-five mortality is estimated at 76 deaths per 1,000 live births (Hug, Sharrow, Zhong *et al.* 2018). In Zambia, under-five mortality reached a peak of 197 in 1996 and is currently estimated at 60 (Hug, Sharrow, Zhong *et al.* 2018).

On the world health agenda, reducing child mortality has been made a priority, especially for low income countries that remain the most affected. Among the targets of the Sustainable Development Goals (SDGs) is reduction of neonatal mortality to at least 12 deaths per 1,000 live births and under-five mortality to 25 deaths by 2030 (United Nations 2015). HIV/AIDS is one of the leading causes of mortality in Zambia and has contributed to the slow decline of under-five mortality (Garenne and Gakusi 2006). Children under the age of five years get infected with HIV mainly through vertical transmission (Fishel, Ren, Barrère *et al.* 2014). In the absence of treatment, vertical transmission of HIV is high and can range between 15 and 45 per cent, reducing below 5 per cent with effective interventions (Barral, Oliveira, Lobato *et al.* 2014).

Despite vertical transmission being the main pathway through which children get infected with HIV, little research has been done to determine the significance of maternal HIV status on under-five mortality in Zambia. The aim of the study was, therefore, to determine the extent to which mortality of children with HIV-positive mothers differs from that of children with HIV-negative mothers. The Zambia Demographic and Health Survey (ZDHS) data for 2007 and 2014 which contain HIV serotesting data were used. Survival analysis using Poisson regression was used to model the influence of maternal HIV status taking into account confounding factors.

The results of the study indicate that maternal HIV status was significantly associated with child mortality in both survey periods but by 2013/14 the influence of maternal HIV status had reduced and was insignificant for children born within one year of the 2013/14 survey. The reduction in the risk of dying between the inter-survey period may be as a result of increased coverage of prevention of mother-to-child transmission (PMTCT) and antiretroviral therapy (ART) services over the years. In order to reach universal coverage, there is need for increased provision of PMTCT and ART treatments and support for HIV strategies such as the 90 90 90 target.

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AIDS	Acquired Immunodeficiency Syndrome
AIM	AIDS Impact Model
ART	Antiretroviral Therapy
ARVs	Antiretroviral Drugs
CBH	Central Board of Health
CHER	Children with HIV Early Antiretroviral Therapy
CMC	Century Month Code
CSO	Central Statistical Office
DHS	Demographic and Health Survey
HIV	Human Immunodeficiency Virus
IRRs	Incidence Rate Ratios
MDGs	Millennium Development Goals
MOH	Ministry of Health
PMTCT	Prevention of Mother-to-Child Transmission
SAP	Structural Adjustment Programme
SDGs	Sustainable Development Goals
SEAs	Standard Enumeration Areas
STI	Sexually Transmitted Infection
TDRCZ	Tropical Diseases Research Centre
UNAIDS	Joint United Nations Programme on HIV/AIDS
UNICEF	United Nations Children's Fund
UNZA	The University of Zambia
VIF	Variance Inflation Factor
WHO	World Health Organisation
ZDHS	Zambia Demographic and Health Survey

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1 INTRODUCTION

1.1 Background

Child mortality can be used to measure the level of social development as well as the health status of children (Hill 1991). By world regions, sub-Saharan Africa maintains the highest rates of under-five mortality. Current under-five mortality is estimated at 76 deaths per 1,000 live births (Hug, Sharrow, Zhong *et al.* 2018). In Zambia, under-five mortality reached a peak of 197 in 1996 and thereafter started decreasing, reaching 168 in 2002, 119 in 2007 and 75 by 2014 (CSO, MOH, UNZA Teaching Hospital Virology Laboratory *et al.* 2015).

On the world health agenda, reducing child mortality has been made a priority, especially for low income countries that remain the most affected. In 2000, countries signed the Millennium Development Goals (MDGs) whose target, among others, was to reduce under-five mortality by two-thirds by 2015, which Zambia failed to achieve (ECA, AU, AfDB *et al.* 2015). In 2015, countries further agreed to the Sustainable Development Goals (SDGs). Among the targets is to reduce neonatal mortality to at least 12 deaths per 1,000 live births and under-five mortality to lower than 25 deaths per 1,000 live births by the year 2030 (United Nations 2015). With under-five mortality currently estimated at 60, it remains to be seen if Zambia will achieve the SDG target by 2030 (Hug, Sharrow, Zhong *et al.* 2018).

HIV/AIDS is one of the leading causes of mortality in Zambia and has contributed to the slow decline of under-five mortality (Garenne and Gakusi 2006). It is estimated that about 751,000 children aged 0-14 years died from HIV/AIDS-related illnesses between 2000 and 2017 (UNAIDS 2019). Children under the age of five years get infected with HIV mainly through vertical transmission either during pregnancy, at birth or post-pregnancy through breastfeeding (Fishel, Ren, Barrère *et al.* 2014). In the absence of treatment such as ART during and after pregnancy, vertical transmission of HIV is high and can range between 15 and 45 per cent, reducing below 5 per cent when effective interventions are used (Barral, Oliveira, Lobato *et al.* 2014).

Differences in mortality have been noted between children with HIV-positive mothers and those with HIV-negative mothers. This study is aimed at determining the influence of maternal HIV status on child survival taking into account confounders namely, demographic, socioeconomic and environmental factors. It has been established

that these factors influence child survival (Boerma and Weir 2005; Mosley and Chen 1984).

1.2 Objectives of the study

The primary objective of this research is to examine the relationship between maternal HIV status and mortality in children below the age of 36 months. Specifically, the research aims to determine the extent to which mortality of children with HIV-positive mothers differs from that of children with HIV-negative mothers.

Since the research takes a multivariate approach, the secondary objective of the study is to identify non-HIV determinants of childhood mortality. Specifically, the research examines the impact of demographic, socioeconomic and environmental factors on mortality in children below the age of 36 months.

1.3 Statement of the problem and justification of the study

Under-five mortality still remains high in Zambia and is likely to remain so in the near future. Even though significant improvement has been made in the coverage of ART among infected children and PMTCT almost universal, HIV remains an important contributor to under-five mortality. Currently, only about 79 per cent of the 62,000 children aged 0-14 years living with HIV are on ART (UNAIDS 2019).

Despite vertical transmission being the main pathway through which children get infected with HIV, little research has been done to verify the statistical significance of the association between maternal HIV status and under-five mortality in Zambia. The pattern of research on determinants of under-five mortality has focused mainly on demographic and socioeconomic factors, for example, research by Macwan'gi and Phiri (2008), Madise, Banda and Benaya (2003) and Mulenga, Daka, Mulenga *et al.* (2017). Though in their studies both Madise, Banda and Benaya, and Mulenga, Daka, Mulenga *et al.* acknowledge the possible impact of HIV/AIDS on under-five mortality, no HIV-related factors such as maternal HIV status were considered among the analysed determinants of mortality in children under the age of five. This is probably due to lack of HIV data in the case of Madise, Banda and Benaya since they used ZDHS data for 1991 and 1996 while Mulenga, Daka, Mulenga *et al.* concentrated on demographic, socioeconomic and behavioural factors only despite the 2014 ZDHS containing HIV test data. There is, therefore, need for further research to determine the influence of

maternal HIV-positive status on mortality in children, taking into account confounding factors.

Results of such an analysis could be used as empirical evidence required for policy planning and evaluation of the effectiveness of HIV/AIDS care intervention programmes, and health care programmes in general that pertain to child health (Hug, Sharrow, Zhong *et al.* 2018). The study will also add to the existing literature on HIV/AIDS and mortality in children in Zambia.

2 LITERATURE REVIEW

This chapter summarises the literature on HIV/AIDS and other factors that influence under-five mortality. It starts with an analysis of trends in under-five mortality in Zambia and the contribution of HIV/AIDS. This is followed by a review of the literature on the influence of HIV, demographic, socioeconomic and environmental factors on under-five mortality. Lastly, an analyses of the conceptual framework for factors that affect the risk of HIV infection and health outcome (mortality) is conducted.

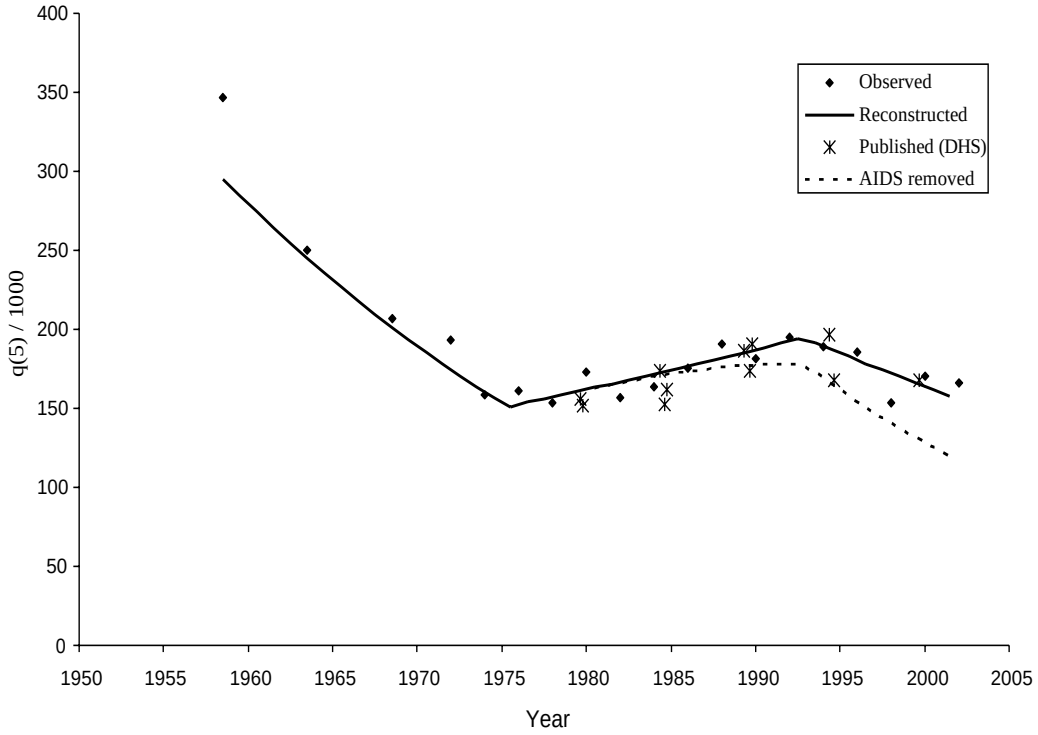
2.1 Trends in under-five mortality in Zambia and the effect of HIV/AIDS

In the past 50 years, Zambia has experienced periods of increase and decrease in under-five mortality. In a reconstruction of trends, Garenne and Gakusi (2006) estimate that in 1960 under-five mortality was 301 per 1,000 live births and was decreasing at a rate of 6.1 per cent per year reaching a low of about 150 in 1975. Thereafter, under-five mortality started increasing at a rate of 1.8 per cent per year reaching 192 in 1993. Bicego and Ahmad (1996), using the ZDHS for 1992, also found similar trends in under-five mortality. They estimated that 10-14 years before the survey, under-five mortality was 151.9, increasing to 162.2 deaths 5-9 years before the survey and 191.2 at the time of the survey. By 1996, under-five mortality reached a peak of 197 and then started decreasing, reaching 168 in 2002 and 119 by 2007 (CSO, CBH and ORC Macro 2003; CSO and Macro International 1997; CSO, MOH, TDRCZ *et al.* 2009). By 2014, under-five mortality had further reduced to 75 (CSO, MOH, UNZA Teaching Hospital Virology Laboratory *et al.* 2015). Current estimates by the UN Inter-Agency Group for Child Mortality Estimation indicate that under-five mortality has further reduced to 60 (Hug, Sharrow, Zhong *et al.* 2018).

The increase in under-five mortality between the 1970s and 1990s is attributed to changes in national income and the negative effects of AIDS. In the 1970s, the country experienced an economic recession which negatively affected per capita income leading to poor nutrition and inadequate provision of health services (Garenne and Gakusi 2006). In 1991, Zambia undertook a structural adjustment programme (SAPs) which significantly reduced government expenditure on health, which in turn affected the provision of health care services, leading to an increase in case fatalities in health facilities (Garenne and Gakusi 2006; Simms, Milimo and Bloom 1998). In the early 1990s, HIV/AIDS became one of the leading causes of mortality among children.

Garenne and Gakusi estimate that in the absence of HIV/AIDS, under-five mortality in Zambia would have started declining around 1990. Figure 2.1 shows how the trend in under-five mortality would have been without AIDS. If it was not for the negative effect of HIV/AIDS, under-five mortality would have been lower and declining at a faster rate since 1990 thus, the observed steeper slope of mortality with AIDS removed.

Figure 2.1 Reconstructed trends in under-five mortality, Zambia 1958-2001



Source: Derived from Garenne and Gakusi (2006)

Despite reduction in per capita income in the 1990s, Garenne and Gakusi attribute the decline in under-five mortality experienced since the mid-1990s to positive cumulative effects of educational efforts during the 1960s and 1970s and changes in the health system. Changes that occurred in the health system include: increase in the number of health personnel; decentralization of management leading to efficient delivery of health care; increase in coverage of immunisation and; availability of medicine which countered nutrition deficiency among children (Garenne and Gakusi 2006).

After the year 2000, Zambia initiated HIV/AIDS prevention programmes such as PMTCT and ART (Fagan and Zeng 2015). These efforts resulted in a decrease in AIDS-related mortality in children under the age of 14 years from a peak of 14,681 deaths in 2003 to 7,282 in 2009 (Mulenga, Witola, Buyu *et al.* 2009). Table 2.1 shows estimates of HIV infections and deaths in Zambia between 1990 and 2018 among children aged 0-14

years. The number of children aged 0-14 years living with HIV increased from about 18,000 in 1990 to 77,000 in 2010, but decreased to about 62,000 by 2018. There was an increase in the number of HIV-exposed but uninfected children from about 26,000 in 1990 to 560,000 in 2018. Over the same period, the number of new HIV infections reduced from about 9,700 in 1990 to 5,400 in 2018. The introduction of PMTCT services led to an increase in the number of averted HIV infections from about 7,400 in 2010 to 8,800 in 2018. HIV-related deaths also decreased from about 12,000 in 2000 to 3,000 in 2018.

Table 2.1 Estimated infections, averted infections and deaths among children aged 0-14 years in Zambia

Coverage	1990	2000	2010	2018
Living with HIV	18,000	74,000	77,000	62,000
HIV-exposed but uninfected	26,000	260,000	470,000	560,000
New HIV infections	9,700	18,000	8,800	5,400
New infections averted due to PMTCT			7,400	8,800
AIDS-related deaths	4,700	12,000	5,900	3,000

Source: Derived from UNAIDS (2019)

Table 2.2 Estimated percentage coverage of pregnant women and children receiving ART in Zambia

Year	Coverage	
	Pregnant women receiving ART for PMTCT	Children 0-14 years receiving ART
2010	71	31
2011	75	37
2012	80	46
2013	86	54
2014	92	63
2015	95+	76
2016	95+	76
2017	95+	71
2018	95+	79

Source: Derived from UNAIDS (2019)

Table 2.2 shows ART coverage among pregnant women and children aged 0-14 years between 2010 and 2018. Coverage of ART among pregnant women increased from about 71 per cent in 2010 to 92 per cent in 2014, and has been more than 95 per cent since 2015. Coverage of ART among children aged 0-14 years has also increased from about 31 per cent in 2010 to 79 per cent in 2018.

2.2 Review of the literature on the influence of HIV, demographic, socioeconomic and environmental factors on under-five mortality

This section reviews the literature on the influence of HIV, demographic, socioeconomic and environmental factors on under-five mortality. The section first reviews the literature on the transmission of HIV and its impact on health outcomes in children under the age of five years as well as the influence of ART on increased chances of survival among people infected with HIV. Thereafter, a review of the literature on demographic, socioeconomic and environmental factors is presented.

2.2.1 Transmission of HIV from mother to child

As alluded to earlier, children acquire HIV mainly through vertical transmission in utero, at birth, or after birth through breastfeeding (Fishel, Ren, Barrère *et al.* 2014). The rate of vertical transmission is associated with the timing of infection. Where ART or medical interventions are not used, vertical transmission generally ranges from 15 to 45 per cent, with 15 to 20 per cent resulting from breastfeeding alone, while when effective interventions are used, the infection rate can reduce to as low as 5 per cent (Newell, Brahmbhatt and Ghys 2004; WHO 2019). Using information of women giving birth at a local hospital who were tested for HIV, Hira, Kamanga, Bhat *et al.* (1989) found that prenatal transmission was 39 per cent. Other studies have found that the risk of infection among children increases as the mother's CD4-cell count decreases. Coovadia, Rollins, Bland *et al.* (2007) found that the risk of being infected with HIV among children with mothers whose CD4-cell count was below 200 was 3.9 times more compared to children whose mother's CD4-cell count was above 500. Women with advanced AIDS have also been found to have a higher chance of pregnancy loss and perinatal mortality which also increases the risk of vertical transmission of HIV (Kim, Kasonde, Mwiya *et al.* 2012).

Thus, as part of PMTCT during and after pregnancy, WHO recommends that all HIV positive women are put on lifelong treatment called Option B+ irrespective of CD4-cell count (Avert 2019). In addition to this, since vertical transmission of HIV after birth is mainly through breastfeeding, WHO recommends that children be exclusively breastfed during their first 6 months of life, and thereafter given other foods alongside breastfeeding up to the age of 2 years (WHO 2017). This is because exclusive breastfeeding is associated with lower vertical transmission of HIV, with the effects observed in older ages. Iliff, Piwoz, Tavengwa *et al.* (2005) found that the risk of vertical transmission among children aged 6 months who were introduced to solid foods or

animal milk (mixed breastfeeding) before the age of 3 months was about 4 times more compared to children who were exclusively breastfed. They also found that the chances of vertical transmission among children aged 12 months who were both breastfed and given other foods before the age of 3 months were 3.8 times more compared to those who were exclusively breastfed. At the age of 18 months the differences in the chances of vertical transmission persisted but reduced to 2.6.

Using data of an intervention cohort study of uninfected and infected women who received antenatal care in KwaZulu Natal, Coovadia, Rollins, Bland *et al.* (2007) also found that the risk of vertical transmission and percentage of children who were given both breastmilk and solid foods was higher compared to infants who were given breastmilk only. They further established that the likelihood of vertical transmission among infants who were both breastfed and given solid foods any time after birth was 10.9 times more compared to children who were exclusively breastfed. They also found that at 14 weeks of age, children who were breastfed and at the same time given formula milk were 1.8 times more likely to be infected by their mothers compared to exclusively breastfed infants. They further found that by the age of 6 weeks, about 14 per cent of infants that were exclusively breastfed became infected, increasing to about 20 per cent by the age of 6 months.

2.2.2 Mortality among HIV positive and negative children

It has been established that children who are infected with HIV have a higher risk of mortality than children who are not infected. Using data from seven randomized intervention trials of vertical transmission in sub-Saharan Africa, Newell, Coovadia, Cortina-Borja *et al.* (2004) observed that infected children were 8.16 times more likely to die than uninfected children. Using Cox proportional hazards regression models, Munthali, Jacobs, Sitali *et al.* (2015) investigated factors associated with morbidity and mortality in under-five children admitted in hospital for severe acute malnutrition. They found that HIV-infected children were 80 per cent more likely to die than those who were not infected. It has been established that the risk of dying among HIV-positive children increases as viral load increases. In a study by Brahmbhatt, Kigozi, Wabwire-Mangen *et al.* (2006) in Rakai, a rural district in Uganda, it was found that the likelihood of dying among children with viral load between 4.13-4.83 copies/mL was 1.32 times more than children with viral load below 4.13 copies/mL. The risk of dying increased to 5.65 and 8.54 among children with viral load between 4.83-5.65 and above 5.65, respectively.

Marinda, Humphrey, Iliff *et al.* (2007) attempted to compare differences in mortality between HIV-positive and -negative infants born to mothers who were positive. They found that among infants who had become infected, 62.6 per cent of them died by the age of 2 years compared to 9.2 per cent among uninfected infants. This study seem to validate one of the older studies conducted during what can be considered as the early years of the HIV/AIDS epidemic which estimated 2-year mortality of infected children at 44 per cent (Hira, Kamanga, Bhat *et al.* 1989).

Marinda, Humphrey, Iliff *et al.* went further to look at the survival of children from time of infection to death and established that children who got infected early had a shorter survival period compared to those who got infected later. Mortality at 2 years of age was 67.5 per cent among children who were infected during pregnancy, 65.1 per cent for those infected during birth, and 33.2 per cent among those infected after birth. They further established that on average children who were infected during pregnancy died within 208 days of being infected while those who were infected during birth died within 380 days. More than half of those who got infected after birth were still alive at the end of the study follow-up at 731 days.

2.2.3 Child mortality experience among HIV positive and negative mothers

Regardless of the HIV status of children, it has been established that mortality among children with HIV-positive mothers is higher than among those with HIV-negative mothers. In Rakai, Brahmbhatt, Kigozi, Wabwire-Mangen *et al.* (2006) found that the risk of dying for children born to HIV positive mothers was 2.04 times more compared to those born to HIV negative mothers. If the child was also HIV-positive, the risk of dying increased to 3.78. Using data collected from a rural population South-West of Uganda, Nakiyingi, Bracher, Whitworth *et al.* (2003) found similar results to that of the study by Brahmbhatt, Kigozi, Wabwire-Mangen *et al.*. The study used data for a cohort of about 10,000 women followed between 1989 and 2000. They established that the likelihood of dying among children born to mothers who were infected with HIV was 3.16 times more than those whose mothers were not infected. Nakiyingi, Bracher, Whitworth *et al.* further found that infant mortality rate for children born to HIV-positive mothers was 225 per 1,000 live births compared to 53 for children born to HIV-negative mothers. Child mortality was found to be 313 for children born to mothers who were infected and 114 for children born to mothers who were not infected. Using pooled data from three longitudinal studies in Uganda, Tanzania and Malawi and classifying births by HIV status of the mother, Zaba, Whitworth, Marston *et*

al. (2005) also found that the risk of dying for children born to HIV-positive mothers was 2.89 times more compared to children born to HIV-negative mothers.

Some studies have analysed the risk of mortality by age among children born to HIV-positive and HIV-negative mothers. Using data from the Karonga demographic surveillance area for children born between 2006 and 2011, Chihana, Price, Floyd *et al.* (2015) classified children by age and fit a Poisson model accounting for water source, sex, marital age and maternal age. They established that the likelihood of dying among neonatal children[1] born to HIV-infected mothers was 1.5 times more compared to mothers who were not infected. The risk of dying for post-neonatal children[2] born to mothers who were infected was 11.5 times more compared to children born to mothers who were not infected. It was further established that among children aged 1-4 years, the risk of dying was 4.6 times more among children born to infected mothers compared to those born to uninfected mothers. In another study, Marinda, Humphrey, Iliff *et al.* (2007) found that by the age of 2 years, 23.3 per cent of children born to mothers who were HIV-positive had died while only 2.9 per cent children had died among HIV-negative mothers.

Before the Demographic and Health Survey (DHS) started collecting HIV biomarker data, most studies conducted in developing countries depended on cohort, longitudinal, and clinical data to examine the association between mortality in children and maternal HIV status or HIV in general. These have extensively been reviewed above. One of the earliest, perhaps the first, analyses of the relationship between maternal HIV and child mortality using nationally representative sample data was conducted by Fishel, Ren, Barrère *et al.* (2014) using the Demographic and Health Survey data for 13 countries in sub-Saharan Africa and one from Latin America. They first calculated neonatal, post-neonatal, infant[3], child[4] and under-five[5] mortality rates separately for children whose mothers tested positive for HIV and for those whose mothers tested negative. They then calculated the relative risk of mortality as a ratio of mortality rates for children whose mothers tested positive against those whose mothers tested negative.

[1] Children aged between 0-28 days
[2] Children aged between 29-364 days of age
[3] Children aged less than 1 year
[4] Children aged between 1-5 years
[5] Children aged below 5 years

For most countries analysed, the relative risk of mortality at every stage of childhood was greater than one, implying that children whose mothers were HIV-positive had a higher risk of mortality than children whose mothers were HIV-negative. The analysis for Zambia revealed that at neonatal stage, the risk of dying among children whose mothers tested positive was 2.13 times more than those whose mothers tested negative. At post-neonatal stage, the relative risk of mortality was 2.45 times more for children with mothers who tested positive than those whose mothers tested negative. In infancy, the relative risk of mortality was 2.29 while for the child stage it was 2.46 compared to children with HIV-negative mothers. At under-five level, children with HIV-positive mothers were 2.27 times more likely to die than those with HIV-negative mothers.

Several other studies using DHS data have found similar results. Using the AIDS Indicator Surveys for 2003, 2007 and 2011, Arunda, Choudhry, Ekman *et al.* (2016) found that maternal HIV-positive status was associated with under-five mortality in Tanzania. In 2003, the odds that children whose mothers were infected with HIV would die was 1.5 times more than for those whose mothers were not infected. In 2007, the odds of dying among children whose mothers were infected was 4.6 times more than for those whose mothers were negative. By 2011, the odds of dying for children with HIV-positive mothers had reduced to 2.4. They attributed the increase in the risk of dying for children with HIV-positive mothers in 2007 to the increase in HIV prevalence and inadequate provision of ART and PMTCT treatment, and the observed decrease in 2011 to the provision of free ART rolled out in 2007. In Kenya, Opiyo and Sawhney (2014) found that risk of dying among children whose mothers tested positive for HIV was 2.5 times more than those whose mothers were negative.

2.2.4 Mortality among children whose mothers died from HIV/AIDS

HIV/AIDS has both a direct and indirect negative effect on child survival. As earlier established in the literature, HIV directly increases the risk of dying for infected children. The indirect negative effect of HIV on child survival is as a result of increased risk of dying for children whose mothers died - in high HIV prevalence settings, the likely cause of death of mothers would be AIDS. Since children are mostly taken care of by their mothers, their chances of survival decrease when their mothers die as a result of inadequate care. Zaba, Whitworth, Marston *et al.* (2005) observed that children whose mother died were more likely to die too within a two-year period following their mother's death. They further established that, regardless of whether their mothers were

HIV-positive or not, the risk of dying for children who lost their mother increased by more than three times relative to those whose mothers were still alive. Newell, Coovadia, Cortina-Borja *et al.* (2004) also observed that regardless of their HIV status, the risk of dying for children whose mothers had advanced AIDS or died was higher than for those whose mothers did not have advanced AIDS or were still alive.

2.2.5 The influence of ART on chances of survival among HIV infected people

It has been noted that the use of ART increases the CD4-cell count and inhibits HIV infection from advancing into AIDS, especially where treatment is commenced early (Bolton-Moore, Mubiana-Mbewe, Cantrell *et al.* 2007; Violari, Cotton, Gibb *et al.* 2008). Using data for a cohort of children collected in 18 health facilities in Lusaka, Bolton-Moore, Mubiana-Mbewe, Cantrell *et al.* found that the use of ART increased the CD4-cell percentage from 12.9 per cent at baseline (initiation) to 23.7 per cent after 6 months and between 27-28 per cent after 12 months. In their study, using data from the Children with HIV Early Antiretroviral Therapy (CHER) randomized trial in South Africa, Violari, Cotton, Gibb *et al.* (2008) found that progression to AIDS among children who were put on antiretroviral treatment early when they were around 7 weeks old decreased to as low as 6.3 per cent compared with 25.6 per cent among those who started medication late at an estimated median age of 21 weeks. Mortality also reduced to 4 per cent among infants who were put on ART early compared to 16 per cent for infants who were initiated late. Similar effects of ART on mortality were also observed by Bolton-Moore, Mubiana-Mbewe, Cantrell *et al.* They observed that mortality was high within the first 90 days of being put on ART as many of the children were already extremely ill at the time of initiation. However, mortality decreased thereafter. Overall for all children, the death rate was 17.4 deaths per 100 person-years in the first 90 days of being on ART, reducing to 2.9 after 90 days but within the observed period. They also found that mortality was higher among younger children compared to older ones. Among children aged below 18 months, mortality rate was 52.2 in the first 90 days of being put on ART, reducing to 7.3 thereafter. For children aged 60 months and above, mortality was 11.1 in the first 90 days of being on ART, reducing to 2.3 thereafter.

Generally, ART has been observed to have a positive effect on reducing morbidity, mortality, and HIV transmission as treatment reduces the viral load to as low as undetectable levels where infection cannot be passed on from one person to the other (Avert 2019; WHO 2016). However, for these benefits to be realized, not only are HIV infected people required to take effective antiretroviral drugs but must also be

initiated early and adhere to the treatment regimen (Williams, Lima and Gouws 2011). Thus, the WHO recommends commencement of ART among infected people (both children and adults) regardless of the severity of the HIV/AIDS disease or CD4 cell count (WHO 2015b). The WHO also recommends that children born to mothers who are infected with HIV be tested within 4 to 6 weeks after birth, and immediately be initiated on treatment if found HIV-positive (WHO 2015a). For the United States of America, the Department of Health and Human Services recommends that a virologic test be conducted at birth for children born to HIV-positive mothers who did not receive prenatal care or ARV drugs (AIDSinfor 2020).

Since the inception of ART, there has been significant improvement in survivorship among people infected with HIV, with further scale-up expected to yield greater health benefits (Forsythe, McGreevey, Whiteside *et al.* 2019). Using the Spectrum package containing the AIDS Impact Model (AIM), Forsythe, McGreevey, Whiteside *et al.* modelled the social and economic benefits of the global increase in ART coverage between 1995 and 2030. The study reveals that without ART, yearly global AIDS deaths would have reached a high of about 2.5 million by 2013 and thereafter remaining constant, hence representing an equilibrium between the number of AIDS deaths and new HIV infections post 2013. However, the scale-up and introduction of more effective treatment averted a high number of global AIDS deaths, with about 1.12 million annual deaths recorded in 2015, representing a considerable decrease compared to the no-ART scenario of 2.5 million deaths. The study further estimates that between 1995 and 2015, about 9.5 million AIDS deaths were averted by the introduction and scale-up of ART while further scale-up is expected to avert about 34.9 million deaths between 1995 and 2030. As the scale-up of ART continues, it is expected that the number of new HIV infections will also continue dropping, with an estimated 40.2 million infections to be averted between 1995 and 2030 (Forsythe, McGreevey, Whiteside *et al.* 2019).

Estimates by (UNAIDS 2020) also indicate decreases in global new HIV infections and AIDS-related deaths and increases in deaths averted due to increase in coverage of ART among people infected with HIV. It is estimated that cases of new annual HIV infections increased from about 1.9 million in 1990, reaching a peak of about 2.8 million people in 1999 before declining to about 1.7 million in 2019. The HIV/AIDS era prior to 2010 is characterized by low coverage of ART, with only about 7.8 million (25 per cent) HIV-infected people accessing treatment by the year 2010. It is

no surprise, therefore, that during this period, there was an increase in annual AIDS-related deaths from about 300,000 in 1990, reaching a peak of about 1.7 million in 2005, and then reducing to about 1.1 million by 2010. Post-2010, global ART coverage continued increasing with about 17.2 million (49 per cent) people on treatment in 2015 and 25.4 million (67 per cent) by 2019. The scale-up of ART beyond 50 per cent during this period ensured a sustained downward trend in annual AIDS-related deaths by very significant margins. It is estimated that about 830,000 AIDS-related deaths occurred in 2015, reducing to 690,000 by 2019. This period also saw the annual number of AIDS-related deaths averted due to ART increasing from about 960,000 in 2010 to 1.3 million in 2015 and 1.4 million by 2019 (UNAIDS 2020).

2.2.6 Demographic, socioeconomic and environmental determinants of childhood mortality

Since the study takes a multivariate approach to determining the influence of maternal HIV status on child mortality, it is also necessary to review the literature on the influence of demographic, socioeconomic and environmental factors. According to Mosley and Chen (1984), demographic and environmental factors such as age, maternal age, sex, birth interval, sanitation, water, flooring etc. are classified as proximate determinants and directly affect under-five mortality whereas socioeconomic factors such as marital status, education, place of residence and place of delivery etc. work through proximate determinants to affect mortality. Research has shown that these variables are significantly associated with under-five mortality.

Mortality in children under the age of five years has been found to differ by age: younger children are more likely to die than older children, with most deaths occurring in the neonatal stage. This is because babies are predisposed to infections as their immune system is not yet fully developed at that stage. Hug, Sharrow and You (2017) estimate that about 46 per cent of global under-five deaths occur during the neonatal period. In a cohort study of the survival of children among women with HIV in Uganda, it was observed that mortality declined rapidly with age, from infancy to the age of 3 years and older (Nakiyingi, Bracher, Whitworth *et al.* 2003). It was found that children aged one year were 0.54 times less likely to die compared to children under the age of one year.

Maternal age is associated with higher risk of child mortality at younger and older ages (Bicego and Ahmad 1996). In a study conducted in Zimbabwe, Kembo and Van Ginneken (2009) established that the risk of infant mortality among young mothers

aged less than 20 years and older mothers aged between 40-49 years was as high as 15 per cent more compared to mothers aged 30-39 years. They further established that in 1994, under-five mortality experience among mothers who were less than 20 years old was 34 per cent higher compared to children born to mothers who were between 30-39 years old. This reduced to 21 per cent in 1999. Among older women aged between 40-49 years, under-five mortality experience was even higher at 79 and 61 per cent in 1994 and 1999, respectively, relative to children born to mothers aged 30-39 years. Acheampong and Avorgbedor (2017) also made similar findings in Ghana and attributed the cause of high under-five mortality among young mothers to unequal health and economic experiences compared to older mothers. The study applied logistic regression and conducted a retrospective analysis of under-five mortality in Ghana using data from the Ghana Demographic and Health Surveys conducted between 1988-2014.

It has been found that children that are closely spaced are more likely to experience mortality (Bicego and Ahmad 1996). Hobcraft, McDonald and Rutstein (1983) observed that in most developing countries, excess mortality in children was as a result of premature and abrupt weaning due to frequent births. The direct competition between births results in reduced care and attention to the older child. Using the 1997 Household Survey data, Buwembo (2013) applied logistic regression in analysing factors associated with under-five mortality among children born within five years of the survey and found that children who were born within a short interval of less than 24 months were 2.2 more times likely to die before the age of five years compared to first births and those born after a 24 month interval. In the same study using the 2002 General Household survey and the same methodology, the risk of dying for closely spaced children was estimated at 1.9 compared to those born after an interval of 24 months. In contrast to these results, in Ghana, Acheampong and Avorgbedor found that the odds of dying increased as birth interval increased. However, the study acknowledged the unusual results which are contrary to the norm.

Another factor that influences mortality in children is sex of the child. Differences in survival rates between males and females have been attributed to the genetic pattern: males tend to have higher mortality at all ages of childhood than females (Sullivan, Rutstein and Bicego 1994). In a comparative study of infant and child mortality in developing countries using DHS data, Sullivan, Rutstein and Bicego observed that, on average, under-five mortality was 11 per cent higher among males than females. In South Africa, between 1993 and 1997 a boy child was 1.2 times more

likely to die compared to a girl child and the risk increased slightly to 1.3 between 1998 and 2002 although this only became significant after controlling for place of delivery (Buwembo 2013). In Malawi using DHS data for 2004 and 2010, it was found that male children aged 1-4 years were about 1.2 times more likely to experience mortality than female children in both periods (Lemani 2013).

Differences in child survival have been observed between married and unmarried mothers, with children of unmarried mothers experiencing higher mortality. It is argued that marriage offers a sense of security and social support for women which in turn yields better healthcare for children (Defo 1996). In Cameroon, children born to married women were 55 per cent less likely to die compared to children born to women who were unmarried (Defo 1996). Acheampong and Avorgbedor found that children under the age of five years whose mothers had never married before were twice more likely to experience mortality than those whose mothers were married.

Among the socioeconomic determinants of child mortality, maternal education has been singled out as the most significant (Caldwell 1979). Perhaps this is so because mother's education affects other determinants of child survival such as resource availability in the household (Gaigbe-Togbe 2015). According to Gaigbe-Togbe, children born to women with higher level of education are less likely to die because their mothers are more likely to acquire knowledge and practices such as good hygiene essential for child survival. He further argues that educated women are more likely to understand instructions given by health personnel on how to take care of a sick child or have better judgement about the health status of their children. In South Africa, between 1993 and 1997, the odds of a child dying before the age of five years was 1.9 times higher among mothers who did not complete matric level of education compared to mothers who had completed matric or higher education. The odds reduced to 1.6 between 1998 and 2002 (Buwembo 2013).

Coupled with prenatal care and medical assistance at birth, the chance of survival for children delivered at a health facility is higher than for those born elsewhere. This is because children delivered at a health facility receive correct health care from qualified health personnel during and after delivery (Rutstein 2000). In Ghana, Acheampong and Avorgbedor observed that children whose mothers did not receive any assistance at birth were 1.4 times more likely to die compared to those whose mothers received assistance from qualified personnel. In South Africa between 1993 and

1997 the odds of a child dying were 3.4 times higher for children who were born outside a hospital or clinic. This reduced to 1.7 in the period 1998-2002 (Buwembo 2013).

Area of residence has also been found to influence child survival. In most cases, area of residence is classified as either rural or urban though classifications are country dependent (Sullivan, Rutstein and Bicego 1994). Area of residence tends to influence access to health facilities, which gets more difficult the further away one resides. It is also associated with cost of transportation to a health facility, ability to pay for medical care and access to educational opportunities (Mahy 2003). In a study of under-five mortality experience in the developing world, Mahy established that the risk of dying for children who live in rural areas was about 61 per cent more than those who live in urban areas. In the same study, in Latin America, child mortality in rural areas was found to be almost twice higher than urban areas. Similar results were obtained elsewhere (Bicego and Ahmad 1996; Kembo and Van Ginneken 2009).

Mortality among children is also influenced by environmental factors. According to Mosley and Chen (1984), environmental factors have a direct impact on child mortality as they act both as source and pathway for infectious disease-causing agents. For instance, lack of clean drinking water and good sanitation is likely to cause diarrhoeal diseases. Diarrhoea is one of the major causes of mortality, contributing as high as 8 per cent of global under-five deaths (Hug, Sharrow and You 2017). Kembo and Van Ginneken established that the likelihood of dying among children who came from households that had piped drinking water was 39 per cent less compared to those from households that did not have piped drinking water. Kembo and Van Ginneken also established that children who came from households with improved toilet facilities were about 60 per cent less likely to die compared to those who came from households that did not have improved toilet facilities.

2.3 Summary of the literature review

HIV-positive children are more likely to die than children who are HIV-negative. Furthermore, regardless of their HIV status, children with infected mothers have a higher likelihood of dying than those whose mothers are not infected, with the risk increasing if the children are also HIV-positive. Children whose mothers died are also more likely to die following their mothers' death due to inadequate care - with the number increasing in high HIV prevalence settings. It is also noted that vertical transmission of HIV is high in the absence of ART and PMTCT treatment. Mothers

with a low CD4-cell count have a higher chance of infecting their children with HIV. Thus, ART plays a very important role in reducing the transmission of the virus, including vertical transmission, as well as increasing survivorship among HIV infected people by reducing the viral load to undetectable levels where infection cannot be passed on. Hence, greater health benefits are expected if all infected people were not only put on ART but also adhere to the treatment regimen.

Apart from HIV/AIDS, there are many other influences of mortality in children such as demographic, socio-economic and environmental factors. Demographic factors such as age and sex of child, age of mother, child spacing, and marital status influence childhood mortality. Among children, mortality has been found to decrease with age with the risk higher among male children than females. Younger mothers are more likely to experience death of their children than older mothers while closely spaced children have a higher risk of dying than children born at least 24 months apart, being the recommended minimum spacing. Children whose mothers are married are also more likely to survive compared to children whose mothers are not married. Among socioeconomic factors that influence childhood mortality include maternal education, place of baby delivery and area of residence. Mothers who are more educated are less likely to experience death of their children compared to mothers who are less educated or are not educated. The risk of mortality for children whose mothers delivered at a health facility is less than for children whose mothers delivered at home. It is also noted that children whose mothers live in rural areas are more likely to die than children whose mothers live in urban areas. Availability of water and toilet facility are some of the environmental factors associated with childhood mortality. It is noted that children whose mothers come from homes with piped water and an improved toilet facility are less likely to die than children whose mothers come from homes without piped water and an improved toilet facility.

While the literature reviewed in this chapter prove that HIV/AIDS contributes to childhood mortality, there is need for further analyses of the impact of HIV in the presence of other important factors that are associated with childhood mortality such as demographic, socioeconomic, and environmental factors. For this reason, the study combines both HIV and non-HIV factors that influence childhood mortality by analysing mortality experience between children whose mothers are HIV-positive and those whose mothers are HIV-negative in the presence of demographic, socioeconomic and environmental factors. The study by Fishel, Ren, Barrère *et al.* did not consider

such factors but instead calculated relative risk of mortality as a ratio of mortality rates for children whose mothers tested HIV-positive against those whose mothers tested negative. Other reviewed studies by Arunda, Choudhry, Ekman *et al.* and Opiyo and Sawhney used a multivariate approach but without comprehensive consideration of demographic, socioeconomic, and environmental variables. It is also noted that some of the literature reviewed used cohort, longitudinal, and clinical data to examine the influence of HIV on mortality in children. These studies were localised with limited sample size compared to representative survey data such as that collected by the DHS, which this study uses. Lastly, in the absence of data on the HIV status of children, this study uses maternal HIV status as it has a direct influence on a child's susceptibility of HIV infection through vertical transmission.

2.4 The proximate-determinants framework for the study of the distribution and determinants of HIV/AIDS in populations.

Boerma and Weir (2005) developed a conceptual framework that combines both demographic and epidemiological approaches for the study of the distribution and determinants of HIV infections. The framework is based on the proximate determinants conceptual frameworks for the study of fertility and child survival developed by Davis and Blake (1956) and Mosley and Chen (1984), respectively. According to Boerma and Weir, the framework can be used in the formulation of a study design, analysis and interpretation of risk factors that involve biological and behavioural data.

The framework identifies underlying factors that work through proximate and biological determinants to influence HIV infection and health outcomes. The underlying factors affect proximate determinants which in turn affect biological determinants that ultimately influence HIV infection, disease and mortality. The framework thus, provides an explanatory sequence of events from HIV exposure, transmission, infection, development of disease and ultimately death.

Boerma and Weir classify underlying determinants that influence HIV infection into two main types: contextual variables and interventions programmes. Contextual variables are classified as either demographic, socioeconomic or sociocultural while interventions are programmes such as counselling and testing, STI control, promotion of condom use, education for knowledge and changing attitudes, blood safety, safe injections and harm reductions. Changes in the underlying determinants affect the level of HIV infection and hence disease and mortality.

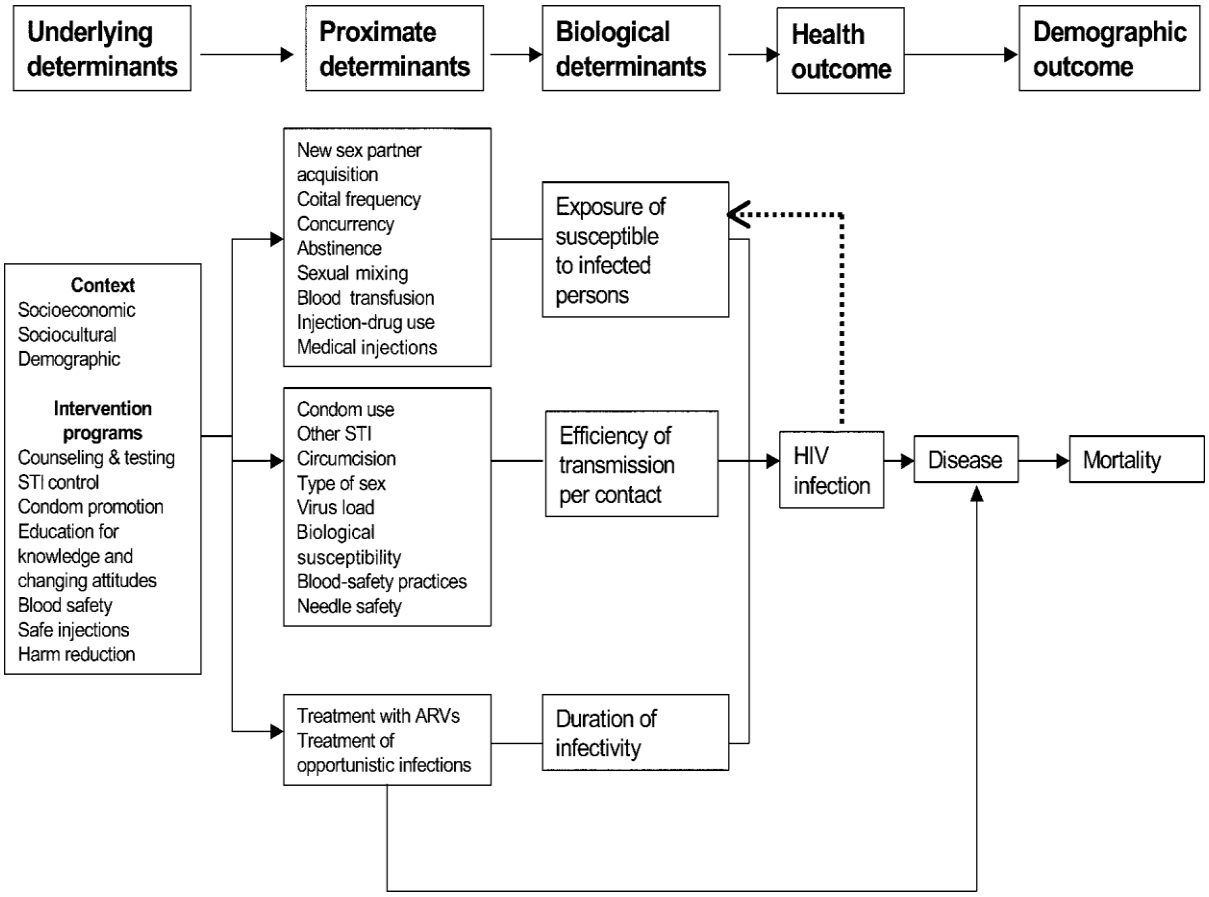
Proximate determinants, which have behavioural and biological components, are directly influenced by underlying determinants. They involve both physical barriers and practices that limit exposure to HIV infection such as acquisition of a new sex partner, coital frequency, abstinence, blood transfusion, use of condoms, use of gloves when handling infected blood, circumcision, type of sex, viral load, biological susceptibility and treatment with antiretroviral drugs (ARVs) etc. These factors in turn directly affect the biological determinants to influence HIV infection.

Biological determinants are those factors that influence the reproductive number of new HIV infection and prevalence leading to disease and premature death. Boerma and Weir define the reproduction number of new infections as the average number of secondary cases for every new case of infection. The reproductive number is determined by three biological factors namely, the rate of contact between an infected person and a susceptible person, efficiency of HIV transmission from the infected individual to the susceptible individual based on the period of infectivity and exposure time. If any of the three biological factors decreases, transmission of HIV also decreases. If any of the three factors is reduced to zero, HIV transmission also gets eliminated. Boerma and Weir identify the biological susceptibility of the exposed person and the amount of HIV in body fluids as key biological mechanisms that determine how efficient the transmission of HIV will be. The period of infection is influenced by the effectiveness and extent of coverage of HIV treatment. It is divided into three stages: the acute initial stage characterised by high viral load, the subsequent phase with reduced viral load and the final stage associated with an increase in the viral load again.

Even though Boerma and Weir provide a sequence of events from HIV exposure, transmission, infection, disease to death, their model does not directly include perinatal transmission of HIV. The model's primary focus of HIV infection is sexual transmission. However, they allude to the fact that HIV infection during the perinatal period depends on a number of factors like type of delivery, genetic susceptibility, viral load of the mother, and use of antiretroviral drugs. This validates the use of the model in studying mortality associated with HIV/AIDS in children regardless of timing of transmission since children get infected almost exclusively from the mother, both before and after birth. Therefore, in adopting this model, the risk of HIV infection and health outcomes in children are assumed to be influenced by both biological and proximate determinants. Hence, 'exposure of susceptible to infected persons' under biological determinants is regarded as child's exposure to an HIV infected mother during

pregnancy, delivery and after birth. 'Efficiency of transmission per contact' can be regarded as the rate at which vertical transmission occurs while 'duration of infectivity' is period from time of infection for both mother and child. On the other hand, 'treatment with ARVs' under proximate determinants is regarded as PMTCT and regular ART treatment given to the mother which influence a child's susceptibility to HIV infection. The efficiency of transmission of HIV from mother-to-child gets eliminated for a mother who is on ART treatment and whose viral load reduces to undetectable levels. A lack of ART and PMTCT treatments increases a child's susceptibility to acquiring HIV from an infected mother since her viral load will be high thereby increasing the 'efficiency of transmission per contact'. In addition, maternal HIV status can be classified as a proximate determinant which influences a child's exposure and susceptibility, efficiency of transmission and period of infectivity. For an HIV-negative mother, vertical transmission is nil hence, zero child exposure and susceptibility to HIV. For an HIV-positive mother, exposure and susceptibility commences at time of infection of the mother, both during pregnancy and after the child is born, with efficiency of transmission dependent on ART and PMTCT treatment. Figure 2.2 provides a diagrammatic expression of how underlying factors working through proximate and biological determinants lead to HIV infection, disease and finally mortality.

Figure 2.2 Proximate-determinants conceptual framework for factors that affect the risk of HIV infection and health outcome



Source: Derived from Boerma and Weir (2005)

3 METHODOLOGY

3.1 Data source

The study uses data from the ZDHS for 2007 and 2013/14 which also conducted HIV testing among selected respondents. Data collection for the 2007 survey was conducted between April and October, 2007 while the 2013/14 survey was conducted from August-2013 to April-2014. The 2007 survey was conducted by the Central Statistical Office (CSO) with technical support from Macro International, Ministry of Health and the University of Zambia while the 2013/14 survey was conducted by the Central Statistical Office and Ministry of Health with technical assistance from ICF International and the University of Zambia (CSO, MOH, TDRCZ *et al.* 2009; CSO, MOH, UNZA Teaching Hospital Virology Laboratory *et al.* 2015).

The 2000 Zambia Census for Population and Housing was used as a sampling frame for the 2007 survey while the 2013/14 used the 2010 census. Representative samples were drawn using a two-stage stratified cluster sample design method. In the first stage, Standard Enumeration Areas (SEA's), divided into rural and urban clusters, were selected. In the second and final selection stage, households were selected from within the SEA's. All women and men aged 15-49 who were permanent residents or visitors present in the household on the night before the survey were eligible to participate.

A representative sample of about 8,000 households was selected for the 2007 survey and 18,052 households for the 2013/14 survey. In the 2007 survey, 7,146 men and 7,408 women were selected to take part in the survey. For the 2013/14 survey, 16,209 men and 17,064 women were selected.

The DHS collects data using three different types of questionnaires: woman's, man's and household questionnaires. All information required for this study is generated from the woman's questionnaire compiled in the women's recode. The woman's questionnaire captures information on women such as their background characteristics, socioeconomic status, reproductive behaviour and intentions, contraception, antenatal, delivery, and postnatal care, children's health and husband's background.

HIV testing data is a sub-sample of households selected to participate in the ZDHS. Blood samples were collected from individuals who voluntarily consented to the test. To ensure confidentiality, blood samples were collected on an anonymous basis and results stored separately from information collected in the main survey. The

procedure used to collect the data allows for merging and matching of the HIV test results to the data collected in the women's questionnaire.

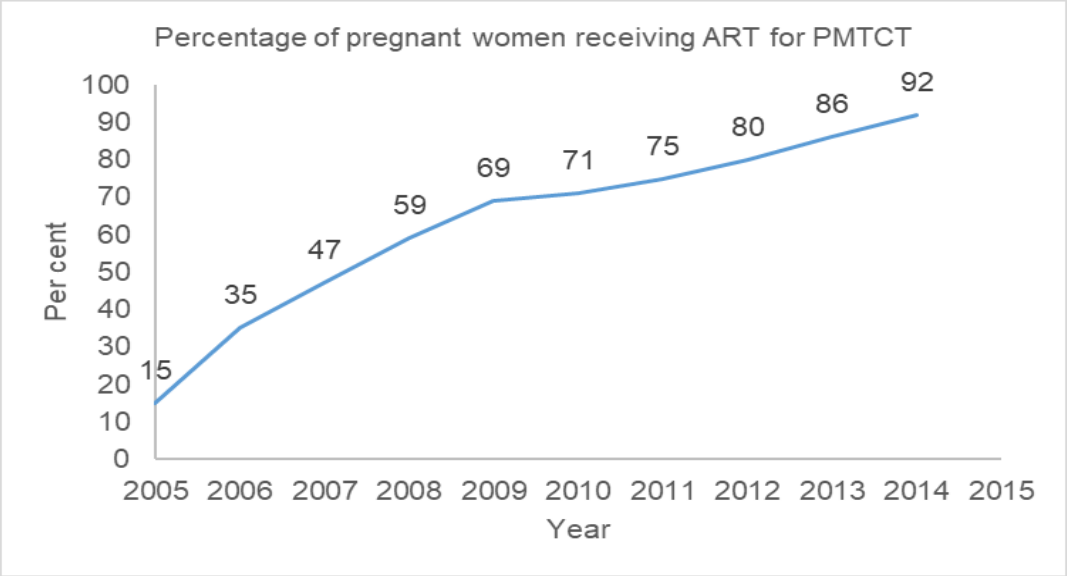
3.2 Biases in survey data

As with any survey, the DHS is liable to both sampling and non-sampling errors. Sampling errors arise from the fact that a representative sample and not the whole population is enumerated. This bias is unavoidable since the chosen sample cannot fully represent the whole population (Singh 2007). Sampling errors can also be caused by inaccuracies in the data collected. Accuracy of certain collected information such as age of respondent, child's date of birth, age of child at death, age of mother at birth of child etc. may rely on the memory of the respondent (Boerma and Sommerfelt 1993). However, over the years the quality of data collected by the DHS has improved, largely due to improved training of data collectors in interviewing techniques such as probing which helps to verify accuracy of information provided (Moultrie 2019). The DHS questionnaires also have a number of cross-checking questions that are used to ensure that correct information is collected from respondents. For example, a woman's response to a question on total children ever born to her can be cross-checked against her responses on questions that ask about her daughters and sons who live home, those who live elsewhere and those who have died (ICF 2011).

Bias in survey data may also arise from omission of births and deaths of children. This negatively affects estimates of child mortality based on information on child survival as reported by the mother due to selection bias especially in populations experiencing a generalised HIV/AIDS epidemic. In such populations, both mother and child face a higher risk of mortality and, therefore, children who died in the distance past (particularly those born five or more years) before the survey are omitted since the mother is not there to report (Hill 2013). In other words, bias in direct estimates of mortality increases with increased period of analysis from the survey date and where the HIV epidemic is stable or increasing (Hallett, Gregson, Kurwa *et al.* 2010). Though the use of ART and PMTCT treatments reduce bias by extending survival time, the benefits are not immediate since bias persists for about 10 years or more after introduction of effective treatment (Hill 2013). As such, estimates derived from using old data during periods when coverage of ART was low are likely to be underestimated. Bias is expected for both the 2007 and 2014 surveys due to low coverage of ART for PMTCT, especially in the period prior to 2010. Figure 3.1 shows estimates of ART coverage for PMTCT

among pregnant women in Zambia between 2005 and 2014. Coverage has been increasing steadily from about 15 per cent in 2005 to 92 per cent by 2014.

Figure 3.1 Trends in the coverage of women receiving ART for PMTCT in Zambia between 2005-2014



Source: UNICEF (2007, 2008a, 2008b, 2009, 2010) and UNAIDS (2019)

Poor participation in the survey is also likely to affect the reliability of estimates made from the collected information (CSO, CBH and ORC Macro 2003). If some respondents selected to take part in the survey refuse to be enumerated, the representativeness of the collected data may be affected as some groups of people may be underrepresented. For example, HIV-positive people have been found to have lower participation rates compared to those who are HIV-negative (Reniers and Eaton 2009). Table 3.1 shows response rates for households, men and women in the 2007 and 2013/14 surveys. In both surveys, response rates for HIV testing were low compared to the other rates. In 2007, the HIV response rate among men was 72.2 per cent, increasing to 83.7 per cent in 2013/14. Among women, the response rate in 2007 was higher than men's at 77.1 per cent and increased to 90.4 per cent in 2013/14. The low participation in HIV testing may affect generalisation of estimates derived using HIV test results, especially for the 2007 survey. The response rates for households, men and women were all high, ranging from 91.0 per cent among men in the 2007 survey to 97.9 per cent among households in the 2013/14 survey. The reasons cited for non-response were refusal to be interviewed and failure to find eligible respondents at home, especially men, despite enumerators making several attempts (CSO, MOH, TDRCZ *et al.* 2009).

Table 3.1 Zambia Demographic and Health Survey response rates

Participation	2007	2013/14
Households	97.8	97.9
Men	91.0	91.1
Women	96.5	96.2
Men HIV test	72.2	83.7
Women HIV test	77.1	90.4

Source: Derived from ZDHS 2007 and 2013/14 reports

3.3 Imputation of date variables and exact age at death

The derivation of accurate child mortality estimates among others relies on the accuracy of age at death, and dates of birth, death and survey. However, the reported age at death is not very accurate as it does not take into account day of death and is affected by age heaping. Age heaping refers to concentration of the age distribution around ages ending in particular digits, usually 0 and 5 (Moultrie 2013b). The reported dates of birth and survey are also not precise as they are in century month code (CMC) form which does not take into account the day when the event took place. It is, therefore, necessary that precise age at death and dates of birth, death and survey are imputed to facilitate selection of the correct study sample and accurate measurement of child mortality estimates. The sections below explain the criteria used to impute the exact age at death and dates of birth, death and survey that are used in this study to generate the sample and results.

3.3.1 Calculation of precise date of survey

The DHS reports the date of interview in CMC format, which takes into account the month and year of interview only, despite information on day of interview also being collected. This date is, therefore, not very precise as it does not take into account the day the interview took place. A precise date of interview is, therefore, calculated by dividing the day of interview by the number of days of the month in which the interview took place to get a decimal fraction of a month. The result is then added to the reported date of interview (in CMC format) to obtain a precise date of interview.

3.3.2 Imputation of precise date of birth

The study sample is selected on the basis of the child's date of birth. In order to accurately select the sample, child's date of birth needs to be more precisely calculated than the reported date which is calculated using the child's month and year of birth and expressed in CMC format since 1900. In order to calculate the precise date of birth, day, month and year of birth are required. However, for both the 2007 and 2013/14 surveys,

day of birth was not collected and is, therefore, imputed. To do this, the child's day of birth is randomly selected using the *runiformint ()*[6] command, a random number generator function in Stata, taking into account the length of month of birth and leap years. Depending on the month in which the child was born, a day of birth is randomly selected between the first and last day of the month. The selected day is then divided by the number of days in the month in which the child was born to get a decimal fraction of a month. The result is added to the reported CMC date of birth of the child to get an exact date of birth. The same procedure is followed to impute the mother's exact date of birth in CMC format.

3.3.3 Imputation of precise age at death and date of death

The DHS does not provide the child's date of death but age at death recorded in months. However, the reported age at death is not very accurate due to truncation and misreporting. If a child is reported to have died in days, age at death is truncated into months and if reported to have died in years, age at death is imputed into months (ICF 2013). The imputed age at death in months represents the lower bound of the age interval and this may lead to systematic mis-location of deaths in time (Hill 2013). In addition, the imputed age at death in months is not very accurate as it does not take into account day of death. Misreporting due to rounded off age at death results in heaping at particular ages such as 12 and 24 months. In such cases, children are falsely reported to have died at the rounded off age when they actually died slightly before or after. The procedure for the imputation of day of death, precise age at death in months and date of death is described below for children who died in months and years. For children whose age at death is recorded in days, their age at death is taken to be accurately reported (Hill 2013).

Reported age at death is derived from the three-digit code that the DHS uses to record age at death. In this code, the first digit represents the unit in which age at death is reported. Thus, a code starting with digit 1 represents age at death reported in days, digit 2 for months and digit 3 for years. The last two digits of the respective codes represent the actual days, months and years at which the child died. For example, code 102 means the child died 2 days after birth, code 210 means the child died at 10 months and code 303 would mean the child died at 3 years. Where records of age at death are missing, the hot dock imputation method used by the DHS is adopted to fill the entries

[6] To ensure reproducibility of results, *set seed* the random number generator before running it by selecting any number or a combination of numbers. For example, *set seed* 4283 followed by the random number generator.

by getting the age at death from the observation of the same birth order that comes immediately before the observation with missing age at death.

To impute the exact age at death in months for children reported to have died within days of their birth, the reported age at death in days is divided by the length of month of birth. For children whose age at death is reported in months but below 12 months, a day of death, as a decimal fraction of a month, is randomly selected[7] between 0 and 1 and then added to the reported age at death. For children whose age at death is one year and above, the reported age at death is first multiplied by 12 to convert it into months. A day of death, as a decimal fraction of a month, is then randomly selected between 0 and 1 and multiplied by 12 and the result added to the reported age at death converted into months. To get a precise date of death, the imputed age at death in months is added to the imputed date of birth[8].

Figure 3.2 and Figure 3.3 show the percentage distribution of both the reported and imputed age of child at death in months for children born within the last 36 months prior to the 2007 and 2014 surveys. In both surveys, there is high heaping for reported age at death for ages 12 and 24 months and minimal heaping at age 6 months. In both surveys, imputation of exact age at death in months greatly reduced age heaping by redistributing the reported age at death especially at ages 12 and 24 were the problem is more pronounced.

[7] The random selection of a day of death as a decimal fraction of a month is done using Stata's random number function *runiform()* which selects a number between zero and one but excludes one.

[8] However, for some children, especially those who died within a few days to the survey, the imputed age at death may produce a date of death that is greater than the date of survey. To correct the affected observations, exact age at death is randomly selected between the CMC date of death (calculated by adding reported age at death and imputed date of birth) and the exact CMC date of survey. If this still does not solve the problem for some observations, then random selection of the day of birth for the particular observation is also restricted to a shorter interval in order to lower the CMC date of birth, which in turn lowers the CMC date of death.

Figure 3.2 Percentage distribution of age at death, ZDHS 2007.

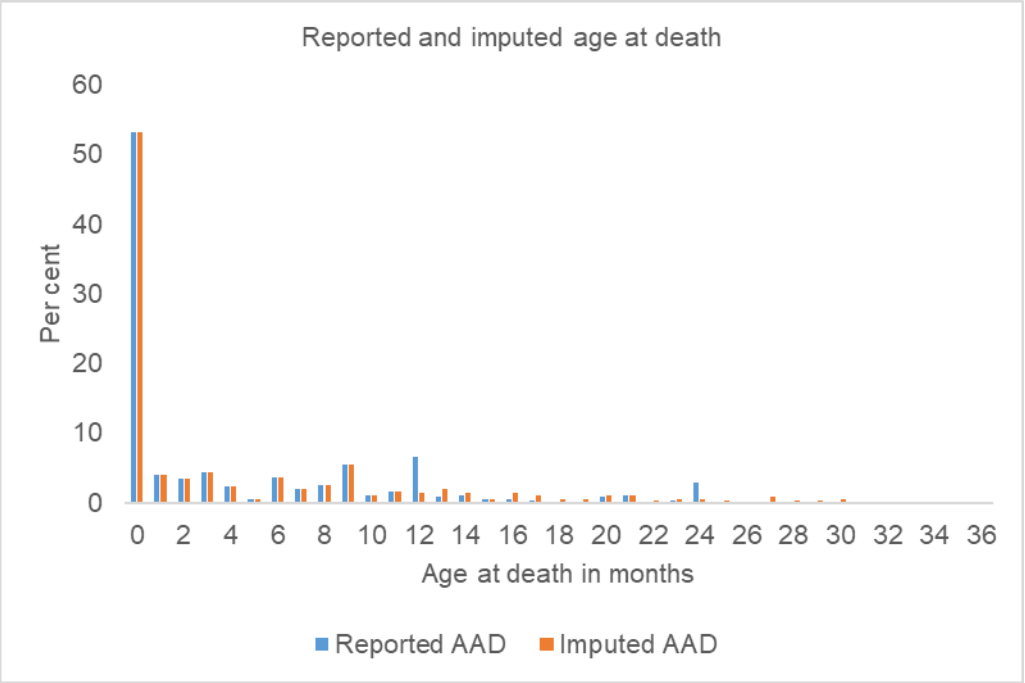
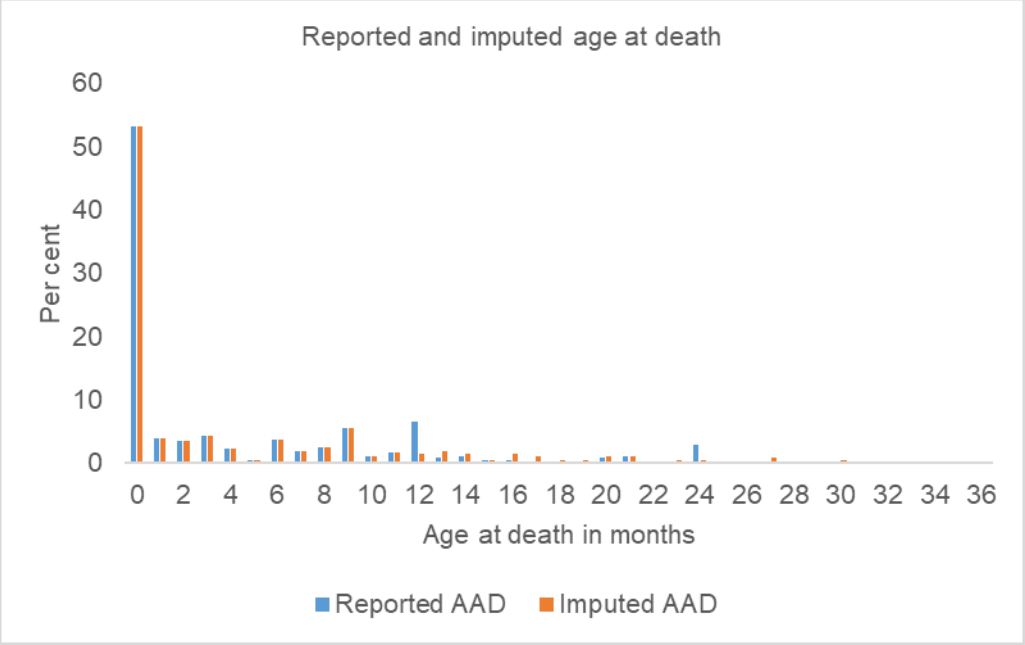


Figure 3.3 Percentage distribution of age at death, ZDHS 2013/14.



3.4 The Poisson distribution and regression

This section describes the method of analysis that is used to model the influence of maternal HIV status on mortality in children under the age of five years. A multivariate approach to analysing the risk of child death is used in order to control for confounding factors that affect child survival. Based on Mosley and Chen's analytical framework for the study of determinants of child survival, confounding factors considered are demographic, socioeconomic and environmental factors. Poisson regression, a method based on survival analysis, is used as the method of analysis.

The Poisson distribution, the basis on which Poisson regression models are built, expresses the probability of a certain number of events occurring within a specified period of time given that the events are independent and occur at a constant rate. The distribution establishes a relationship between the independent variable(s) and the dependent variable(s). This relationship can be expressed in a mathematical equation. Let:

μ = the rate or mean number of occurrences of an event during a given period of time (dependent variable).

y = the vector of linearly independent variables that determine μ.

t = the exposure (time period in which the events occur),

then the relationship between μ and y can be expressed in a Poisson distribution in a rate form with the density:

$$\Pr(y|\mu) = \frac{e^{-\mu t}(\mu t)^{y}}{y!} \quad \text{for } y = 0,1,2,3\ldots,$$

where the mean is equal to the variance, that is:

$$\in(\gamma) = V(\gamma) = \mu t$$

If the length of exposure time t is set to unity, the Poisson distribution changes to the form:

$$\Pr(y|\mu) = \frac{e^{-\mu}\mu^{y}}{y!} \quad \text{for } y = 0,1,2,3\ldots,$$

Based on the above distribution, Poisson regression, which is a nonlinear regression model, can be used to analyse data by allowing the parameter μ to depend on the regressor y (Cameron and Trivedi 2013). For data to be used in a Poisson regression model, the dependant variable should be a non-negative count variable. In its basic form, the following assumptions are made about a Poisson regression model: the rate at which events occur is measured by the incidence rate; to get the expected number of observed events, the incidence rate is multiplied by exposure time; when exposure time

is small the probability of many events occurring is also small, and; non-overlapping exposures are said to be mutually independent (StataCorp 2017).

Using natural logs to express the link between the dependent variable and independent variables, the Poisson regression model is given by:

$$log\mu_j = \beta_0 + \beta_1 X_{1,j} + \cdots + \beta_k X_{k,j}$$

where β_k = Coefficients,

$X_{k,j}$ = Covariates.

Taking the exponent, the model is expressed as:

$$\mu_j = e^{\beta_0 + \beta_1 X_{1,j} + \cdots + \beta_k X_{k,j}}$$

Given the exposure time, E_j, the expected number of events, C_j, is given by:

$$C_j = E_j e^{\beta_0 + \beta_1 X_{1,j} + \cdots + \beta_k X_{k,j}}$$

Instead of coefficients, the Poisson model can generate Incidence Rate Ratios (IRR), which are used in this study. IRRs estimate the amount of change that occurs in the dependent variable for a one-unit change in the independent variable. For grouped count data, used in this study, the IRRs indicate the number of times an event (death) is likely to occur relative to the reference category in the independent variable. The IRR is given by:

$$R_{ij} = \frac{e^{\ln(E) + \beta_1 X_1 + \cdots + \beta_i (X_i + 1) + \cdots + \beta_k X_k}}{e^{\ln(E) + \beta_1 X_1 + \cdots + \beta_i X_i + \cdots + \beta_k X_k}} = e^{\beta_i}$$

The IRRs can be interpreted as follows: person *i* is e^{β_i} times likely to experience event μ compared to person *j*.

In this study, estimators are considered to be statistically significant at 95 per cent confidence level with P-value below 0.05.

3.5 Poisson regression model in Stata

In order to estimate the exposure time to occurrence of the event, the Poisson model is run using survival-time data. In this study, survival-time is the time period from birth to death of a child or to the end of the observation period (interview date) if the child does not die. It measures time at risk of death for a child born within the observation period. The event is recorded as failure if a child dies within the observation period and censored if it survives beyond the interview date.

To conduct survival analysis in Stata, the *stset* function is used to declare survey data as survival-time data. In order for the function to work, three main parameters are defined:

Failure or censoring time: Failure or censoring time marks the end of the observation period, that is, time at which a child dies or is censored. A variable that defines failure and censoring time is created based on the child's status at the time of the survey; whether the child is alive. The variable takes date of death as failure time if the child is dead and date of interview as censoring time if the child is alive.

Failure event: The failure event represents death of a child. A failure variable is generated which takes value 1 if the child is dead and 0 otherwise. The variable is then indicated within the *failure()* function.

Commencement of analysis time: Analysis time commences at the time the subject of analysis becomes at risk of experiencing an event. In this case, date of birth is the time at which a child becomes exposed to the risk of dying. The child's date of birth is indicated within the *origin()* function as the analysis time. If analysis time is not indicated, then all children would be assumed to have been exposed at the same point in calendar time.

When data are declared survival-time data, a new variable (*_d*) is automatically generated based on the failure variable which is also generated based on status of the child (whether alive). If the child died, *_d* takes the value 1 and 0 if censored. Variable *_d* is used as the dependent variable in the Poisson regression model.

A secondary function called *stsplit* is performed when data has been *stset*. The function is used to split children's records at specified age bands based on analysis time, which is time since being at risk of dying. The split age bands are stored in a variable that is created when data are split. The number of age bands created for each child is dependent on the length of exposure time. For example, if age is split every three months and a child is aged 13 months at the time of the survey, then four exposure time bands are created at age 3, 6, 9 and 12 months. This ensures that the risk of dying is calculated based on duration of exposure in each age band and not age of child. In the same vein, if the risk of dying is analysed at age 9 months, the calculation of the risk of dying takes into account duration of exposure from ages 0-3, 3-6 and 6-9 months only even though the child is aged 13 months. In order for the *stsplit* function to be used, the following three parameters are defined:

Time variable: This is a child's age variable that is created when data are split at specified age bands. It indicates duration of exposure at risk of dying in each age band until time of failure or censoring. The variable is used in the Poisson regression model

as an independent variable to determine the risk of dying associated with length of exposure.

Analysis time splitting: It defines specific analysis time at which records are split. It is defined by the *at()* function. In Model 1, analysis time is split at ages 0, 1, 3, 6, 9 and 12 months; Model 2 at ages 0, 1, 3, 6, 9, 12, 18 and 24 months and; Model 3 at ages 0, 1, 3, 6, 9, 12, 18, 24, 30 and 36 months.

Reference time: Reference time specifies commencement of analysis time. It's defined by the *after()* function. Date of birth of child is used to define reference time.

To account for duration of a child's exposure to the risk of dying, an exposure variable is created and used within the Poisson regression model. Exposure time is calculated from the difference between variables *t* and *t0* automatically generated after the data have been *stset*. Variable *t0* is the beginning of analysis time, in this case, date of birth of child. Variable *t* is the end of analysis time, in this case, date of death of child or time of censoring.

In order to generalise findings of the study to the whole population, data are weighted using sample weights (*pweights*) found in the women's recode. The DHS weight which is expressed in millions is divided by 1,000,000 before being used. The sample weight variable is specified within the *svyset* function used to declare the dataset as survey data. The survey data are stratified by region and area of residence with a centred single sampling unit (individual observations).

3.6 The study sample and models of data analyses

In order to accurately estimate the influence of maternal HIV status on the risk of dying, the study uses data for children born in the recent past prior to the survey. Three models of analyses are used. Model 1 analyses the risk of dying for children born in the 12 months before the survey. Model 2 analyses the risk of dying for children born in the 24 months before the survey and model 3 for children born in the 36 months before the survey. This is premised on several reasons. First, HIV status of the mother refers to her status at the time of the survey and, therefore, it is not known for how long the child had been exposed. If all children born to a woman are included in the analysis, estimates may be misleading since some women may not have been HIV-positive in the distant past prior to the survey. Second, studies have shown that transmission of HIV from the mother to the child is high among newly infected women and those with advanced infection (Drake, Wagner, Richardson *et al.* 2014; Kim, Kasonde, Mwiya *et al.* 2012).

Third, it is observed that in populations like Zambia experiencing a generalised HIV/AIDS epidemic, estimates are likely to be underestimated with increased period of analysis due to selection bias (omission of child births and deaths) as a result of death of mothers who are respondents (Hill 2013). Since coverage of ART and PMTCT treatment was low in Zambia prior to 2010, it is likely that some children born in the distant past (particularly five years or more) prior to the survey were omitted due to death of their mothers. This is explained in detail in section 3.2. Fourth, taking into account increased coverage of PMTCT and ART over the years which increase survival time, there is need to compare trends in the risk of dying associated with maternal HIV-positive status for different time periods up to the survey. Hence a comparison of models is necessary since benefits of PMTCT and ART are seen years after commencement of treatment while at the same time having "a quick effect on reducing bias for the most recent time period" (Hill 2013).

3.7 Description of background characteristics

This section describes the selection process of independent variables, their recoding and distribution.

3.7.1 Collinearity and selection of independent variables

All independent variables were checked for collinearity using the correlation matrix, a widely used approach (Kennedy 2008). The correlation matrix checks for collinearity between two independent variables. The diagonal line where the covariate is compared with itself has value of one. Values between 0 and 0.5 indicate moderate correlation between two independent variables not severe enough to require corrective measures. Values above 0.5 indicate moderate to high correlation. The disadvantage of the correlation matrix is that it only detects collinearity between the two compared independent variables. In this study, if collinearity is equal to or exceeds 0.5, one of the two variables that are collinear is removed. To determine which variable to remove between the two collinear variables, a Stata command *collin* developed by Philip Ender, which on its own also detects collinearity, is used. The method computes various collinearity diagnostic measures among them the Variance Inflation Factor (VIF) and tolerance values for each independent variable. If the VIF value is above 2.5 and or tolerance value is below 0.4, the variable is removed (Williams 2015).

Initially, the following independent variables were considered for analysis: maternal HIV status, maternal age at birth of child, birth order, child's sex, preceding

birth interval, marital status, place of delivery, mother's level of education attained, father's level of education attained, place of residence, type of toilet facility used, source of drinking water, main floor material of the house, birth weight and household wealth index. Due to collinearity, birth order, father's level of education attained and household wealth index were removed. Birth weight was also removed due to missing values amounting to 49.5 per cent in the 2007 survey and 30.7 per cent in the 2013/14 survey.

3.7.2 Recoding of independent variables

To enable comparison of the risk of dying of children in one category relative to the other, continuous variables are recoded into categorical variables. A reference category in each variable is chosen for the purpose of making comparisons with the other categories. Some variables that are already categorical are regrouped into fewer broader categories to make analysis easier. Regrouping is also done for variables that have very few observations. Categories labelled either 'unknown' and or 'non-residents' are created for observations whose status is unknown, have missing responses or are non-residents. This is done for purposes of retaining such observations in the regression model since their responses in other variables are known. For example, a mother whose HIV status is known may have unknown place of delivery, educational level attained or could be a non-resident. Removing such an observation from the model on account of an unknown or missing response would compromise the findings due to reduced sample size. All variables used in the analysis are obtained from the women's recode apart from the variable for mother's HIV status which is found in the HIV testing recode.

Maternal HIV status variable is derived from the HIV test results variable, which contains results for both men and women and found in the HIV testing recode. To enable analysis together with the other variables, the HIV testing recode is merged with the women's recode. During merging, care is taken to ensure that observations in both recodes are exactly matched. The recodes are merged in the following manner: First, a sex variable is created in both the women's and men's recode. The variable is coded 'male' in the men's recode and 'female' in the women's recode. Second, using the cluster number, household number and respondent's line number to uniquely identify and match observations, the men's recode (containing these three variables and the sex variable only), is appended to the women's recode. The men's observations are automatically placed at the end of the women's recode during the appending process. A count is done to ensure that all observations from the men's recode have successfully been appended. Third, using the cluster number, household number and respondent's

line number to uniquely identify and match observations, the HIV testing recode is merged to the women's recode containing appended men's observations. For the 2007 survey, a total of 10,876 observations were matched and 3,032 were not, while from the 2013/14 survey, a total of 29,007 observations were matched and 2,855 were not. In the 2007 survey, out of the 3,032 unmatched observations, 2,770 of them were from the appended recode and 262 from the HIV testing recode. In the 2013/14 survey, out of the 2,885 unmatched observations, 2,177 of them were from the appended recode and 678 from the HIV testing recode. The unmatched observations from the appended recode (2,770 in 2007 and 2,177 in 2013/14) are men and women who were not subjected to an HIV test since testing was done on a selected number of respondents within the survey sample. The unmatched observations from the HIV testing recode (262 in 2007 and 678 in 2014) could not be located in either the women's recode or men's recode. These observations are most likely men and women who took an HIV test but refused to participate in the main survey or had incomplete responses in the main survey to warrant their inclusion. A verification using the sex variable created prior to merging the datasets confirmed that none of these observations were from the women's or men's recode. These observations are consequently not included in the sample since they cannot be linked to any variable in the main dataset. Lastly, men are removed from the merged recode using the created sex variable. The HIV test variable has three categories and takes the value 1 if the mother is positive and 0 otherwise. The third category contains observations that have inconclusive HIV test results. These observations together with women who were not tested are coded into one category called 'unknown HIV status'.

Maternal age at birth of child is calculated by subtracting the imputed CMC date of birth of the mother from the imputed CMC date of birth of the child. The difference is divided by 12 to get the age of the mother in years. The variable is then recoded into three categories: adolescents and young women (below 25 years), middle-aged women (25-39 years) and older women (40 years and above). The categories are created on the basis that younger and older women are more likely to experience a poor maternal outcome which increases the risk of death of their children compared to middle aged women. HIV increases the likelihood of a poor maternal outcome in maternal ages that are highly infected with HIV. In sub-Saharan Africa, adolescent girls and young women aged 15-24 face a higher risk of HIV infection accounting for about

25 per cent - that is, one in every four - despite being 10 per cent of the population (UNAIDS 2018).

Preceding birth interval is coded in two categories of short and long intervals. In this study, an interval of 9-23 months is classified as a short birth interval while an interval of minimum of 24 months is classified as a long birth interval. The classification takes into account WHO recommendation for a minimum of 24 months interval between a live birth and the next pregnancy to reduce the risk of poor maternal and child health outcomes (WHO 2007).

Marital status is a current status variable referring to a woman's marital status at the time of the survey. Results are, therefore, likely to be biased because among the women who did not have a partner at the time of the survey, some may have had a partner prior to the survey, for example, women who got widowed close to the survey. With high HIV prevalence rates among adults in Zambia, it is very likely that some women may have lost their husbands to AIDS within the five-year period prior to the survey. UNAIDS (2019) estimates that between 2003-2007, Zambia experienced about 115,000 AIDS-related deaths among male adults aged 15 years and above and about 69,400 between 2008-2014. To avoid the bias mentioned above, the variable is recoded into two categories to compare mortality among children whose mothers had never been married before and those who had ever married. The first category of 'never married' consists of women who had never been in a union while the second category of 'ever married' is made up of women who were married, lived with a partner, widowed, and divorced. Research has shown that single women are seen to have inadequate economic resources to support themselves and their children compared to married women (Clark and Hamplová 2013).

Place of delivery has several categories which are re-categorised into two between women who delivered at home and those who delivered from a health facility. Women who delivered from home, respondent's home and other home are categorised as having delivered from home. Those who delivered from a government, private, mission or other health facility are categorised as having delivered from a health facility. The observations coded 'other' and those missing are categorised as 'unknown' since the place of delivery is not known.

Mother's highest education level variable has four categories namely, no education, primary, secondary and higher. Since the selected sample had a small number of women who attained higher education, this category is merged with secondary

education to create a new category for secondary and higher education attained. The missing observations are recoded as 'unknown' to retain them in the model.

Type of toilet facility variable has several categories. To make analysis easier, the responses are reorganised into three broader categories namely, households with access to a flushing toilet, those that use pit latrines, and those with no toilet facility. The responses for non-de jure members, other and the missing are re-categorised as 'unknown and non-residents' to retain them in the model.

3.7.3 Distribution of births and deaths by background characteristics

This section presents information on the distribution of births and deaths in the 36 months prior to the survey by background characteristics. Table 3.2 shows the distribution of births and deaths by mother's HIV status and demographic characteristics. A total number of 4,019 children were born within the 36 months prior to the 2007 survey. In the 2013/14 survey the number increased to 7,906 children. Out of the total number of children born within 36 months prior to the 2007 survey, 3,712 children, representing 92.4 per cent of the sample, were still alive while 307 children, representing 7.9 per cent of the sample, had died by the time of the survey. In the 2013/14 survey, 95.6 per cent of children born within 36 months prior to the survey were still alive by the survey date while 4.4 per cent had died.

Table 3.2 Distribution of births and deaths by mother's HIV status and demographic characteristics (weighted), ZDHS 2007 and 2013/14.

	Births				Deaths			
	2007		2014		2007		2014	
Background characteristics	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Whether child is alive								
No	307	7.6	346	4.4				
Yes	3712	92.4	7560	95.6				
Total	4019	100.0	7906	100.0				
Sex of child								
Male	2001	49.8	3996	50.5	158	51.4	186	53.6
Female	2017	50.2	3910	49.5	149	48.6	161	46.4
Total	4019	100.0	7906	100.0	307	100.0	346	100.0
Maternal HIV status								
HIV negative	2776	69.1	6643	84.0	173	56.3	244	70.4
HIV positive	400	10.0	729	9.2	76	24.8	70	20.2
Unknown	843	21.0	535	6.8	58	18.9	32	9.4
Total	4019	100.0	7906	100.0	307	100.0	346	100.0
Maternal age								
14 and below	19	0.5	25	0.3	2	0.5	5	1.4
15-19	653	16.2	1544	19.5	52	16.9	90	26.0
20-24	1141	28.4	1988	25.2	85	27.7	92	26.5
25-29	990	24.6	1883	23.8	71	23.2	58	16.7
30-34	669	16.6	1349	17.1	50	16.2	53	15.4
35-39	384	9.6	827	10.5	30	9.7	29	8.5
40-44	140	3.5	261	3.3	11	3.7	13	3.8
45-49	23	0.6	29	0.4	7	2.3	6	1.8
Total	4019	100.0	7906	100.0	307	100.0	346	100.0
Preceding birth interval								
Short interval (9-23 months)	493	12.3	878	11.1	45	14.8	48	13.9
Long interval (24+ months)	2748	68.4	5300	67.0	182	59.4	185	53.3
First births	778	19.4	1728	21.9	79	25.9	114	32.8
Total	4019	100.0	7906	100.0	307	100.0	346	100.0

In both surveys, there was an almost equal number of male and female children born within the 36 months prior to the survey. The 2007 survey recorded an unusual sex ratio having slightly more females than males. At birth and in early ages, it is normally expected that there will be slightly more males than females. However, the recorded sex ratio is within the acceptable range of between 0.99-1.06 to warrant further scrutiny (Moultrie 2013a). Slightly more males died in both surveys, with the number of male deaths increasing from 51.4 per cent to 53.6 per cent between the two surveys while female deaths reduced from 48.6 per cent to 46.4 per cent.

The number of children whose mothers were HIV negative at the time of the survey increased from 69.1 per cent in 2007 to 84.0 per cent in 2013/14 while the number of those who had HIV positive mothers decreased slightly from 10.0 per cent to 9.2 per cent. There was also a decrease in the number of children whose mother's HIV status was unknown from 21.0 per cent in 2007 to 6.8 per cent in 2013/14. This decrease may be attributed to the increase in the response rate for HIV testing among women between the 2007 and 2013/14 surveys. There is a possibility that among children whose mothers were not tested for HIV, some of their mothers could have

been HIV-positive. Therefore, mortality is likely to be underestimated especially for the 2007 survey which has a high percentage of children with mothers who were not tested for HIV. In both surveys, over half of child deaths occurred to mothers who were HIV-negative, with the number increasing by 14.1 per cent in 2014 from 56.3 per cent in 2007. Child deaths for HIV positive women decreased from 24.8 per cent in 2007 to 20.2 per cent in 2013/14.

In both surveys, the majority of children were born to women who were in their twenties, accounting for 53.0 per cent in the 2007 survey and 49.0 per cent in the 2013/14 survey. The number of children born to women in their thirties slightly increased from 26.2 per cent to 27.6 per cent between the survey periods. There was also a very slight decrease in the number of children born to very young women below the age of 15 years and older women in their forties, with their overall contribution below 5 per cent in both surveys. Mothers in their twenties experienced more child deaths, contributing 50.9 per cent in 2007 and 43.2 per cent in 2013/14. Teenage mothers experienced an increase in child deaths from 17.4 per cent in 2007 to 27.4 per cent in 2013/14.

The majority of children were born after a long interval between the current and previous birth, though the number slightly decreased from 68.4 per cent to 67.0 per cent between the two surveys. The number of children born after a short interval also decreased from 12.3 per cent to 11.1 per cent between the 2007 and 2013/14 surveys. The decrease in the number of children born after both long and short preceding birth intervals between the two surveys could be as a result of an increase in the number of first time mothers from 19.4 per cent to 21.9 per cent. More than half of child deaths occurred to women who had a long birth interval between the present and previous birth. This is expected since more births occurred to women with long birth interval.

Table 3.3 shows the distribution of births and deaths by mother's socioeconomic characteristics. For both surveys, the majority of children had mothers who were married at the time of the survey. However, the percentage reduced from 83.4 per cent in 2007 to 80.9 per cent in 2013/14. There were minor increases in the percentage of children born to mothers who had never been married before, those who were living together with their partner, the divorced, and those who were no longer living together with their partner. The percentage of children whose mothers were widowed reduced from 2.0 per cent to 1.4 per cent between 2007 and 2013/14. In 2007,

82.1 per cent of deaths occurred among children whose mothers were married, decreasing to 75.3 in 2013/14.

Table 3.3 Distribution of births and deaths by mother's socioeconomic characteristics (weighted), ZDHS 2007 and 2013/14

	Births				Deaths			
	2007		2014		2007		2014	
Background characteristics	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Current marital status								
Never married	298	7.4	738	9.3	22	7.3	36	10.5
Married	3353	83.4	6395	80.9	252	82.1	261	75.3
Living together	23	0.6	64	0.8	2	0.8	11	3.0
Widowed	82	2.0	114	1.4	7	2.4	12	3.4
Divorced	178	4.4	394	5.0	18	5.9	16	4.7
No longer living together	83	2.1	201	2.5	5	1.5	11	3.1
Total	4019	100.0	7906	100.0	307	100.0	346	100.0
Place of delivery of child								
Home	2078	51.7	2218	28.1	140	45.8	104	30.0
Public Health facility	1722	42.9	5181	65.5	143	46.7	224	64.6
Private health facility	196	4.9	407	5.2	18	5.9	13	3.6
Other	17	0.4	93	1.2	1	0.4	4	1.1
Missing	6	0.1	7	0.1	4	1.2	2	0.6
Total	4019	100.0	7906	100.0	307	100.0	346	100.0
Highest level of education								
No education	550	13.7	873	11.0	45	14.7	33	9.6
Primary	2537	63.1	4304	54.4	187	60.9	186	53.7
Secondary	837	20.8	2443	30.9	62	20.2	117	33.7
Higher	95	2.4	279	3.5	13	4.3	9	2.7
Missing			7	0.1			1	0.3
Total	4019	100.0	7906	100.0	307	100.0	346	100.0
Type of place of residence								
Urban	1187	29.6	2697	34.1	104	33.8	127	36.7
Rural	2831	70.5	5209	65.9	203	66.2	219	63.3
Total	4019	100.0	7906	100.0	307	100.0	346	100.0

Slightly over half of children in the 2007 survey were born from home. This reduced significantly to 28.1 per cent by 2013/14. The number of children born from both public and private health facilities increased by 23.0 per cent from 47.8 per cent in 2007 to 70.7 per cent in 2013/14. In the 2007 survey, 52.6 per cent of child deaths occurred among women who delivered at a health centre, with the number increasing to 68.2 per cent in 2013/14. Child deaths occurring among women who delivered at home reduced significantly from 45.8 per cent in 2007 to 30.0 per cent by 2013/14.

There was a small decrease of 2.7 per cent among children whose mothers never went to school between 2007 and 2013/14. In both surveys, over half of children were born to mothers who attained primary level of education. The percentage of children whose mothers attained secondary and higher level of education increased by 11.2 per cent between the two surveys. In both surveys, more than half of deaths occurred to women who attained primary level of education though the number reduced from 60.9 per cent in 2007 to 53.7 per cent in 2013/14. There was a 13.5 per cent increase in child deaths among women who attained secondary education between the two surveys.

In 2007, about 70 per cent of children had mothers who lived in rural areas at the time of the survey while about 30 per cent lived in urban areas. By 2013/14 children whose mothers lived in rural areas decreased by 4.6 per cent. In both surveys, more than half of child deaths occurred to women who lived in rural areas though by 2013/14 there was a 2.9 per cent decrease.

Table 3.4 shows the distribution of births and deaths by environmental characteristics. The majority of children had mothers who came from households that used pit latrines, with the number increasing from 60.9 per cent in 2007 to 67.0 per cent by 2013/14. The number of children whose mothers came from households that had no toilet facility reduced from 27.1 per cent in 2007 to 19.1 per cent by 2013/14. There was a substantial increase between 2007 and 2013/14 in the percentage of child deaths occurring to mothers whose households used pit latrines, from 59.3 per cent to 67.6 per cent.

Child deaths occurring to women whose households did not have a toilet facility decreased by 8 per cent from 26.5 per cent to 18.5 per cent between the two surveys. This could be associated with a decrease in the number of children whose mothers came from households that had no toilet facility, which also decreased by 8 per cent.

In 2007, over half of children had mothers who came from households that got drinking water from unprotected water sources. By 2013/14, this reduced to 38.2 per cent, a reduction of 20.0 per cent that also equalled the increase in the percentage of those who got drinking water from protected water sources. The number of children whose mothers came from households that used piped water increased marginally from 23.1 per cent in 2007 to 25.8 per cent in 2013/14.

Table 3.4 Distribution of births and deaths by environmental characteristics (weighted), ZDHS 2007 and 2013/14

	Births				Deaths			
	2007		2014		2007		2014	
Background characteristics	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Type of toilet facility								
Flush toilet	356	8.9	876	11.1	33	10.7	36	10.4
Pit latrine	2446	60.9	5298	67.0	182	59.3	234	67.6
No facility	1088	27.1	1513	19.1	81	26.5	64	18.5
Other facility	22	0.5			1	0.4		
Not a dejure resident	104	2.6	209	2.6	9	3.1	12	3.6
Missing	2	0.1	9	0.1				
Total	4019	100.0	7906	100.0	307	100.0	346	100.0
Source of drinking water								
Piped water	927	23.1	2037	25.8	81	26.6	92	26.6
Protected water	523	13.0	2599	32.9	43	14.1	117	33.7
Unprotected water	2340	58.2	3017	38.2	162	52.8	122	35.3
Other	125	3.1	34	0.4	11	3.5	3	0.8
Not a dejure resident	104	2.6	209	2.6	9	3.1	12	3.6
Missing			11	0.1				
Total	4019	100.0	7906	100.0	307	100.0	346	100.0
Main floor material of the house								
Natural	2690	66.9	4809	60.8	189	61.5	202	58.3
Rudimentary	1	0.0	1	0.0	1	0.2		
Finished	1219	30.3	2882	36.5	106	34.7	132	38.1
Other	4	0.1			2	0.5		
Not a dejure resident	104	2.6	209	2.6	9	3.1	12	3.6
Missing	2	0.0	6	0.1				
Total	4019	100.0	7906	100.0	307	100.0	346	100.0

The percentage of children dying among mothers who came from households that got drinking water from protected water sources[9] more than doubled from 14.1 per cent in 2007 to 33.7 per cent in 2013/14. The percentage of children dying among mothers who came from households that got drinking water from unprotected water sources[10] reduced from 52.8 per cent to 35.3 per cent, with no change observed among children with mothers who came from households with piped water.

In 2007, about 67 per cent of children came from households whose floor of the house was made using natural materials while about 30 per cent came from households that used finished materials. By 2013/14, there was a 6.1 per cent decrease in children who came from households that used natural materials as floor of the house. This is an indication that more households were adopting finished materials in place of natural materials as floor of the house. In both surveys, more than half of child deaths occurred among women who came from households that used natural materials as floor of the house. Among women who came from households that used finished materials for the floor of the house, child deaths increased from 34.7 per cent to 38.1 per cent.

[9] Refers to water from tube well/borehole, protected well, protected spring, tanker truck and bottled water.

[10] Refers to water from unprotected well, unprotected spring, rain water, cart with small tank, and from sources like river, dam, lake, ponds, stream, canal and irrigation channels.

4 RESULTS

This chapter presents results of the Poisson regression for models 1, 2 and 3 for children born within 12, 24 and 36 months before the survey, respectively. The table of regression results for maternal HIV status and exposure duration, being the main variables that were found significant, are given below while results for other significant variables are given in the appendix where full regression tables are presented by model.

4.1 Maternal HIV status and mortality in children under five years

Table 4.1 displays results of Poisson regression for maternal HIV status for all the three models, i.e. children born within 12, 24 and 36 months of the 2007 and 2013/14 surveys.

Table 4.1 Poisson regression results for maternal HIV status for children born within 12, 24 and 36 months of the survey (weighted), ZDHS 2007 and 2013/14

	ZDHS 2007		ZDHS 2013/14	
Independent variables	**IRR**	**P-value**	**IRR**	**P-value**
Model 1 - Children born within 12 months of the survey				
HIV positive	5.292	0.000	1.526	0.313
Unknown HIV status	0.952	0.905	0.312	0.222
HIV negative (ref)				
Model 2 - Children born within 24 months of the survey				
HIV positive	4.445	0.000	3.291	0.000
Unknown HIV status	1.302	0.267	1.388	0.451
HIV negative (ref)				
Model 3 - Children born within 36 months of the survey				
HIV positive	3.824	0.000	3.474	0.000
Unknown HIV status	1.148	0.446	1.883	0.025
HIV negative (ref)				

Results for Model 1 indicate that in 2007, children with HIV-positive mothers were 5.3 times more likely to die compared to children with HIV-negative mothers. By 2013/14, maternal HIV status was no longer associated with the risk of dying for children born within 12 months of the survey.

In Model 2, the risk of dying for children with HIV-positive mothers relative to children with HIV-negative mothers reduced between the two survey periods. In 2007, the risk of dying for children with HIV-positive mothers was 4.5 times more compared

to children with HIV-negative mothers while in 2013/14 the risk was 3.3 times more, translating to 1.2 times less than in 2007.

In the full model, in 2007, the risk of dying for children with HIV-positive mothers was 3.8 times more compared to children with HIV-negative mothers. In 2013/14, the risk was slightly lower. Children with HIV-positive mothers were 3.5 times more likely to die compared to children with HIV-negative mothers. Children with mothers whose HIV status was unknown was also significant in the 2013/14 survey. Children with such mothers were 1.9 time more likely to die compared to children with HIV-negative mothers.

4.2 Exposure duration and mortality in children under five years

Table 4.2 displays results of Poisson regression for child's exposure duration[11] or age of child for all the three models, i.e. children born within 12, 24 and 36 months of the 2007 and 2013/14 surveys.

Table 4.2 Poisson regression results for child's period of exposure for children born within 12, 24 and 36 months of the survey (weighted), ZDHS 2007 and 2013/14

	ZDHS 2007		ZDHS 2013/14	
Independent variables	**IRR**	**P-value**	**IRR**	**P-value**
Model 1 - Children born within 12 months of the survey				
Less than 1 month	5.588	0.000	8.958	0.000
1 month	0.755	0.566	1.025	0.966
3 months	0.367	0.103	0.793	0.720
9 months	0.753	0.790	0.000	0.000
6 months (ref)				
Model 2 - Children born within 24 months of the survey				
Less than 1 month	17.629	0.000	22.557	0.000
1 month	3.762	0.001	1.918	0.234
3 months	2.098	0.079	2.339	0.142
6 months	1.937	0.130	2.067	0.193
9 months	2.391	0.045	1.811	0.295
18 months	0.899	0.899	1.405	0.656
12 months (ref)				
Model 3 - Children born within 36 months of the survey				
Less than 1 month	9.680	0.000	23.462	0.000
1 month	1.993	0.066	1.900	0.159
3 months	1.329	0.462	2.187	0.095
6 months	1.135	0.751	2.145	0.088
9 months	1.259	0.562	2.498	0.041
12 months	0.702	0.382	1.600	0.304
18 months	0.981	0.962	1.444	0.448
30 months	0.445	0.443	0.000	0.000
24 months (ref)				

[11] As explained in Section 3.5, child exposure duration refers to time since being at risk of dying, which essentially is equal to age of child at occurrence of the event of interest (death) or censoring time.

In Model 1, child's period of exposure was significant for children exposed for less than 1 month in both surveys while the category for children exposed for 9 months was significant in the 2013/14 survey only. In 2007, children exposed for less than 1 month were 5.6 times more likely to die relative to children exposed for 6 months. In 2013/14, the risk of dying for children exposed for less than 1 month increased to 9.0 times more relative to children exposed for 6 months. In 2013/14, though significant, the difference in the risk of dying for children exposed for 9 months was negligible relative to children exposed for 6 months.

In Model 2, child's period of exposure was significant for children exposed for less than 1 month in both surveys, while the categories for children exposed for 1 month and 9 months were significant in 2007 only. In 2007, children exposed for less than 1 month were 17.6 times more likely to die than children exposed for 12 months. The risk was higher in 2014 with children who were exposed for less than 1 month 22.6 times more likely to die compared to children aged 12 months. In 2007, children exposed for 1 month were 3.8 times more likely to die compared to children exposed for 12 months while the risk of dying for those exposed for 9 months was 2.4 times more.

In Model 3, child's duration of exposure was significant in both surveys for children exposed for less than 1 month, while results for those exposed for 9 and 30 months were significant in the 2013/14 survey only. In 2007, children exposed for less than 1 month were 9.7 times more likely to die compared to children exposed for 24 months. In 2013/14, the risk of dying for children exposed for less than 1 month was 23.5 times more relative to those exposed for 24 months, about 14 times more than in 2007. In 2013/14, children exposed for 9 months were 2.5 times more likely to die compared to children who were exposed for 24 months while for those exposed for 30 months the difference in the risk of dying was negligible.

4.3 Poisson regression results for other significant variables

Apart from maternal HIV status and child's period of exposure, main floor material of the house and maternal age were the other significant variables. Both were significant in the 2007 survey only. Main floor material of the house was significant in Model 1 when the regression was run without an interaction term, while maternal age was significant in Model 3. The results for these are given in Table 7.1 and Table 7.3 where full regression tables by model are presented.

In Model 1, initially and as displayed in Table 7.1, floor material of the house was significantly associated with the risk of dying in 2007. Children who came from households that used finished materials as floor of the house were 2.2 times more likely to die compared to children who came from households that used natural materials. However, when the model was run again including an interaction term between area of residence and floor material of the house, the effect of floor material of the house disappeared. This is an indication that floor material of the house had no real influence on the risk of child death. An interaction term was introduced on the basis that socioeconomic factors (area of residence) tend to influence environmental factors (floor type) which in turn influence morbidity and mortality (Mosley and Chen 1984). Further, the 2007 sample consisted mostly of children whose mothers resided in rural areas (67.6 per cent), where majority households (87.2 per cent) used natural materials as floor of the house.

Maternal age was significant in 2007 for the category of mothers who were aged 40 years and above. Children born from these mothers were 2.0 times more likely to die than children born to mothers who were aged below 25 years.

4.4 Discussion of results

Generally, in both survey periods, mother's HIV status was significantly associated with child mortality. Children whose mothers were HIV-positive at the time of the survey had a higher risk of dying compared to children whose mothers were HIV-negative. The results obtained are similar to results of studies reviewed in the literature that found that children with HIV-positive mothers were more likely to die than children with HIV-negative mothers (Arunda, Choudhry, Ekman *et al.* 2016; Brahmbhatt, Kigozi, Wabwire-Mangen *et al.* 2006; Fishel, Ren, Barrère *et al.* 2014; Opiyo and Sawhney 2014; Zaba, Whitworth, Marston *et al.* 2005).

A comparison of models for the 2007 survey shows that the risk of dying among children with HIV-positive mothers was increasing from Model 3 to Model 1[12]. The increasing trend in the risk of dying may possibly entail that there were more HIV infected women closer to the survey date and passed on the infection to their children. Even though HIV prevalence among adults aged 15-49 years has been decreasing in Zambia since 1998, the number of people living with HIV has been increasing. In 1990, the number of people aged 15 years and above living with HIV was about 370, 000, increasing to 820,000 in 2000, then 930,000 in 2010 and 1,200,000 in 2018 (UNAIDS 2019). In addition, prior to 2010, the coverage of ART for PMTCT among pregnant women was very low and concentrated in a few health centres, hence HIV transmission rates are expected to have been high during this period (Stringer, Sinkala, Maclean *et al.* 2005; Stringer, Zulu, Levy *et al.* 2006). In 2005, only about 15 per cent of women were taking ART for PMTCT, reaching about 47 per cent by 2007 (UNICEF 2007, 2008).

A comparison of models for the 2013/14 survey indicates that the risk of dying among children with HIV-positive mothers was decreasing from Model 3 to Model 1 and became insignificant by 2013/14. However, the difference in the decrease between Models 3 and 2 was very small. The decrease and disappearance of the relationship between maternal HIV-positive status and the risk of dying could be attributed to the increase in coverage of pregnant women taking ART for PMTCT, which reached 69 per cent in 2009 and more than 95 per cent by 2012 (UNICEF 2010, 2013). At the same time, the number of HIV-positive children aged 0-14 years receiving ART has been increasing over the years. In 2009, 36 per cent of HIV-positive children aged 0-14 years were receiving ART, increasing to 52 per cent in 2012 and 61 per cent by 2015

[12] Models 3, 2 and 1 analyses the risk of childhood mortality associated with maternal HIV status for children born within 36, 24 and 12 months of the survey, respectively

(UNICEF 2010, 2013, 2016). Results of the full model for the 2013/14 survey also indicate a significant association between children with mothers whose HIV status was unknown and the risk of dying. Children with mothers whose HIV status was unknown faced a higher risk of dying compared to children with HIV-negative mothers. It is highly likely that there was a significant number of HIV-positive women among women whose HIV status was unknown. It is also likely that these mothers knew their status and were on ART hence the disappearance of the influence in later years (i.e. for births closer to the survey).

A comparison of results between the two surveys indicate that the influence of maternal HIV status on mortality declined between 2007 and 2013/14. In all the three models, children with HIV-positive mothers had a high risk of dying in 2007 compared to 2013/14, with the risk being insignificant for children born within one year of the 2013/14 survey. For model 3, the risk of dying was 3.8 in 2007 and declined to 3.5 by 2013/14. For model 2, the risk was 4.5 in 2007 declining to 3.3 in 2013/14 while for model 3, it was 5.3 in 2007 and reduced to an insignificant figure of 1.5 in 2013/14. As alluded to earlier, the decreasing trend between the two surveys could be attributed to the yearly increase in coverage of ART for PMTCT among HIV pregnant women which may have reduced vertical transmission. In a similar study in Tanzania, Arunda, Choudhry, Ekman *et al* attributed the higher risk of dying among children whose mothers were HIV-positive between 2003 and 2007 to high HIV prevalence and inadequate provision of PMTCT treatment, and the decrease between 2007 and 2011 to the provision of free ART that was rolled out in 2007.

As much as the risk of mortality (demographic outcome) among children is associated with maternal HIV status as indicated by the results of this study, the risk is significantly reduced by medical interventions such as ART and PMCT that affect both proximate and biological determinants (Boerma and Weir 2005). ART and PMTCT reduce the viral load of the mother thereby reducing the child's susceptibility to vertical transmission of the virus. When the risk of infection reduces, the risk of HIV related mortality among children also reduces. Where the viral load is reduced to undetectable levels, vertical transmission of the virus becomes zero (Avert 2019). Therefore, reducing the viral load in infected mothers cancels the influence of maternal HIV-positive status on the risk of mortality among children.

In both surveys and in all the three models, children aged less than one month faced a relatively higher risk of dying compared to older children. In model 1, children

aged less than one month were compared with children aged 6 months, in model 2 they were compared with children aged 12 months, while in model 3 they were compared with children aged 24 months. The observed higher risk of dying among children aged less than a month relative to ages 6, 12 and 24 months is expected since mortality in younger ages decreases with age (Timæus and Moultrie 2013). It is also observed that the risk of dying among children aged less than one month increased between 2007 and 2013/14. Despite the risk of dying attributed to maternal HIV-positive status reducing between the inter-survey period, the increased risk of dying among children under the age of one month could be explained by other factors such as infections that newly-born children are susceptible to due to their weak immune system. A study at the University Teaching Hospital, Zambia's biggest referral hospital, indicates that in 2015 the death rate among neonatal children reached 60 per cent, mostly caused by sepsis (Sakala 2019). Though a generalisation cannot be drawn, it is highly likely that other health facilities prior to or around that period may also have had similar challenges in preventing such infections among neonates.

The study also established that in 2007, children born to older women aged 40 years and above faced a higher risk of dying compared to children born to mothers aged below 25 years of age. However, this relationship was only significant in the full model for the 2007 survey. This finding is not unusual as childbearing by women in older ages is associated with a "heightened risk of dying in the first five years after birth" (Bicego and Ahmad 1996). With current total fertility rate in Zambia as high as 4.7, childbearing in older ages may not entirely be a choice but a sign of lack of access to contraceptives, since only about 46 and 37 per cent of married women aged 40-44 and 45-49 years, respectively, are using contraceptives (CSO, MOH and ICF 2019).

5 CONCLUSION

The aim of this study was to determine the influence of maternal HIV status on child mortality taking into account confounding factors. The ZDHS data for 2007 and 2013/14 which contain HIV serotesting data were used. The study applied survival analysis method using Poisson regression. To reduce selection bias due to possible omission of older children as a result of death of their mothers, only children born in the last 36 months of the survey were eligible for selection in the study.

HIV status of the mother was significantly associated with child mortality in both survey periods, though the relationship was insignificant in 2013/14 for children born in the last 12 months of the survey. Other significant factors were exposure duration (age of child) and maternal age.

The study has provided insights on the contribution of maternal HIV status on mortality in children that policy makers can use to formulate appropriate programmes or strategies aimed at reducing under-five mortality. The findings of the study indicate that the influence of maternal HIV status on mortality in children has been reducing over the years. This may be attributed to the increase in coverage of ART and PMTCT services thereby reducing vertical transmission of HIV. To further reduce the influence of maternal HIV on mortality in children, there is need for continued increase in coverage of PMTCT and ART services until universal coverage is achieved. Current coverage of ART (for PMTCT) among pregnant women is estimated to be above 95 per cent and 79 per cent among children aged 0-14 years (UNAIDS 2019).

There is also need for government's continued support towards meeting the 90 90 90 targets launched in 2014 by UNAIDS whose aim by 2020 is that 90 per cent of people living with HIV should know their status, 90 per cent of those diagnosed to be on ART, and 90 per cent of those on ART to achieve viral suppression (UNAIDS 2014). Achieving all the three targets would lower new HIV infections and prevalence in the country. Once these targets are met, the government can aim for universal coverage of ART to end the AIDS epidemic.

The research results indicate that there is a persistent high risk of mortality among children under the age of one month despite the influence of HIV reducing over the years. This can be attributed to susceptibility to infectious diseases among newborns, such as sepsis. Therefore, to reduce mortality among neonates, there is need for increased child healthcare coverage such as immunisations and vaccinations to prevent

them from acquiring preventable infections. There is also need for more public health awareness and adherence to child healthcare guidelines regarding handling of newborns both at home and health facilities to avoid transmission of disease pathogens. As reported by Sakala, hand hygiene using a low-cost alcohol hand-rub and cleaning of the environment with disinfectants would greatly reduce infectious diseases that affect newborns.

The study also indicates that childbearing in older ages (40 years and above) is more risk than in younger ages, even though the results were only significant for the 2007 survey. Childbearing in older ages may be associated with low use of contraceptives by older women. There is, therefore, need to make modern contraceptive methods more available and affordable as well as providing a wider choice. This could be coupled with creating health awareness on the dangers of bearing children in older ages to both mother and child.

The data used in this study are from a nationally representative sample. Therefore, the findings can be generalized to the whole population. However, a number of challenges, such as the ones highlighted below, could have affected the findings.

An assessment of age at death indicated that some ages were affected by heaping, which was worse at ages 6, 9, 12 and 24 months. Even though corrections were made, especially for ages 12 and 24 months, age heaping may lead to underestimation of deaths and hence compromise estimates.

In the 2007 survey, the response rate for HIV testing among eligible women was low compared to the 2013/14 survey, resulting in a huge percentage of children with mothers whose HIV status was unknown. This may affect comparability of findings as 2007 estimates may have been underestimated. In addition, in both surveys, a number of observations in the HIV test recode could not be linked to the women's recode and were, therefore, not included in the analyses. These women, together with women whose HIV status was unknown, could lead to underestimation of estimates if a significant number of them were HIV-positive.

The findings of this study only indicate the existence of correlation and not causation. The study lacked information to ascertain actual cause of death of the child or HIV status for living children. Children who died and whose mothers were HIV-positive at the time of the survey may not necessarily have died from HIV/AIDS-related causes.

Women were tested for HIV at the time of the survey. It is, therefore, not possible to know whether those found HIV-positive became infected before or after the death of their children. This may lead to exaggeration of the influence of maternal HIV-positive status on mortality especially in cases were the mother became infected after the child died.

The findings may not reflect the current status of the influence of maternal HIV-positive status on mortality in children due to lack of current data. The study relied on old data as it was conducted before the ZDHS for 2018 was released. It is, therefore, recommended that further research that incorporates the latest ZDHS data be conducted.

Information on both living and dead children whose mothers died prior to the survey is not included in this study. This is because in the DHS information on full birth history is collected from mothers. In a situation where mortality of mothers is high and correlated with mortality of their children, as the case is in populations with high HIV prevalence, research findings may be underestimated since many children would have been left out of the study on account of death of their mothers. Adjustments for this possible bias was out of scope of this study.

There are many other determinants of under-five mortality besides the ones that were considered in this study. Only demographic, socioeconomic and environmental factors with high response rates and low collinearity were considered as confounding factors in the multivariate model used to estimate the influence of maternal HIV status on mortality in children.

Apart from incorporating the latest ZDHS data, it is recommended that future research also focuses on analyzing regional variations in the risk of childhood mortality associated with maternal HIV status. This would help in identifying regions with persistent high risk of childhood mortality associated with maternal HIV. This would further help identify factors contributing to HIV-related mortality in the identified high-risk regions such as distance covered to health centre, low coverage of PMTCT and ART services, and lack of adherence to medication etc.

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7 APPENDIX

Table 7.1 Model 1: Poisson regression results for children born within 12 months of the survey (weighted), ZDHS 2007 and 2013/4

	ZDHS 2007		ZDHS 2013/14	
Independent variables	**IRR**	**P-value**	**IRR**	**P-value**
Age of child (exposure duration)				
Less than 1 month	5.588	0.000	8.958	0.000
1 month	0.755	0.566	1.025	0.966
3 months	0.367	0.103	0.793	0.720
9 months	0.753	0.790	0.000	0.000
6 months (ref)				
Maternal HIV status				
HIV positive	5.292	0.000	1.526	0.313
Unknown HIV status	0.952	0.905	0.312	0.222
HIV negative (ref)				
Maternal age				
25-39 years	0.834	0.618	1.403	0.419
40 years and above	0.864	0.847	2.445	0.182
Below 25 years (ref)				
Sex of child				
Female	0.966	0.901	1.170	0.603
Male (ref)				
Preceding birth interval				
Normal interval (24-35 months)	1.701	0.437	0.770	0.572
First births	2.172	0.295	1.885	0.346
Short interval (< 24 months) - ref				
Current marital status				
Ever married	1.264	0.647	0.664	0.432
Never married (ref)				
Place of delivery of child				
Health facility	0.665	0.277	0.544	0.152
Unknown	2.553	0.442	0.000	0.000
Home (ref)				
Mother's highest level of education				
Primary education	1.072	0.877	1.383	0.530
Secondary or higher	0.962	0.947	1.488	0.518
Unknown			0.000	0.000
No education (ref)				
Type of place of residence				
Rural	1.627	0.264	0.636	0.254
Urban (ref)				
Type of toilet facility				
Traditional toilet	0.770	0.464	1.893	0.169
Modern toilet	0.526	0.350	0.798	0.777
Unknown & non-residents	0.519	0.312	1.731	0.562
No toilet (ref)				
Source of drinking water				
Protected water	1.173	0.777	0.969	0.954
Unprotected water	0.682	0.477	1.179	0.756
Unknown & non-residents	0.078	0.001	3.850	0.194
Piped water (ref)				
Main floor material of the house				
Finished	2.162	0.039	1.273	0.584
Unknown & non-residents	28.490	0.001	0.297	0.154
Natural (ref)				
Number of observations	4,328		8,376	

Table 7.2 Model 2: Poisson regression results for children born within 24 months of the survey (weighted), ZDHS 2007 and 2013/4

	ZDHS 2007		ZDHS 2013/14	
Independent variables	**IRR**	**P-value**	**IRR**	**P-value**
Age of child (exposure duration)				
Less than 1 month	17.629	0.000	22.557	0.000
1 month	3.762	0.001	1.918	0.234
3 months	2.098	0.079	2.339	0.142
6 months	1.937	0.130	2.067	0.193
9 months	2.391	0.045	1.811	0.295
18 months	0.899	0.899	1.405	0.656
12 months (ref)				
Maternal HIV status				
HIV positive	4.445	0.000	3.291	0.000
Unknown HIV status	1.302	0.267	1.388	0.451
HIV negative (ref)				
Maternal age				
25-39 years	1.358	0.175	0.790	0.430
40 years and above	2.234	0.077	1.234	0.669
Below 25 years (ref)				
Sex of child				
Female	0.949	0.774	1.081	0.693
Male (ref)				
Preceding birth interval				
Normal interval (24-35 months)	0.906	0.736	1.015	0.964
First births	1.827	0.101	1.728	0.175
Short interval (< 24 months) - ref				
Current marital status				
Ever married	1.309	0.457	0.941	0.854
Never married (ref)				
Place of delivery of child				
Health facility	1.034	0.875	0.986	0.954
Unknown	1.554	0.693	0.000	0.000
Home (ref)				
Mother's highest level of education				
Primary education	1.333	0.363	1.305	0.431
Secondary or higher	1.431	0.317	1.507	0.296
Unknown			0.000	0.000
No education (ref)				
Type of place of residence				
Rural	0.995	0.983	0.945	0.828
Urban (ref)				
Type of toilet facility				
Traditional toilet	1.034	0.883	1.056	0.834
Modern toilet	0.853	0.701	0.746	0.605
Unknown & non-residents	0.543	0.761	1.183	0.794
No toilet (ref)				
Source of drinking water				
Protected water	1.165	0.665	1.111	0.738
Unprotected water	1.369	0.306	1.190	0.592
Unknown & non-residents	0.922	0.903	1.754	0.458
Piped water (ref)				
Main floor material of the house				
Finished	1.514	0.115	1.150	0.650
Unknown & non-residents	3.145	0.551	0.735	0.635
Natural (ref)				
Number of observations	12,811		25,190	

Table 7.3 Model 3: Poisson regression results for children born within 36 months of the survey (weighted), ZDHS 2007 and 2013/14

	ZDHS 2007		ZDHS 2013/14	
Independent variables	**IRR**	**P-value**	**IRR**	**P-value**
Age of child (exposure duration)				
Less than 1 month	9.680	0.000	23.462	0.000
1 month	1.993	0.066	1.900	0.159
3 months	1.329	0.462	2.187	0.095
6 months	1.135	0.751	2.145	0.088
9 months	1.259	0.562	2.498	0.041
12 months	0.702	0.382	1.600	0.304
18 months	0.981	0.962	1.444	0.448
30 months	0.445	0.443	0.000	0.000
24 months (ref)				
Maternal HIV status				
HIV positive	3.824	0.000	3.474	0.000
Unknown HIV status	1.148	0.446	1.883	0.025
HIV negative (ref)				
Maternal age				
25-39 years	1.131	0.469	0.768	0.169
40 years and above	2.021	0.035	1.529	0.198
Below 25 years (ref)				
Sex of child				
Female	0.925	0.582	0.971	0.838
Male (ref)				
Preceding birth interval				
Normal interval (24-35 months)	0.709	0.087	0.768	0.208
First births	1.316	0.285	1.416	0.175
Short interval (< 24 months) - ref				
Current marital status				
Ever married	1.269	0.413	1.166	0.569
Never married (ref)				
Place of delivery of child				
Health facility	1.052	0.751	0.865	0.392
Unknown	4.015	0.016	0.139	0.053
Home (ref)				
Mother's highest level of education				
Primary education	0.886	0.557	1.196	0.461
Secondary or higher	0.833	0.474	1.138	0.657
Unknown			9.085	0.049
No education (ref)				
Type of place of residence				
Rural	1.037	0.853	0.961	0.839
Urban (ref)				
Type of toilet facility				
Traditional toilet	1.040	0.825	0.943	0.756
Modern toilet	1.255	0.488	0.757	0.473
Unknown & non-residents	0.351	0.608	0.795	0.698
No toilet (ref)				
Source of drinking water				
Protected water	1.240	0.396	0.969	0.892
Unprotected water	1.191	0.437	1.083	0.736
Unknown & non-residents	1.475	0.368	1.252	0.784
Piped water (ref)				
Main floor material of the house				
Finished	1.159	0.476	1.048	0.832
Unknown & non-residents	3.139	0.565	0.945	0.923
Natural (ref)				
Number of observations	23,011		46,825	