The Impact of HIV/AIDS on Under-Five Mortality in Malawi

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To mum, uncle, aunt, sister and cousins for their continued love, encouragement, and support.

Keywords

AIDS Impact Model

DemProj

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Malawi

Mortality

Mother-to-Child Transmission

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Under-five mortality

Abstract

Although the under-five mortality rate in Malawi has been declining since 1960, it still remains one of the highest in the world. In order to appropriately target interventions to achieve substantial reductions in deaths among children under the age of five years in Malawi, there is an ongoing need for better knowledge of the proportion of cause-specific under-five mortality in the country. Responding to this need, this study has estimated the proportion of under-five mortality directly attributable to HIV/AIDS in Malawi during the period 2000 to 2004. The study used some of the existing indirect methods and mathematical models. To a larger extent, the study adopted the methods and approaches recommended by UNAIDS and WHO, particularly those implemented in DemProj and AIDS Impact Model both of which are part of the Spectrum package. HIV/AIDS is estimated to have directly caused about 12.6 percent of under-five mortality in Malawi between 2000 and 2004 and to have significantly hampered achievement of the country's overall under-five mortality reduction goals. Although expansion of coverage of treatment with Nevirapine (which is the currently available prevention of mother-to-child transmission (PMTCT) service in Malawi) would help reduce HIV/AIDS attributable under-five mortality, the conclusion drawn from the findings of this study is that in order to make substantial contributions to the country's overall under-five mortality reduction goals, Malawi needs to intensify its efforts in all the four key components of a comprehensive set of PMTCT services. Furthermore, Malawi also needs to strengthen its efforts in addressing other major causes of under-five mortality besides putting in place a comprehensive set of PMTCT services in order to achieve further substantial reductions in deaths among children less than five years of age.

Declaration

I declare that *The Impact of HIV/AIDS on Under-Five Mortality in Malawi* is my own work, that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

Chodziwadziwa Whiteson Kabudula November 2007

Signed:.....

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Acronyms and abbreviations

ANC	Antenatal clinic
AIDS	Acquired Immunodeficiency Syndrome
AIM	AIDS Impact Model
DHS	Demographic and Health Survey
HIV	Human Immunodeficiency Virus
IDU	Injection drug users
MDG	Millennium Development Goals
MLT	Model Life Table
MSM	Men who have sex with men
MTCT	Mother-to-child transmission
NAC	National AIDS Commission [Malawi]
NSO	National Statistical Office [Malawi]
PMTCT	Prevention of mother-to-child transmission
PTR	Perinatal transmission rate
SSA	Sub-Saharan Africa
U5MR	Under-five mortality rate

Chapter 1

Introduction

1.1 Background to the study

Most countries in the world registered substantial reductions in mortality among infants and children during the late 20th century (Ahmad et al., 2000). However, under-five mortality still remains one of the leading challenges for public health especially in the developing world. About 11 million children still die every year before their fifth birthday worldwide and more than 10 million of these deaths occur in the developing world (Hill and Amouzou, 2006; Black et al., 2003). Within the developing world, Sub-Saharan Africa (SSA) is the most severely affected region and accounts for more than one-third of global under-five deaths (Hill and Amouzou, 2006).

Factors responsible for the high levels of under-five mortality in the developing world and SSA in particular are many and varied. The high mortality levels are either the effect of poor social, economic, cultural, and health system conditions that operate through a set of proximate determinants that directly influence the risk of disease and the outcome of disease processes proposed by Mosley and Chen (1984) or negative changes in the proximate

determinants themselves. A study conducted by Rutstein (2000) illustrates the association between high mortality among children less than five years of age and negative changes in some of the proximate determinants of child mortality in developing countries. Factors examined by Rutstein (2000) include fertility behaviours, nutritional status of children and patterns of breastfeeding and infant feeding, maternal and child health status and the use of health services, environmental health conditions and socioeconomic factors. Although these factors influence the occurrence of a wide spectrum of childhood diseases, only five communicable diseases (pneumonia, diarrhea, malaria, measles and HIV/AIDS) are responsible for more than half of deaths in children under the age of five years in developing countries (Bryce et al, 2005; WHO, 2005a). Being the world's most severely HIV/AIDS affected region (UNAIDS 2006), the under-five mortality burden of HIV/AIDS is most pronounced in SSA. There is an indication that paediatric HIV infection contracted through mother-to-child transmission (MTCT) is significantly contributing to the observed level of under-five mortality in SSA countries with high adult HIV prevalence (Adetunji, 2000; Walker, 2002; Garenne and Gakusi, 2006).

Although the under-five mortality rate (U5MR) in Malawi has been declining since 1960 (Hill et al, 1998; Ahmad et al., 2000, UNICEF, 1998 and 2005), Malawi's under-five mortality remains one of the highest in the world. As of 2004, Malawi's under-five mortality was ranked 19 in the world in terms of severity (UNICEF, 2005). With respect to adult HIV/AIDS infection, Malawi also has one of the highest prevalence rates in the world. According to UNAIDS (2006), HIV prevalence rate among adults aged 15 to 49 stands at 14.1%. Without doubt, the high adult HIV prevalence in Malawi has an effect on the levels of under-five mortality in the country. However, the magnitude of the contribution of HIV/AIDS to the most recent estimates of under-five mortality in Malawi is not clearly known. In order to appropriately target interventions to reduce deaths among children under the age of five years and to monitor progress there remains an ongoing need to understand better the proportion of cause-specific under-five mortality. Therefore, this study aims at estimating the direct contribution of HIV/AIDS to the observed level of under-five mortality in Malawi during the period 2000 to 2004.

1.2 Statement of the problem

The most recent estimates of U5MR in Malawi available at the time of conducting this study are based on the 2004 Malawi Demographic and Health Survey (DHS). The estimates indicate that the number of deaths among children aged below five years stood at 133 deaths per 1 000 live births for the period 2000 to 2004 (NSO and ORC Macro, 2005). However, the proportion of under-five mortality that can be directly attributed to HIV/AIDS contracted through MTCT during this period is not clearly known. Therefore, there is need for estimates of the under-five mortality directly attributable to HIV/AIDS during this period to assess the magnitude by which prevention of mother-to-child transmission (PMTCT) programmes currently being implemented in Malawi would potentially have reduced this observed level of under-five mortality.

1.3 Aim and objectives of the study

The aim of this study is to estimate the direct contribution of HIV/AIDS to the observed level of under-five mortality in Malawi during the period 2000 to 2004. Although there are many ways in which adult HIV/AIDS could affect the level of under-five mortality as outlined by Adetunji (2000) and Walker et al. (2002), this study will only estimate the contribution of HIV/AIDS to under-five mortality that resulted through vertical or perinatal transmission of HIV from infected mothers to their children. Thus, estimates of the indirect effects of adult HIV/AIDS on under-five mortality are outside the scope of this study. Specifically, the objective of this study is to estimate how much of the under-five mortality observed in Malawi for the period 2000 to 2004 is directly attributable to HIV/AIDS.

1.4 Research question

This study attempts to answer the following question: *What proportion of the under-five mortality observed in Malawi for the period 2000 to 2004 would be directly attributed to HIV/AIDS?*

1.5 Rationale and significance of this study

Like majority of countries in the world, Malawi signed the Millennium Declaration that was adopted in September 2000 (http://www.ohchr.org/english/law/millennium.htm) and therefore became party to the Millennium Development Goal (MDG) of reducing by two thirds the U5MR observed in 1990 by 2015 (http://www.un.org/millenniumgoals/; Hill and Amouzou, 2006; Walker et al., 2002, Malawi millennium development goals report 2003). This reduction translates into an annual average reduction rate of 4.3%.

Malawi's U5MR was one of the highest in SSA in 1990. Estimates based on the 1992 Malawi DHS indicate that the number of deaths among children aged below five years for the period 1988 to 1992 was 234 deaths per 1 000 live births (NSO and ORC Macro, 1994). This means that Malawi targets to reduce its U5MR to 78 deaths per 1 000 live births by the year 2015, which is still high by world standards.

Although Malawi experienced a decline in under-five mortality from 234 deaths per 1 000 live births in 1990 to 133 deaths per 1 000 live births in 2004 (NSO and ORC Macro, 1994 and 2005), the annual average rate of reduction (3.96%) during this period is lower than the expected target of 4.3%. Thus, Malawi is slightly off track in meeting the child-survival MDG. Therefore, in order to properly target interventions to achieve further substantial reductions in U5MR, the Malawian government and other stakeholders need cause-specific estimates of the country's under-five mortality. Malawi being a country with one of the highest HIV prevalence rates in the world, it is of interest to estimate the proportion of under-

five mortality that is directly attributable to HIV/AIDS to guage the potential contribution of PMTCT programmes towards meeting the overall child-survival MDG. Further, for the first time Malawi now has national HIV prevalence estimates for men and women derived from the 2004 Malawi DHS which included HIV testing (NSO and ORC Macro, 2005). As estimates of HIV prevalence are an integral part of the process of estimating the direct effect of HIV/AIDS on under-five mortality, it is inevitable to incorporate the information on HIV prevalence from this general population-based survey into the existing data and make new estimates of the direct impact of HIV/AIDS on under-five mortality in Malawi. Results of this study are expected to be of policy relevance to Malawi and other countries experiencing similar HIV prevalence and mortality patterns.

1.6 Conceptual framework

This study is based on the premise that the number of children under the age of five years who die of HIV/AIDS is directly related to the number of children who acquired HIV infection from their mothers. Therefore, the proportion of under-five year old children dying from HIV/AIDS is a function of the proportion of HIV-infected mothers, the rate of MTCT and the proportion of infected children who die before their fifth birthday (Adetunji, 2000).

1.7 Research methodology

While population-based data on total under-five mortality are increasingly available through the DHS (http://www.measuredhs.com/), population-based epidemiological data are extremely limited in SSA countries. In most countries reliable data on cause of death are uncommon because vital registration systems have extremely limited coverage (Adetunji, 2000; Salomon and Murray, 2001; Walker et al. 2002). For this reason, demographers

and health researchers have tended to resort to indirect methods, including the use of mathematical models in estimating the proportion of cause-specific under-five mortality. With respect to HIV/AIDS, some of the indirect methods and mathematical models used to estimate its contribution towards under-five mortality include those reported by Adetunji (2000), Walker et al. (2002), Zaba et al. (2003), Stover (2005) and Johnson and Dorrington (2006). This study uses some of the existing indirect methods and mathematical models to derive estimates of under-five mortality directly attributable to HIV/AIDS in Malawi for the period 2000 to 2004. To a larger extent, the study adopted the methods and approaches recommended by UNAIDS and WHO that are implemented in DemProj and AIDS Impact Model computer packages (The UNAIDS Reference Group on Estimates, Models and Projections, 2003; Stover and Kirmeyer, 2004; Stover 2005). No new data were collected, instead the study used secondary data and published reports.

1.8 Definitions of key concepts

The following definitions of the key concepts or terms are used in this study.

Acquired Immunodeficiency Syndrome (AIDS): A disease of the body's immune system caused by the human immunodeficiency virus (HIV). It is characterized by the death of CD4 cells (an important part of the body's immune system), which leaves the body vulnerable to life-threatening conditions such as infections and cancers.

Death: Permanent disappearance of all evidence of life at any time after birth has taken place.

Epidemic: A disease that has spread rapidly through a segment of the human population in a given geographic area.

Human Immunodeficiency Virus (HIV): The virus that causes AIDS. HIV belongs to the retrovirus family, and has two subtypes: HIV-1, which is responsible for most HIV

infections throughout the world, and HIV-2 which is found primarily in West Africa.

HIV prevalence: The number of HIV-infected people in a population at a given time.

Mortality: A general term for incidence of deaths in a population or group.

Mother-to-Child Transmission (MTCT): The passage of HIV from an HIV-infected mother to her infant. The infant may become infected while in the mother's womb, during labour and delivery, or through breastfeeding.

Sub-Saharan Africa: The term used to describe the area of the African continent which lies south of the Sahara desert.

Under-five mortality: The probability of dying between birth and the fifth birthday.

Women of reproductive age: Women aged from 15 to 49 years.

1.9 Structure of the thesis

This chapter has outlined the main research problem under investigation in this study. The chapter has presented the main aims and objectives of this study and provided the rationale for carrying out the study. This chapter has also briefly described the conceptual framework for this study as well as the methodology used. Chapter two presents a review of the literature on a number of aspects pertaining to this study, which include: a brief history of HIV/AIDS; an overview of the global HIV/AIDS situation; an overview of the HIV/AIDS situation in Malawi; mechanisms through which HIV/AIDS contributes to child mortality; and ways of reducing HIV/AIDS attributable mortality in children. Chapter three provides a detailed description of the methods and approaches used in this study. Chapter four contains the results of the study. Chapter five presents a discussion of the results of the study and conclusions drawn from the findings. Lastly, the Appendix contains selected

programs written in R that were used to obtain the results of this study.

Chapter 2

Literature review

This chapter presents a review of the literature on a number of aspects pertaining to this study. The chapter consists of six sections. The first section presents a brief natural history of HIV/AIDS. The second section presents an overview of the global HIV/AIDS situation. The third section presents an overview of the HIV/AIDS situation in Malawi. The fourth section describes the mechanisms through which HIV/AIDS contributes to child mortality. The fifth section presents ways of reducing HIV/AIDS attributable mortality in children. Finally, the sixth section presents information pertaining to Malawi's response to the HIV/AIDS epidemic and efforts to to reduce under-five mortality attributable to HIV/AIDS.

2.1 Brief natural history of HIV/AIDS

AIDS initially emerged as two rare illnesses that affected a few homosexual men in California and New York City in the United States of America in 1981. These were five cases of Pneumocystis carinii pneumonia (CDC, 1981a) and 26 cases of a vascular skin tumor known as Kaposi's sarcoma among young and otherwise health homosexual men (CDC, 1981b).

It was discovered that both of these rare diseases were associated with a deficiency in the immune system evidenced by a decline in the number of helper T lymphocytes (CD4 + T Lymphocytes) (Brookmeyer and Gail, 1994:3). However, case reports of all these patients indicated that none of them suffered from any underlying illness that would be responsible for the development of these often fatal and uncommon diseases (CDC, 1981a; CDC, 1981b; Brookmeyer and Gail, 1994:3; Kelly and St. Lawrence, 1988:2). The Centers for Disease Control and Prevention (CDC) then named the syndrome accounting for these few cases of mysterious illnesses as acquired immune deficiency syndrome (AIDS) in 1982 (Brookmeyer and Gail, 1994:3).

The CDC defined AIDS as a disease that was "at least moderately predictive of a defect in cell-mediated immunity, occurring in a person with no known cause for diminished resistance to that disease" such as Pneumocystis carinii pneumonia, Kaposi's sarcoma and serious opportunistic infections (CDC, 1982). From June 1, 1981 to September 15, 1982, the CDC received reports of 593 AIDS cases out of which 243 (41%) cases had died (CDC, 1982). Thereafter, the number of AIDS cases and deaths began to rise, but the underlying causes of the immune deficiencies seen in the AIDS cases were unknown. In response, medical investigators scrambled to find a cause and more importantly a cure for this new disease. Then in 1983, investigators at the Institut Pasteur in France identified unusual serum antibodies in a majority of AIDS patients and isolated a retrovirus that they believe to be responsible for those antibodies (Cichocki, 2006). They named this virus as lymphadenopathy-associated virus (LAV) (Kelly and St. Lawrence, 1988:2). A year later the United States government announced that their scientist, Dr. Robert Gallo of the National Cancer Institute isolated a retrovirus called human T-cell lymphotropic virus type III (HTLV-III), that he too claimed was responsible for the AIDS outbreak. This resulted in a dispute between teams from the two research institutions (Barnett and Blaikie, 1992:2). Two years later it was confirmed that HTLV-III and LAV were actually the same virus (Cichocki 2006; Kelly and St. Lawrence, 1988:2), and Gallo was still credited with its discovery (Cichocki, 2006). Following this confirmation, an international committee of scientists renamed the virus as Human Immunodeficiency Virus (HIV) (Cichocki, 2006; Kelly and St. Lawrence,

1988:2; Brookmeyer and Gail, 1994:4).

The discovery of HIV set the stage for advancing knowledge about the dynamical features of HIV and AIDS. A wealth of information is now available on the transmission mechanism of HIV and the progression from HIV infection through AIDS. It is now known that HIV transmission can occur when there is contact between specific body fluids, particularly blood, vaginal secretions, semen, pre-ejaculatory fluid and breast milk of an HIV-infected person and the blood and/or mucous membranes of an uninfected person (Lewthwaite and Wilkins, 2005; Schoeberlein, 2001; Levy, 1993). Currently there is no evidence that HIV can be transmitted through pure tears, mucous from the nose, saliva, sweat, urine and feces (Schoeberlein, 2001; Levy, 1993).

It is also now known that in adults, after acquisition of HIV, there are at least three phases to the course of HIV infection, which include primary HIV infection phase, latent phase, and symptomatic HIV infection phase (San Francisco AIDS Foundation 2006; Lewthwaite and Wilkins, 2005; Mindel and Tenant-Flowers, 2001; Bannister et al., 2000). Primary HIV infection, which is also called acute HIV infection or seroconversion illness represents the first stage of HIV infection after the acquisition of HIV when antibodies are developing (Mindel and Tenant-Flowers, 2001). During the primary or acute HIV infection phase, HIV makes its way to the lymph nodes and actively replicates and releases new virus particles into the bloodstream (San Francisco AIDS Foundation 2006). People at this stage often have a very high HIV viral load and the concentration of CD4+ T cells measured in their blood declines (Mindel and Tenant-Flowers, 2001; Bannister et al, 2000; Perelson and Nelson, 1999; Levy, 1993). Also during the primary or acute HIV infection phase some people experience flu-like symptoms, such as fevers, chills, night sweats, and rashes which usually last between two to six weeks and resolve without specific treatment (San Francisco AIDS Foundation 2006; Mindel and Tenant-Flowers, 2001; Bannister et al, 2000; Perelson and Nelson, 1999). However, people with acute HIV infection usually do not test positive for HIV antibodies until seroconversion, which commonly occurs between 6 to 12 weeks after infection is complete (San Francisco AIDS Foundation 2006; Piot and Colebunders, 1987). The latent phase of HIV infection succeeds seroconversion. After seroconversion, the concentration of CD4+

T cells in the blood usually increases again and declines gradually during the latent phase (Lewthwaite and Wilkins, 2005; Bannister et al, 2000; Perelson and Nelson, 1999). Also after seroconversion, the viral load in the blood falls to a much lower level called the 'set point' and remains relatively constant during the latent phase of HIV infection (Lewthwaite and Wilkins, 2005; Mindel and Tenant-Flowers, 2001; Bannister et al, 2000; Perelson and Nelson, 1999). Although, HIV antibodies continue to be detectable in the blood, for much of the latent phase the infected person looks and feels completely well and is not unduly susceptible to infections (San Francisco AIDS Foundation 2006; Bannister et al., 2000; Perelson and Nelson, 1999). In the absence of treatment, it has been reported that the latent phase of HIV infection lasts from 18 months to 15 years or more (Bannister et al, 2000; Callaway et al., 1999). A substantial reduction in the concentration of CD4+ T cells and increase in the viral load marks the end of the latent phase and the beginning of the symptomatic HIV infection phase (Bannister et al, 2000). During the early and medium stages of the symptomatic HIV infection phase, many people begin to experience some mild HIV infection symptoms, such as skin rashes, fatigue, night sweats, slight weight loss, mouth ulcers, and fungal skin and nail infections (San Francisco AIDS Foundation 2006; Piot and Colebunders, 1987). In the late stage of the symptomatic HIV infection phase called AIDS, the damage to the immune system is more severe. CD4+ T cell count falls below 200 cells per micro liter (Callaway et al., 1999) and viral load in the blood reaches above 10 000 genome copies per milliliter (Bannister et al, 2000). The overall weakness of the immune system during the late stage of the symptomatic HIV infection phase allows the establishment of opportunistic infections such as Pneumocystis carinii pneumonia, Mycobacterium avium complex disease, Kaposi's sarcoma, cytomegalovirus, toxoplasmosis, and candidiasis which eventually lead to death (San Francisco AIDS Foundation 2006; Bannister et al, 2000; Callaway et al., 1999; Piot and Colebunders, 1987). The course of HIV infection described above is summarized in Figure 2.1.

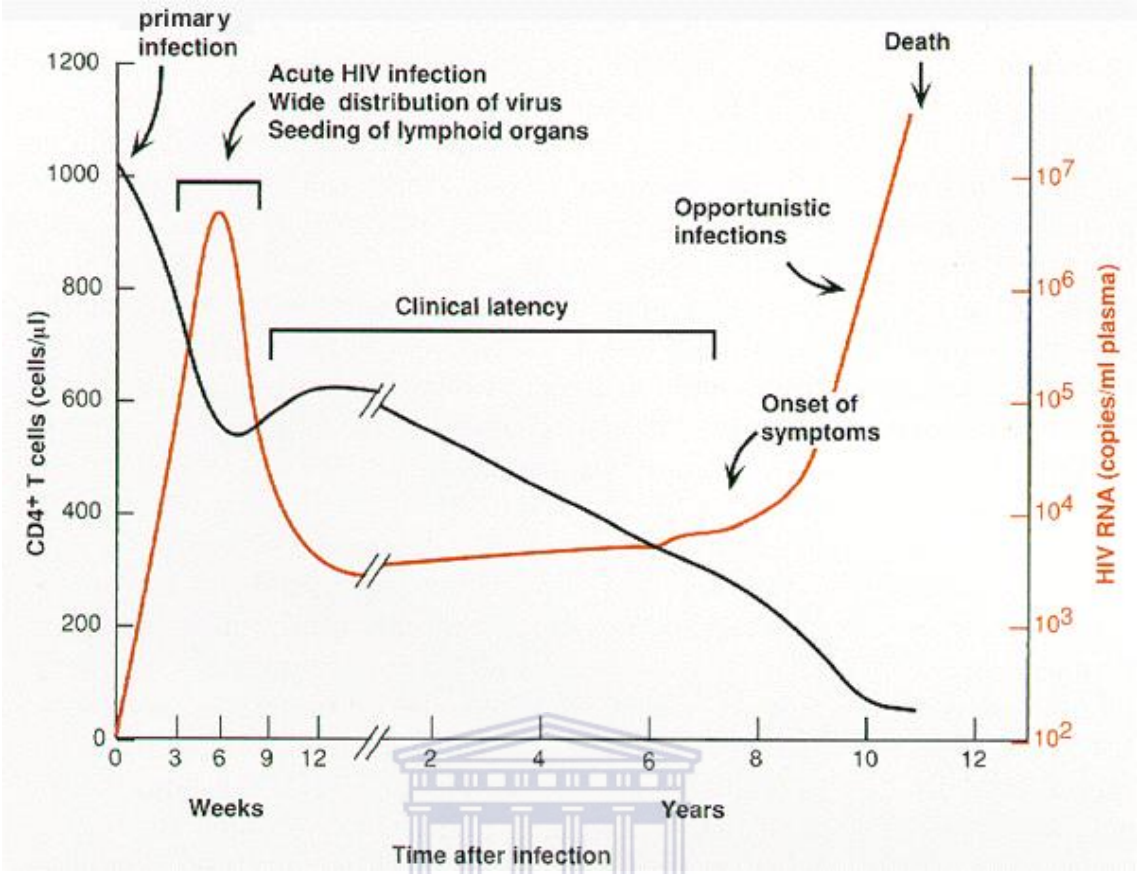

Figure 2.1: Stages of HIV infection.

Source: http://msl.cs.uiuc.edu/~yershova/bcb495/bcbProject-3_files/image015.gif.

Accessed on 20 June 2007.

2.2 Global HIV/AIDS situation

Since the first AIDS cases were reported among a few gay men in the United States of America quarter a century ago, AIDS has grown into a global epidemic in nearly every country worldwide. According to UNAIDS (2006), HIV has globally now infected more than 65 million people of whom an estimated 25 million people have died. In 2005 alone, an estimated 2.8 million people lost their lives to AIDS, 4.1 million people were newly infected with HIV and 38.6 million people were living with HIV worldwide.

Although the HIV/AIDS epidemic has emerged into a global epidemic, it is inaccurate to

speak of a single global HIV/AIDS epidemic. The HIV/AIDS epidemic has disproportionately affected certain geographic regions (for example, SSA and the Caribbean) and subpopulations (for example, women in SSA, men who have sex with men (MSM), injecting drug users (IDUs), and sex workers). Therefore, when assessing the global HIV/AIDS situation, it is important to take this heterogeneity into account. In the next paragraphs we present a summary of current HIV/AIDS trends in selected regions of the world based on the 2006 UNAIDS Report on the Global AIDS Epidemic and a report published on the eve of the 16th International AIDS Conference (August 13-18, 2006, in Toronto, Canada) in the Morbidity and Mortality Weekly Report by CDC.

Currently, SSA is rated as the world's most severely HIV/AIDS affected region because it has just over 10% of the total world's population but it is home to about 64% of all the people living with HIV in the world. The HIV/AIDS epidemic is suspected to have probably began in SSA about 75 years ago after some people who ate wild chimpanzees in Cameroon became infected with a low-virulence progenitor of the virus that causes AIDS (Will, 2006). The primarily mode through which HIV is transmitted among adults in this region is heterosexual contact (Buvé et al., 2002) and all the countries except Angola have an estimated HIV prevalence rate of more than 10 percent among adults aged 15 to 49 years. In 2005, an estimated 3.2 million people in the SSA region became newly infected with HIV, while 2.4 million people died of AIDS. The region also has more HIV infected women than men. In 2005, it was estimated that 4.6% of female youth aged 15-24 years were living with HIV compared to 1.7% of males of the same age group.

In SSA, the HIV/AIDS crisis is more severe in southern Africa- the epicenter of the HIV/AIDS epidemic. In Botswana, Lesotho, Swaziland and Zimbabwe, the estimated adult HIV prevalence rates are above 20%. In South Africa, the HIV/AIDS epidemic shows no evidence of abating. In 2005, South Africa had an estimated HIV prevalence rate of 18.8% in adults aged 15-49 years. It has also been estimated that there were 5.5 million people living with HIV in South Africa in 2005. This figure positioned South Africa as the country with the largest number of people living with HIV in the world along with India in Asia.

Despite remaining the world's severely HIV/AIDS affected region, declines in adult HIV prevalence have recently been observed in some countries in SSA. These countries are Kenya, Uganda, Zimbabwe and urban areas of Burkina Faso. Nevertheless, AIDS related deaths continue to rise in these countries.

In Asia, the HIV/AIDS epidemic is driven by sex workers, IDUs and MSM. Estimates for 2005 indicate that 8.3 million people of whom 2.4 million were adult women were living with HIV in Asia. Further, in Asia, an estimated 180 000 children were living with HIV and approximately 930 000 people were newly infected with HIV in 2005. So far, AIDS has claimed approximately 600 000 lives in Asia.

The HIV/AIDS estimates from Asia also indicate that more than two-thirds (about 5.7 million people) of all the people living with HIV in Asia live in India. While approximately 80% of the HIV infections in India are acquired through heterosexual contact, in China 650 000 IDUs account for about half of the people living with HIV, and in Thailand and Cambodia, the epidemic has largely been driven by commercial sex work. In Thailand, there has been a decline in HIV prevalence in pregnant women from 2.4% in 1995 to 1.2% in 2003. In contrast, HIV prevalence among MSM increased from 17% in 2003 to 28% in 2005.

Data from Eastern Europe and Central Asia indicate that the HIV/AIDS epidemic there is also continuing to spread. In 2005 it was estimated that about quarter of a million people were newly infected with HIV. This figure brought the total number of people living with HIV in this region to 1.5 million.

In America, most of the HIV infections occur among MSM, IDUs and sex workers. Brazil, the most populous country in the American continent after the United States had an estimated adult HIV prevalence of 0.5% and was home to approximately 30% of all the people living with HIV in South and Central America and the Caribbean in 2005. The Caribbean is the second most severely HIV/AIDS affected region after SSA and the epidemic there is also largely spread through heterosexual intercourse. Recent data indicate that national HIV prevalence rates in all the areas in the Caribbean except Haiti have remained

constant.Recently, there has also been an increase in evidence of resurgent epidemics in the United States of America and in some countries in Europe among MSM.

These statistics support the remark made by Elias A. Zerhouni and his colleagues from the National Institute of Allergy and Infectious Diseases (NIAID) in their statement on the 25th Anniversary of the First Published Reports of AIDS on June 5, 2006 that AIDS is the deadliest pandemic of our generation and one of the worst in human history (The Body, 2006). The HIV/AIDS epidemic has not spared any region, race, or social class of people worldwide. Both the powerful and powerless in every society worldwide are affected with this lethal epidemic.

2.3 HIV/AIDS situation in Malawi

The first AIDS cases in Malawi were diagnosed in 1985 (Avert, 2007; MEASURE Evaluation, 2004; Yoder and Matinga, 2004; NAC, 2003a). However, it has been argued that the 2% HIV prevalence rate discovered among antenatal clinic attendees at Queen Elizabeth Central Hospital in Blantyre in the southern region in that year suggests that the epidemic may have started in Malawi as earlier as 1977 (Yoder and Matinga, 2004).

Like elsewhere in SSA, in Malawi HIV is predominantly spread through heterosexual intercourse among the adult population and by vertical transmission to infants from HIV-infected mothers (NAC, 2003b). During the first decade of the HIV/AIDS epidemic in Malawi, prevalence among women attending antenatal clinics (ANC) grew rapidly. By 1998, 26% of antenatal clinic attendees in urban areas tested HIV positive (MEASURE Evaluation, 2004). Recent trends indicate that the median HIV prevalence for all antenatal attendees declined from 22.8% in 1999 to 16.9% in 2001, 17.0% in 2003 and 15.0% in 2005 (NAC, 2005). Although HIV prevalence rates remain high in urban areas compared to rural areas (Avert, 2007; WHO, 2005b), recent trends also suggest that HIV prevalence is declining in many urban areas and increasing in many rural ones (Avert, 2007; UNAIDS/WHO,

2005). However, national estimates of HIV prevalence in the adult population are reported to have remained constant since 1996 (NAC, 2005). Furthermore, HIV prevalence rates are particularly highest among women aged between 13 and 24 years (Avert, 2007; WHO, 2005b; UNAIDS/WHO, 2005). As high levels of movement between urban, rural and mining areas are important catalysts for the spread of HIV infection, the main drivers of the HIV epidemic in Malawi are mobile groups, which include truck drivers, sex workers, fishermen, fish traders, migrant and seasonal workers, military personnel, prisoners and refugees (Avert, 2007; WHO, 2005b).

2.4 HIV/AIDS and child mortality

HIV/AIDS contributes to child mortality both directly and indirectly. Directly, HIV/AIDS contributes to child mortality in the sense that children infected with HIV through MTCT themselves die of AIDS (Brahmbhatt, 2006; Hecht et al., 2006; Newell et al., 2004; Ng'weshemi et al., 2003; Adetunji, 2000; Peckham and Gibb, 1995). Indirectly, HIV/AIDS contributes to child mortality in the sense that families and communities weakened by HIV/AIDS render children more susceptible to illness and death from other causes (International AIDS Vaccine Initiative, 2005). There are many possible ways through which HIV/AIDS indirectly leads to negative health outcomes and consequently increased mortality among children regardless of the children's HIV status. Some of these ways include negative health impacts emanating from the death of or frequent illness of parents and care-givers, loss of health workers either through illness and death from HIV/AIDS or attrition of new workers from fear of infection and diversion of resources needed for provision of health care services for children to purchase the expensive drugs needed for caring those living with HIV/AIDS (Hecht et al., 2006; Ng'weshemi et al., 2003; Adetunji, 2000). Since the focus of this study is not on the indirect effects of HIV/AIDS on child mortality, we do not present a detailed review of the many possible scenarios through which HIV/AIDS indirectly contributes to child mortality. In the subsections that follow, we review various

issues pertaining to how HIV/AIDS directly contributes to child mortality which include available knowledge on acquisition of HIV infection in children, survival of HIV infected children and ways of reducing HIV/AIDS attributable child mortality.

2.4.1 Acquisition of HIV infection in children

According to Newell et al. (2004) and De Cock et al. (2000), the epidemiology of HIV/AIDS in children mirrors that among women of reproductive age. Children get infected with HIV nearly always through MTCT which can occur during pregnacy (intrauterine transmission), delivery (intrapartum transmission) and the breastfeeding period (postpartum transmission) (Newell et al., 2004; Dabis et al., 2000; Newell, 1998).

There are various ways in which intrauterine HIV transmission can occur. According to Newell (1998), intrauterine HIV transmission may occur through placental tears that would result in transfusion of HIV infected blood from the mother to the fetal circulation through either transplacental cellular traffic or by progressive infection of different placental layers until the virus reaches the fetoplacental circulation. Based on reviews by Newell (1998) and Newell et al. (2004), the available evidence that supports intrauterine HIV transmission indicates that infection is rare in early pregnancy but more common in late pregnancy. Another review by De Cock et al. (2000) indicate that in the absence of breastfeeding, intrauterine HIV transmission accounts for 30% of pediatric HIV infections and the remaining 70% of infant HIV infections occur during labour and delivery.

The available literature on intrapartum transmission indicates that during labour and delivery, transmission of HIV infection could occur through direct contact of the fetus/infant with HIV infected maternal blood and genital secretions during passage through the birth canal, through ascending infection from the vagina or cervix to the fetal membranes and amniotic fluid, through absorption in the fetal-neonatal digestive tract, and through maternal-fetal microtransfusion during uterine contractions in labour (Newell, 1998).

Some of the risk factors for intrauterine and intrapartum transmission identified in the literature include high maternal viral load, low maternal CD4+ T cell counts, advanced maternal immune deficiency, long labour and prolonged membrane rupture (Newell et al., 2004; De Cock et al., 2000; Newell, 1998; Peckham and Gibb, 1995). According to a review by De Cock et al. (2000), in untreated nonbreastfeeding populations, cumulative rates of HIV transmission during the intrauterine and intrapartum periods range from 14% to 32%.

Newell et al. (2004) report that breastfeeding approximately doubles the risk of HIV transmission. Newell (1998) states that transmission of HIV through breast milk can occur in situations where the mother becomes infected with HIV shortly after delivery as well as in established maternal HIV infections. Although HIV transmission through breast milk can occur at any point during lactation, the empirical evidence from epidemiologic cohort studies and clinical trials reviewed by Fowler and Newell (2002) suggest higher transmission risk in the first six months of life compared with low rates in the second year of life. The risk factors for postpartum transmission of HIV infection through breastfeeding include maternal viral load in plasma and breast milk, HIV-related maternal immune status, breeding nipples, subclinical and clinical mastitis and breast abscesses (UNICEF, UNAIDS, WHO and UNFPA, 2004; Fowler and Newell, 2002). It has also been suggested that seroconversion of the mother during lactation increases the risk of postpartum transmission of HIV infection through breastfeeding (De Cock et al, 2000). In their review, De Cock et al. (2000) found that among breastfeeding populations in resource poor settings cumulative transmission rates of HIV infection range from 25% to 48%.

2.4.2 Survival of HIV infected children

There is limited information regarding the survival status of children who acquire HIV infection from their mothers through MTCT. Very few community-based studies have measured the HIV status of infants and tracked their survival because the persistence of maternal antibodies in the blood of infants makes the standard ELISA HIV tests which are

used for adults inappropriate for testing children and alternative polymerase chain reaction (PCR) tests that can detect the presence of the virus (as opposed to HIV antibodies) are very expensive and difficult to administer outside of a hospital setting (Zaba et al., 2003).

As reported by The UNAIDS Reference Group on Estimates, Modelling and Projections (2002), there is no information on long term survival of children infected with HIV via MTCT. Most of the few studies that have measured the HIV status of infants (for instance, a study in Blantyre, Malawi by Taha et al. (2000) and another study in the Gambia by Ota et al. (2000)) have only tracked their survival up to around 24 to 36 months of life (The UNAIDS Reference Group on Estimates, Modelling and Projections, 2002). Only one study conducted in Kigali, Rwanda followed HIV-infected children until five years of age (Spira et al., 1999).

After reviewing published and unpublished data of some of the studies on survival outcomes of HIV infected children which included studies by Dabis et al. (2001) in Cote d'Ivoire and Burkina Faso, Spira et al. (1999) in Rwanda, Lepage et al. (1998) in Uganda, Jean et al. (1999) in Haiti and Bobat et al. (1999) in South Africa, The UNAIDS Reference Group on Estimates, Modelling and Projections (2002) recommended that survival times for HIV infected children up to 15 years of life be generated by a double Weibull distribution which takes the form,

$$S(y) = 1 - [p(1 - exp(-(\beta_1 y)^{\alpha_1})) + (1-p)(1 - exp(-(\beta_2 y)^{\alpha_2}))] \tag{2.1}$$

where $S(y)$ represents the fraction of children who have not died from HIV-related causes y years after birth, p is the proportion of children who progress to death rapidly, α_1, β_1, α_2 and β_2, are parameters of the component Weibull curves describing mortality amongst the group of children that progress to death rapidly and the group of children that progress to death slowly respectively (Zaba et al., 2003).

The above formulation of the survival curve for HIV infected children allows for two periods of very high mortality: in infancy when HIV frequently overwhelms the immature immune system, and after age nine, when it is assumed that the few remaining survivors will succumb

to opportunistic infections and progress to AIDS in the same way as adults (The UNAIDS Reference Group on Estimates, Modelling and Projections, 2002). Fitting of this curve to the reviewed data suggested that by five years after birth 60% of HIV infected children would be dead.

2.4.3 Reducing under-five mortality attributable to HIV/AIDS

According to Walker et al. (2002), HIV/AIDS attributable under-five mortality can be reduced in three main ways. First is reduction of HIV prevalence in women of childbearing age, second is prevention of unwanted pregnancies in HIV-infected women and third is direct prevention of MTCT of HIV infection from infected mothers to their infants. Interventions designed to reduce HIV prevalence in women of childbearing age are those that are also intended to reduce the spread of HIV in the adult population and they include mass media campaigns, promotion of voluntary counseling and testing, condom social marketing, improved treatment for sexually transmitted infections and public sector condom promotion and distribution (Johnson and Dorrington, 2006; Stover et al., 2002). Presently, the available approaches to interventions to prevent MTCT of HIV infection only target the peripartum period. Interventions demonstrated to be effective include the reduction of maternal viral load through antiretroviral therapy in pregnancy and during delivery, the avoidance of exposure to contaminated maternal secretions through elective caesarean section delivery, and the avoidance of breastfeeding (Newell et al., 2004). The available evidence indicate that MTCT can be greatly reduced by the administration of zidovudine (ZDV) orally to the woman initiated between 14 and 34 weeks of gestation, intravenously during labour and orally to the neonate in the first six weeks of life (Dabis et al., 2000; De Cock et al., 2000). Reductions in transmission of one half to one third have been demonstrated in trials of simplified ZDV regimens in Southeast Asia and SSA (De Cock et al., 2000). Intrapartum and neonatal single-dose of Nevirapine has also been demonstrated to achieve similar reductions in MTCT as ZDV (Guay et al., 1999).

2.5 Malawi's response to the HIV/AIDS epidemic and efforts to reduce under-five mortality attributable to HIV/AIDS

Following the identification of the first AIDS cases, the Malawian government implemented a number of policies, institutional and operational strategies aimed at containing the epidemic and preventing new infections. These included the birth of the National AIDS Control Programme (NACP) in 1989 and the formation of the Cabinet Committee on Health and HIV/AIDS to provide policy and political direction to the Ministry of Health (Malawi HIV and AIDS Monitoring and Evaluation Report 2005).

Between 1989 and 1993, only two major interventions were implemented in an effort to stop the spread of HIV/AIDS in Malawi. These interventions were a blood screening policy and a strategy for health education about HIV/AIDS related risks and prevention (MEASURE Evaluation, 2004). As the toll of HIV/AIDS started to grow, Malawi realized the need to intensify its efforts in fighting the epidemic. By 1993, a multidisciplinary approach that incorporated social, psychological, and economic dimensions into the response to the epidemic was under development. The prevention and control strategies of NACP were broadened and encompassed activities in surveillance, voluntary counseling and testing, home-based care, information and education campaigns, behavioural change communications, control of sexually transmitted diseases and research (ibid). NACP also started to work with other stakeholders such as the private sector, nongovernmental organizations, donors, religious organizations, community-based organizations and people living with HIV/AIDS (ibid).

In 1996, an evaluation of the national response to the HIV/AIDS epidemic by the Malawian government and its collaborating partners in the fight against the epidemic found that although there was high awareness of HIV and AIDS, there was little behaviour change

and the epidemic continued to grow (Malawi HIV and AIDS Monitoring and Evaluation Report 2005). It was therefore recommended that Malawi should develop a comprehensive five-year plan to guide HIV and AIDS prevention, treatment and impact mitigation. This resulted in the development of the Malawi National HIV/AIDS Strategic Framework (NSF) in 1999. The NSF covered the period 2000 to 2004 and focused on prevention, advocacy, and behavior change; treatment, care, and support; sectoral mainstreaming; impact mitigation; and surveillance and monitoring. It also placed emphasis on the need for various stakeholders including the private sector, and teaching institutions to take an active role in designing, implementing, and monitoring the multi-sectoral and multidisciplinary HIV and AIDS interventions in the country (ibid).

The 1996 evaluation of the national response to the HIV/AIDS epidemic in Malawi also revealed that there was insufficient coordination of planning, implementation, monitoring and evaluation of the activities of various agencies involved in the fight against the epidemic and highlighted lack of adequate support to NACP and over-reliance on the health sector for the national response (ibid). In response, with an aim to improve the multisectoral national response, the Malawian government, together with the stakeholders established the National AIDS Commission in July 2001 within the Office of the President and Cabinet to replace NACP. Since its establishment, NAC has been coordinating the multisectoral implementation of the national response and its operations are monitored by a board of commissioners drawn from government, nongovernmental organizations, religious organizations and the private sector (ibid).

Another important step in reorganising the national efforts to fight the HIV/AIDS epidemic in Malawi was the development the national AIDS policy in 2003. The policy stipulates the guiding principles for all national HIV/AIDS programmes and interventions (WHO, 2005b; Malawi HIV and AIDS Monitoring and Evaluation Report 2005; NAC 2003a).

As a consequence of the multi-sectoral and multidisciplinary approach to the fight against the HIV epidemic, Malawi has several public, private, community-based and faith-based organisations involved in various HIV/AIDS programmes and interventions that either aim

at preventing the further spread of HIV infection or mitigating the impact of HIV/AIDS on the socioeconomic status of individuals, families, communities and the nation as stipulated in the National HIV/AIDS policy. These organisations have had a positive impact in raising the levels of awareness about HIV/AIDS in Malawi. Findings from the 2004 Malawi DHS (NSO and ORC Macro, 2005) and the first behavioural surveillance survey conducted in Malawi in 2004 (NAC et al., 2004) indicate that almost every one aged 15 years and above in Malawi has heard about HIV/AIDS. Despite the universal knowledge about the existence of HIV/AIDS these two national surveys found that misconceptions about how HIV is transmitted and how HIV infection can be prevented still exist in Malawi. The findings from the two surveys further indicate that the various organisations involved in HIV/AIDS prevention programmes have not substantially impacted on behaviour change. The progress achieved in adoption of risk-reducing behaviour such as premarital sexual abstinence, limiting the number of sexual partners and consistent condom use with causal partners is not very impressive.

Part of the efforts to mitigate the impact of HIV/AIDS in Malawi has been the provision of free antiretroviral treatment to HIV-infected individuals in the public sector since 2003 (WHO, 2005b). During the intervening years huge progress has been achieved in scaling up treatment. There has been a dramatic rise in the number of HIV-infected individuals receiving antiretroviral treatment from 4 000 individuals by December, 2003 to 81 000 individuals by December, 2006 (Avert, 2007; WHO et al, 2007; WHO, 2005b). The number of sites providing free antiretroviral treatment in the public sector has also been growing exponentially. As of December, 2006 there were 104 sites providing free antiretroviral treatment to eligible HIV-infected patients.

Apart from the HIV/AIDS prevention programmes aimed at primary prevention of HIV infection among women, government and some private and non-governmental organizations have recently become involved in the provision of services aimed at preventing MTCT of HIV infection as part of efforts to reduce under-five mortality directly attributable to HIV/AIDS in Malawi. Beginning 2002, HIV-infected pregnant women in Malawi have been receiving single-dose Nevirapine to prevent them from passing the infection to their infants. According to the Malawi HIV and AIDS Monitoring and Evaluation Report 2005, the number of sites

providing PMTCT services increased from 9 sites in 2002 to 36 sites by end of 2004. The number of HIV-infected pregnant women receiving NVP also increased from 2 198 in 2003 to 2 719 in 2004 and 5 054 in 2005 (Malawi HIV and AIDS Monitoring and Evaluation Report 2005, Ministry of Health, Lighthouse Trust (Lilongwe) and CDC (Malawi), 2006).

Malawi's efforts to fight the HIV/AIDS epidemic are supported by financial assistance from a number of international donors some of which include the World Health Organisation, UNAIDS, the President's Emergency Plan for AIDS Relief (PEPFAR), the Global Fund to Fight AIDS, Tuberculosis and Malaria, the World Bank Multi-Country HIV/AIDS Programme (MAP), the United States Agency for International Development, the United States Centers for Disease Control and Prevention, the United Kingdom Department for International Development and Medecins San Frontiers.

In summary, Malawi has come a long way in putting in place strategies to combat the HIV/AIDS epidemic. Several interventions and programmes have been put in place to halt the spread of the epidemic and mitigate its impact including HIV/AIDS attributable under-five mortality. It is obvious that the impact of the strategies and interventions recently incorporated in the response to the HIV/AIDS epidemic on the trajectory of the epidemic and its impact on the Malawian population would be seen in the years to come. However, there is need to estimate the extent to which these strategies and interventions would reduce the HIV/AIDS burden in Malawi. It is for this reason that this study attempts to examine the extent to which the current PMTCT programmes in Malawi would help in reaching the country's overall under-five mortality reduction goals.

Chapter 3

Research design and methodology

This study did not involve collection of new data but used some of the existing indirect methods and procedures, including mathematical models to derive estimates of the proportion of under-five mortality directly attributable to HIV/AIDS in Malawi during the period 2000 to 2004. To a larger extent, the study adopted the methods and procedures that have been used by a number of researchers worldwide and recommended by UNAIDS and WHO. In this chapter we present details of the methods and procedures used in this study.

3.1 Methodology

This study is subdivided into seven major parts. The first part involves estimating the prevalence of HIV among women aged 15-49 in Malawi for the period 1999 to 2004. The second part involves estimating the number of women in the reproductive age (15-49 years) in Malawi for the period 1999 to 2004. The third part involves applying the estimated HIV prevalence figures to the estimated number of women of reproductive age to estimate the number of HIV infected women. The fourth part involves applying estimates of age-

specific fertility rates to the estimated number of women of reproductive age to estimate the number of children born in each year. The fifth part involves applying mother-to-child transmission (MTCT) rates to the estimated number of children born to HIV infected women to estimate the number of children infected with HIV through MTCT. The sixth part involves applying children's HIV survival distributions to estimate the number of children dying due to HIV/AIDS before their fifth birthday in Malawi during the period 2000 to 2004. In the last part, the estimated number of children dying due to HIV/AIDS before their fifth birthday during the period 2000 to 2004 is used together with the total number of estimated birth from 2000 to 2004 to estimate the proportion of under-five mortality that is directly attributable to HIV/AIDS in Malawi for the period 2000 to 2004. What follows are detailed descriptions of the methods and procedures that have been used in each of the stated parts.

3.1.1 Estimating HIV prevalence among women of reproductive age

Estimates of HIV prevalence among women of reproductive age were largely based on ANC sentinel surveillance data collected in Malawi from 1999 to 2005. In developing countries with generalised epidemics (defined as a prevalence of at least 1% among pregnant women attending antenatal clinics) like Malawi, HIV prevalence among pregnant women is assumed to be a good approximation of HIV prevalence among the general adult population (15-49 years) (WHO and UNAIDS 2003, The UNAIDS Reference Group on Estimates, Models and Projections, 2003). However, ANC surveillance systems are associated with a number of limitations. First, there is high level of diversity in sample sizes among the sites which can result in under-or over-representation of prevalence (Rhucharoenpornpanich and Chamratrithirong, 2001). Second, sites classified as rural are located in small towns and largest rural settlements with higher levels of economic activity and mobility and probably also associated with higher HIV prevalence, therefore may over-estimate prevalence in most remote areas (Schwartlander et al., 1999; WHO and UNAIDS, 2003; The UNAIDS Reference Group on Estimates, Models and Projections, 2003). Third, since testing is only done to those women in the general population who become pregnant, the prevalence from ANC

surveillance may over-estimate the prevalence in the general population as pregnant women may be having unprotected sex at a greater rate than women in the general population. In addition, the prevalence in ANC attendees may under-estimate the prevalence in the general population because women with HIV associated infertility are not captured (NSO and ORC Macro, 2005).

In order to minimise some of the stated sources of bias that are inherent in the ANC sentinel surveillance system, some adjustments are made to the ANC surveillance data when estimating HIV prevalence for all adults. In this section, we describe the procedure that was used in this study to adjust the existing ANC surveillance data in estimating HIV prevalence among women of reproductive age in Malawi from 1999 to 2005.

A number of steps were involved in estimating the HIV prevalence among women of reproductive age. First, we analysed available ANC sentinel surveillance data for the years 1999 to 2005 to obtain unadjusted age-specific HIV prevalence figures among women visiting ANCs in Malawi for the years 1999 to 2005. Although the ANC sentinel sites in Malawi are classified into three categories (urban, semi-urban and rural), in this study they were only split into two categories: urban and non-urban sites (semi-urban and rural sites). Thus, from the analysis we obtained separate age specific HIV prevalence figures for aggregated urban sites and aggregated non-urban sites. These HIV prevalence rates were used as initial estimates of HIV prevalence in each of the two ANC site categories.

Ninety five percent confidence intervals were calculated for the age specific HIV prevalence estimates for each site category obtained above using the adjusted Wald method proposed by Agresti and Coull (1998). The choice of this method was motivated by the fact that it is relatively simple to compute and has been demonstrated to provide the best average coverage even for very small sample sizes than the other methods of calculating binomial confidence intervals (Agresti and Coull, 1998; Sauro and Lewis, 2005). The adjusted Wald method uses the usual simple Wald formula but is "adjusted" in that it adds half of the squared Z-critical value to the numerator and the entire squared critical value to the denominator before computing the interval. Thus, the adjusted Wald method computes the $100(1-\alpha)\%$

confidence interval for p as

$$\hat{p} \pm z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{N}} \tag{3.1}$$

where $\hat{p} = \frac{x+\frac{z^2_{\alpha/2}}{2}}{N}$, $N = n + z^2_{\alpha/2}$, x denotes a binomial variate, n denotes the sample size and z_c denotes the $1-c$ quantile of the standard normal distribution (Agresti and Coull, 1998; Sauro and Lewis, 2005).

Second, the initial HIV prevalence estimates were then adjusted for representativeness by lowering the estimated prevalence in the aggregated non-urban clinic sites. Consistent with the WHO/UNAIDS approach, the adjusted estimate of HIV prevalence in the non-urban sites are equal to 80% of the initial HIV prevalence estimates obtained in the first step above (The UNAIDS Reference Group on Estimates, Models and Projections, 2003).

Third, we calculated national estimates of age specific HIV prevalence among women based on ANC surveillance data by applying the age specific female population size by urban and rural residence. Table 3.1 shows the population of females of reproductive age in urban and rural areas by five year age groups in Malawi as observed in the two most recent censuses. Based on Table 3.1 the percentage of the female population that was in the urban areas in 1987 and 1998 and the annual increase in the urban population assuming a constant annual increase during this period is shown in Table 3.2.

Table 3.1: Urban and rural female populations in Malawi

	1987		1998	
Age group	Urban	Rural	Urban	Rural
15-19	44 637	357900	91196	468875
20-24	46 730	323 389	96 051	447 871
25-29	38 218	270 584	66 409	332 143
30-34	24 726	204 494	44 386	253 775
35-39	20 398	201 303	32 333	213 451
40-44	11 803	139 778	20 149	160 393
45-49	8 894	127 287	15 382	151 116

Source: NSO (1993; 2000)

Table 3.2: Percent of urban and rural female populations in Malawi

	% Urban		
Age group	1987	1998	Annual % increase
15-19	11.1	16.3	0.5
20-24	12.6	17.7	0.5
25-29	12.4	16.7	0.4
30-34	10.8	14.9	0.4
35-39	9.2	13.2	0.4
40-49	7.2	10.2	0.3

Source: Computed by author.

Again assuming constant annual increases, the annual increases in age specific urban female population presented in Table 3.2 were used to calculate estimates of the percentage of female population in the urban and the rural areas in Malawi for the years 1999 to 2005. The calculated estimates of the percentage of urban and rural populations were applied to the HIV prevalence figures in aggregated urban sites and the adjusted HIV prevalence figures in aggregated non-urban sites to obtain national estimates of HIV prevalence among females. The national estimate of HIV prevalence for females aged a in year y were calculated using the following formula:

$$HIV\_Ntn_{f,a,y} = (HIV\_Ubn_{f,a,y} \times Prop\_Ubn_{f,a,y}) + (HIV\_Rl\_Adj_{f,a,y} \times Prop\_Rl_{f,a,y}) \tag{3.2}$$

where $HIV\_Ntn_{f,a,y}$ denotes the estimated national HIV prevalence for females in age group a in year y based on ANC data, $HIV\_Ubn_{f,a,y}$ denotes the estimated HIV prevalence for females in age group a in year y in aggregated urban sites, $Prop\_Ubn_{f,a,y}$ denotes the estimated percentage of females in urban areas in age group a in year y, $HIV\_Rl\_Adj_{f,a,y}$ denotes the adjusted estimate of HIV prevalence for females in age group a in year y in aggregated non-urban sites and $Prop\_Rl_{f,a,y} = (100\% - Prop\_Ubn_{f,a,y})$ denotes the estimated percent of females in non-urban areas in age group a in year y.

Since 1999, ANC sentinel surveillance surveys were only conducted in Malawi every two years. Therefore, after obtaining the national age specific estimates of HIV prevalence for females based on ANC surveillance data, prevalence figures for the years in which the surveys were not conducted were interpolated from these results. Age specific estimates of HIV prevalence for each year in which the survey was not done were calculated as the average of the national age specific estimates of HIV prevalence in the preceding and succeeding year. Thus, the formula:

$$HIV\_Ntn_{f,a,y} = \frac{1}{2}(HIV\_Ntn_{f,a,y-1} + HIV\_Ntn_{f,a,y+1}) \tag{3.3}$$

was used to estimate national age specific HIV prevalence figures for females in Malawi for the years in which ANC sentinel surveillance surveys were not conducted.

Thereafter, the national age specific estimates of HIV prevalence for females for 2004 based

on the ANC sentinel surveillance data were compared with the age specific estimate of HIV prevalence from the 2004 MDHS and age specific ratio of ANC to general population HIV prevalence for Malawi was obtained. Lastly, the age specific ratio of ANC to general population HIV prevalence was used to further adjust the national age specific estimates of HIV prevalence for females based on the ANC surveillance data to obtain final estimates of national HIV prevalence for females in age group a in year y for the years from 1999 to 2005 denoted as $HIV\_prevalence_{f,a,y}$.

3.1.2 Estimating the number of women of reproductive age

Since our interest was in estimating the number of children that died of HIV/AIDS before the age of five years during the period 2000 to 2004, we required the number of children born during the period 2000 to 2004 that acquired HIV infection from theirs mothers. This entailed that we also needed the number of women of reproductive age in those years. The number of women in the 15-49 age group for the years in question was projected from the results of the 1998 census which was conducted from 1^{st} to 21^{st} September 1998. According to the analytic report of the 1998 Malawi census (NSO, 2002), an evaluation of age data showed that the age distribution were distorted by age misreporting. Therefore, in this study we took the age-smoothed population distribution of females as the base year population and then projected this population using the methodology that is used in the mathematical model that is implemented in the DemProj computer program. This model is based on the standard cohort component projection model that has been modified to produce single year projections (Stover and Kirmeyer, 2004).

Consistent with the methodology in the DemProj computer program, we started the projection by separating the age-smoothed base year population in five-year age groups from 5-9 to 45-49 into single years of age using the Beers formulae (ibid). The 5-9 age group was splitted using the following formulae:

$$a_5 = 0.0404 * p_1 + 0.2000 * p_2 - 0.0344 * p_3 - 0.0128 * p_4 + 0.0068 * p_5 \quad (3.4)$$

$$a_6 = 0.0093 * p_1 + 0.2268 * p_2 - 0.0402 * p_3 + 0.0028 * p_4 + 0.0013 * p_5 \quad (3.5)$$

$$a_7 = -0.0108 * p_1 + 0.2272 * p_2 - 0.0248 * p_3 + 0.0112 * p_4 - 0.0028 * p_5 \quad (3.6)$$

$$a_8 = -0.0198 * p_1 + 0.1992 * p_2 + 0.0172 * p_3 + 0.0072 * p_4 - 0.0038 * p_5 \quad (3.7)$$

$$a_9 = -0.0191 * p_1 + 0.1468 * p_2 + 0.0822 * p_3 - 0.0084 * p_4 - 0.0015 * p_5 \quad (3.8)$$

where p_1, p_2, p_3, p_4 and p_5 refer to the population aged 0-4, 5-9, 10-14, 15-19, and 20-24 respectively and a_5, a_6, a_7, a_8 and a_9 refer to the population at single ages 5, 6, 7, 8, and 9 respectively.

The age groups 10-14 to 45-49 were splitted using the following formulae:

$$a_1 = -0.0117 * p_{a-2} + 0.0804 * p_{a-1} + 0.1570 * p_a - 0.0284 * p_{a+1} + 0.0027 * p_{a+2} \quad (3.9)$$

$$a_2 = -0.0020 * p_{a-2} + 0.0160 * p_{a-1} + 0.2200 * p_a - 0.0400 * p_{a+1} + 0.0060 * p_{a+2} \quad (3.10)$$

$$a_3 = 0.0050 * p_{a-2} - 0.0280 * p_{a-1} + 0.2460 * p_a - 0.0280 * p_{a+1} + 0.0050 * p_{a+2} \quad (3.11)$$

$$a_4 = 0.0060 * p_{a-2} - 0.0400 * p_{a-1} + 0.2200 * p_a + 0.0160 * p_{a+1} - 0.0020 * p_{a+2} \quad (3.12)$$

$$a_5 = 0.0027 * p_{a-2} - 0.0284 * p_{a-1} + 0.1570 * p_a + 0.0804 * p_{a+1} - 0.0117 * p_{a+2} \quad (3.13)$$

where a_1, a_2, a_3, a_4 and a_5 denote the first, second, third, fourth and fifth ages in the particular age group and p_{a+i}, $(i = \{-2, ..., 2\})$ is the population of age group i groups older than the reference group.

For each year, the methodology in the DemProj computer program calculates the population of females aged a using the formula:

$$Pop_{f,a,y} = \left(Pop_{f,a-1,y-1} + \frac{Migr_{f,a-1,y-1}}{2} \right) \times S_{f,a-1,y-1} \quad (3.14)$$

where $Pop_{f,a,y}$ is the population of females aged a in year y, $Migr_{f,a-1,y-1}$ is the net number of migrants that were aged $a-1$ in year $y-1$ and $S_{f,a-1,y-1}$ is the survival ratio or proportion of the female population aged $a-1$ in year $y-1$ that survive to age a in year y.

However, migration data were not collected in the 1998 census. So, like in the projections done by the Malawi National Statistical Office for the period 1999 to 2023, in this study net migration was assumed to be zero. Therefore, the population of females aged a in year y

was calculated as:

$$Pop_{f,a,y} = \left(Pop_{f,a-1,y-1}\right) \times S_{f,a-1,y-1} \tag{3.15}$$

The survival ratios in the model implemented in the DemProj computer program are derived from model life tables (MLTs) which, for ages older than five years, provide five-year survival ratios. According to Stover and Kirmeyer (2004), these five-year survival ratios are by definition the proportion of the population of a particular five-year age group that survives to the next five-year age group five years later. In the model these five-year survival ratios are converted to single-year survival ratios by taking the fifth root of the five-year survival ratios. Thereafter, the result is used as the survival ratio for all the five ages in the corresponding age group. The MLTs used in DemProj computer program are the four families of Coale-Demeny MLT system (North, South, East, and West) and the five families of United Nations MLT system (Latin America, Chile, South Asia, East Asia and General).

In the case of Malawi, choosing the appropriate MLT from which to derive the survival ratios required in equation 3.15 among the existing MLTs is a challenge because there is more than one MLT that is asserted to fit the Malawian mortality experience. NSO (2002) indicates that comparison analyses between the reported probability of dying between exact ages x and $x+n$, ${}_nq_x$, values in the 1998 census with the corresponding values in the five families of the United Nations MLT system as well as in the four families of Coale-Denemy MLT system suggested that the north family of Coale-Denemy MLT system was more suitable to represent mortality conditions in Malawi. On the contrary, in preparing the national estimates of HIV/AIDS for Malawi in 2003, the Malawi National AIDS Commission used the South family of Coale-Denemy MLT system (NAC, 2003b). The DemProj computer package also provides the South family of Coale-Denemy MLT system as the default MLT for Malawi. In addition, there is also a set of MLTs for Malawi that have been constructed by WHO and are available online at http://www.who.int/whosis/database/life_tables/life_tables.cfm. Furthermore, Doctor (2004) reports that comparison analyses of the pattern in age specific death rates in Malawi during the 1987-1998 intercensal period with the corresponding age specific death rates from 17 model patterns of mortality: four patterns from the regional MLTs of Coale

and Demeny, five patterns based upon the United Nations MLTs, seven patterns based upon the INDEPTH mortality patterns and one pattern based upon the WHO MLT for 2000 using data from 1987 and 1998 Malawi censuses revealed that the best-fitting model for females in Malawi was Pattern 3 of INDEPTH mortality patterns.

Faced with the challenge of choosing the best MLT from which to derive the survival ratios required in equation 3.15, the approach adopted in this study was to use survival ratios derived from all the four MLTs asserted to fit the Malawian mortality experience. Since, according to INDEPTH Network (2002), Pattern 3 of INDEPTH mortality patterns is most similar to the Far East family of the United Nations MLT system, the United Nations Far East MLT was used instead of Pattern 3 of INDEPTH mortality patterns. The survival ratios used in this study were therefore derived from Coale-Demeny north, Coale-Demeny south, United Nations Far East and WHO MLTs. While the WHO MLT is based on data that include the influence of HIV/AIDS on mortality, as pointed out by INDEPTH Network (2002), the Coale-Demeny and the United Nations families of MLT Systems do not contain an AIDS pattern of mortality, therefore Coale-Demeny north and Coale-Demeny south MLTs may overestimate the annual number of women of reproductive age. Hence, the decision to use the four MLTs was made with an intention to produce alternative estimates of the number of women of reproductive age in Malawi that include all possible scenarios.

The WHO MLT for females in Malawi for the period 2000-2004 is shown in Table 3.3 and the survival ratios corresponding to life expectancy values of 35 to 60 for females for the other three MLTs are presented in Tables 3.4 to 3.6. These survival ratios were obtained from files called "*Cdnorth.f*", "*Cdsouth.f*" and "*Unea.f*" respectively that are contained in a folder named "**DP**" that comes along with the Spectrum Projection Package.

Table 3.3: WHO MLT for females in Malawi, 2000-2004

Age range	${}_nM_x$	${}_nq_x$	l_x	${}_nd_x$	${}_nL_x$	T_x	e_x
<1	0.11583	0.10714	100000	10714	92500	4149713	41.5
1-4	0.01896	0.07255	89286	6477	341597	4057213	45.4
5-9	0.00607	0.02988	82808	2474	407856	3715616	44.9
10-14	0.00274	0.01363	80334	1095	398935	3307760	41.2
15-19	0.00288	0.0143	79240	1133	393364	2908825	36.7
20-24	0.00867	0.04243	78106	3314	382246	2515461	32.2
25-29	0.01874	0.08952	74792	6695	357223	2133216	28.5
30-34	0.03003	0.13968	68097	9512	316704	1775993	26.1
35-39	0.03438	0.15829	58585	9273	269741	1459289	24.9
40-44	0.03201	0.1482	49311	7308	228288	1189548	24.1
45-49	0.02888	0.13467	42004	5657	195877	961260	22.9
50-54	0.02132	0.10122	36347	3679	172538	765383	21.1
55-59	0.02606	0.12231	32668	3996	153351	592845	18.1
60-64	0.02942	0.13704	28672	3929	133539	439494	15.3
65-69	0.04236	0.19153	24743	4739	111868	305956	12.4
70-74	0.06384	0.27528	20004	5507	86253	194088	9.7
75-79	0.09712	0.39074	14497	5665	58325	107835	7.4
80-84	0.14607	0.53498	8833	4725	32350	49510	5.6
85-89	0.21453	0.6982	4107	2868	13367	17160	4.2
90-94	0.30655	0.79845	1240	990	3229	3793	3.1
95-99	0.426	0.85508	250	214	501	564	2.3
100+	0.57571	1	36	36	63	63	1.7

Source: Life Tables for WHO Member States

http://www.who.int/whosis/database/life_tables/life_tables.cfm

Accessed on 10 October, 2007.

Table 3.4: Survival ratios of females from Coale-Demeny north model life table

35.000	40.000	45.000	50.000	55.000	60.000
0.811960	0.843080	0.870220	0.893980	0.914530	0.933720
0.930896	0.943469	0.954425	0.964720	0.974971	0.983186
0.954290	0.963114	0.970610	0.977482	0.983771	0.988791
0.963857	0.971100	0.977138	0.982622	0.987368	0.991165
0.971520	0.977391	0.982240	0.986564	0.990093	0.992931
0.758770	0.797710	0.832410	0.864100	0.892330	0.917840
0.854730	0.881820	0.905100	0.926500	0.946680	0.963230
0.948300	0.957700	0.965850	0.973280	0.980240	0.986030
0.960920	0.967610	0.973440	0.978510	0.983360	0.987640
0.957450	0.964390	0.970440	0.975530	0.980490	0.985000
0.951020	0.958860	0.965700	0.971420	0.976960	0.982060
0.943020	0.952240	0.960280	0.967060	0.973470	0.979400
0.934210	0.944940	0.954300	0.962260	0.969600	0.976400
0.926880	0.938490	0.948620	0.957170	0.964890	0.971700
0.921190	0.933120	0.943530	0.952250	0.959850	0.967230
0.910300	0.923060	0.934190	0.943520	0.951330	0.959090
0.885930	0.901490	0.915080	0.926570	0.935860	0.945220
0.843440	0.864090	0.882150	0.897530	0.909630	0.921940
0.778010	0.805190	0.828980	0.849090	0.864830	0.881040
0.684210	0.719330	0.750110	0.775990	0.796070	0.817000
0.558590	0.601210	0.638650	0.670120	0.694090	0.719390
0.411150	0.458760	0.501170	0.537230	0.564660	0.594040
0.238430	0.267770	0.295010	0.318960	0.337690	0.358230

Source: Spectrum software version 2.39.

http://www.unaids.org/en/HIV_data/Epidemiology/episoftware.asp.

Accessed on 15 August, 2007.

Table 3.5: Survival ratios of females from Coale-Demeny south model life table

35.000	40.000	45.000	50.000	55.000	60.000
0.801360	0.827480	0.849370	0.869030	0.887640	0.905090
0.888564	0.909569	0.928806	0.945698	0.960209	0.973030
0.942252	0.954228	0.964710	0.973559	0.980923	0.987146
0.967642	0.974673	0.980685	0.985652	0.989738	0.993075
0.980993	0.985243	0.988812	0.991732	0.994103	0.995969
0.724450	0.763460	0.798420	0.830200	0.859590	0.886540
0.855300	0.883750	0.909060	0.930510	0.948680	0.964530
0.964550	0.971550	0.978090	0.983600	0.988280	0.992330
0.968120	0.974050	0.979320	0.984180	0.988350	0.991980
0.958240	0.965820	0.972500	0.978760	0.984170	0.988880
0.951470	0.960140	0.967730	0.974820	0.981000	0.986410
0.948400	0.957490	0.965420	0.972750	0.979190	0.984890
0.945670	0.955080	0.963230	0.970670	0.977290	0.983210
0.942820	0.952250	0.960300	0.967660	0.974310	0.980320
0.939350	0.948630	0.956440	0.963560	0.970120	0.976140
0.927620	0.937960	0.946670	0.954430	0.961700	0.968480
0.903250	0.916470	0.927610	0.937430	0.946720	0.955430
0.856870	0.875870	0.891890	0.905970	0.919370	0.932000
0.782020	0.809340	0.832240	0.852420	0.871750	0.890090
0.677510	0.713060	0.742350	0.768630	0.794110	0.818530
0.530860	0.573360	0.607940	0.639160	0.669830	0.699610
0.365560	0.412220	0.450520	0.485370	0.520260	0.554740
0.211520	0.238610	0.262580	0.284730	0.307600	0.330870

Source: Spectrum software version 2.39.

http://www.unaids.org/en/HIV_data/Epidemiology/episoftware.asp.

Accessed on 15 August, 2007.

Table 3.6: Survival ratios of females from UN Far East model life table

35.000	40.000	45.000	50.000	55.000	60.000
0.854070	0.873810	0.892000	0.909000	0.925020	0.940150
0.946773	0.958744	0.968621	0.976799	0.983503	0.988895
0.969120	0.976568	0.982546	0.987330	0.991152	0.994149
0.979263	0.984403	0.988456	0.991684	0.994222	0.996202
0.984988	0.988738	0.991694	0.994019	0.995851	0.997274
0.812460	0.841740	0.867980	0.891350	0.912400	0.931630
0.912680	0.932470	0.948540	0.962050	0.973260	0.982150
0.966600	0.974780	0.981250	0.986400	0.990500	0.993700
0.958170	0.968400	0.976520	0.983000	0.988150	0.992170
0.926650	0.944570	0.958890	0.970350	0.979450	0.986550
0.908920	0.930380	0.947780	0.961900	0.973280	0.982270
0.900350	0.922490	0.940780	0.955930	0.968410	0.978510
0.894430	0.916080	0.934370	0.949890	0.963020	0.973990
0.890040	0.909900	0.927180	0.942350	0.955680	0.967320
0.880100	0.898690	0.915380	0.930540	0.944400	0.957050
0.855870	0.875220	0.893070	0.909760	0.925510	0.940400
0.817460	0.838860	0.859060	0.878440	0.897230	0.915530
0.766770	0.790390	0.813200	0.835610	0.857910	0.880270
0.705470	0.730350	0.754950	0.779730	0.805070	0.831280
0.628230	0.653740	0.679570	0.706250	0.734310	0.764240
0.530040	0.556340	0.583590	0.612440	0.643600	0.677840
0.407740	0.429760	0.452600	0.476220	0.501610	0.529790
0.236550	0.250550	0.263750	0.281130	0.297720	0.316340

Source: Spectrum software version 2.39.

http://www.unaids.org/en/HIV_data/Epidemiology/episoftware.asp.

Accessed on 15 August, 2007.

As described by Stover and Kirmeyer (2005), the format in Tables 3.4 to 3.6 is as follows:

- Row 1: life expectancy at birth
- Row 2: one-year survival ratios for newborns
- Row 3: one-year survival ratios for ages one to two
- Rows 4, 5, 6: one-year survival ratios for ages two to three, three to four, and four to five.
- Row 7: the proportion of births during a five-year period that will survive within the 0-4 age group to the end of the period.
- Row 8: the proportion of those aged 0-4 who will survive into the 5-9 age group five years later.
- Rows 9-23; the proportion of the age group (5-9, 10-14,$\cdots$, 75-80) that will survive into the next age group five years later.
- Row 24: the proportion of the age group 80+ that will survive five years later.

In the case of the WHO MLT, the survival ratios used in this study were computed from the ${}_nL_x$ column of Table 3.3 whereas for the other three MLTs the survival ratio values used in the study were determined based on projected information about expectation of life at birth done by the Malawi National Statistical Office. The projected life expectancy at birth values for females for the period under consideration in this study are presented in Table 3.7. Since the exact life expectancy at birth values presented in Table 3.7 are not available in Tables 3.4 to 3.6, linear interpolation was used to estimate the survival ratios corresponding to the given life expectancy at birth values.

Table 3.7: Projected life expectancy at birth values for females in Malawi

Year	1998	1999	2000	2001	2002	2003	2004
Life expectancy at birth	43.23	43.77	44.33	44.90	45.47	46.03	46.60

Source: http://www.nso.malawi.net/. Accessed on 15 August, 2007.

3.1.3 Estimating the number of HIV infected women

The number of women of a particular age, a, who are infected with HIV in year y, was calculated using a formula similar to the one used in the mathematical model for making HIV/AIDS projections which is implemented in a computer program called AIDS Impact Model (AIM) (Stover, 2005). Below is the formula that was used for this task.

$$HIV_{f,a,y} = Pop_{f,a,y} \times HIV\_prevalence_{f,a,y} \tag{3.16}$$

where, $HIV_{f,a,y}$ is the number of HIV infected women in age group a in year y, $Pop_{f,a,y}$ is the population of females aged a in year y obtained from equation 3.15 and $HIV\_prevalence_{f,a,y}$ is the estimated prevalence of HIV for females aged a in year y obtained in section 3.1.1.

3.1.4 Estimating the number of children

The methodology in the DemProj computer program was again adopted in calculating the number of children born to all women in each year. For each year, the number of children born to females in age group a was calculated as:

$$births_{f,a,y} = Pop_{f,a,y} \times ASFR_{f,a,y} \tag{3.17}$$

where $births_{f,a,y}$ is the number of children born in year y to women of age a, $Pop_{f,a,y}$ is the population of females aged a in year y obtained from equation 3.15 and $ASFR_{f,a,y}$

is the age specific fertility rate (ASFR) in year y for women of age a. Here, since the base year population we used was recorded in September we assume that $Pop_{f,a,y}$ would be approximately equal to the mid-year population of females aged a in year y.

The ASFRs required in equation 3.17 were derived from the 2000 and 2004 Malawi DHSs (NSO and ORC Macro, 2001 and 2005). We assumed a constant annual change in the ASFRs between 2000 and 2004 and estimated the ASFRs for the years from 1999 to 2004 by linear interpolation.

For each year, after calculating the number of children born to women in a particular age group, the total number of children born to all women of reproductive age was calculated using the formula:

$$births_{y} = \sum_{a=15-19}^{45-49} births_{f,a,y} \tag{3.18}$$

3.1.5 Estimating the number of children infected with HIV through mother-to-child transmission

We adopted the approach by UNAIDS/WHO in estimating the number of children acquiring HIV infection from their mothers. For each year, we started by calculating the number of children born to HIV infected women.

Two studies conducted in Uganda found that HIV-infected women had lower fertility rates than HIV-negative women. One of the studies was done in rural Rakai district and found that HIV infected women had ASFRs which were 55% less than those of non-HIV infected women (Gray et al.,1998). The other study was conducted among rural women in Masaka and found that the fertility rate in HIV-infected women was 26% lower than that of uninfected women (Carpenter et al., 1997). On the basis of the findings from these studies it is assumed that fertility might be 20 to 50 percent lower among HIV infected women compared to uninfected women (The UNAIDS Reference Group on Estimates, Models and Projections,

2003). However, The UNAIDS Reference Group on Estimates, Models and Projections (2003) argues that fertility among young women who are HIV positive is likely to be higher than that of all women since all HIV positive women are sexually active but not all young women are sexually active. Therefore, in the UNAIDS/WHO approach it is assumed that fertility among 15-19 year old women is 50% higher among HIV positive women than HIV negative women and that fertility among women aged 20-49 is 20% lower among HIV positive women than HIV negative women (The UNAIDS Reference Group on Estimates, Models and Projections, 2003).

Let $B^{+}_{f,a,y}$ denote the number of children born to HIV-positive women aged a years in year y, $B^{-}{}_{f,a,y}$ denote the number of children born to HIV-negative women aged a years in year y and $Neg_{f,a,y}$ denote the mid-year population of HIV-negative women aged a years in year y. Then using equations 3.15, 3.16 and 3.17 we have:

$$births_{f,a,y} = B^{+}_{f,a,y} + B^{-}_{f,a,y} \tag{3.19}$$

$$Pop_{f,a,y} = HIV_{f,a,y} + Neg_{f,a,y} \tag{3.20}$$

$$ASFR_{f,a,y} = \frac{B_{f,a,y}}{Pop_{f,a,y}} = \frac{B^{+}_{f,a,y} + B^{-}_{f,a,y}}{HIV_{f,a,y} + Neg_{f,a,y}} \tag{3.21}$$

From equation 3.21 we obtain

$$B^{+}_{f,a,y} + B^{-}_{f,a,y} = Pop_{f,a,y} \times ASFR_{f,a,y} \tag{3.22}$$

Dividing both sides of equation 3.22 by $Neg_{f,a,y}$ yields

$$\frac{B^{+}_{f,a,y}}{Neg_{f,a,y}} + \frac{B^{-}_{f,a,y}}{Neg_{f,a,y}} = \frac{Pop_{f,a,y}}{Neg_{f,a,y}} \times ASFR_{f,a,y} \tag{3.23}$$

Now assuming that fertility among 15-19 years old women is 50% higher among HIV-positive than HIV-negative women we have

$$\frac{B^{+}_{f,a,y}}{HIV_{f,a,y}} = 1.5 \times \frac{B^{-}_{f,a,y}}{Neg_{f,a,y}} \tag{3.24}$$

$$\Rightarrow \frac{B^{-}_{f,a,y}}{Neg_{f,a,y}} = \frac{B^{+}_{f,a,y}}{1.5 \times HIV_{f,a,y}} \tag{3.25}$$

where $a = 15 - 19$.

Substituting equation 3.25 in equation 3.23 yields

$$\frac{B^+_{f,a,y}}{Neg_{f,a,y}} + \frac{B^+_{f,a,y}}{1.5 \times HIV_{f,a,y}} = \frac{Pop_{f,a,y}}{Neg_{f,a,y}} \times ASFR_{f,a,y} \quad (3.26)$$

$$\Rightarrow \frac{B^+_{f,a,y}(1.5 \times HIV_{f,a,y} + Neg_{f,a,y})}{1.5 \times HIV_{f,a,y} \times Neg_{f,a,y}} = \frac{Pop_{f,a,y}}{Neg_{f,a,y}} \times ASFR_{f,a,y} \quad (3.27)$$

$$\Rightarrow B^+_{f,a,y} = \frac{1.5 \times HIV_{f,a,y} \times Pop_{f,a,y} \times ASFR_{f,a,y}}{1.5 \times HIV_{f,a,y} + Neg_{f,a,y}} \quad (3.28)$$

Similarly, assuming that fertility among women 20-49 years old is 20% lower among HIV-positive women than HIV-negative women we have

$$\frac{B^+_{f,a,y}}{HIV_{f,a,y}} = 0.8 \times \frac{B^-_{f,a,y}}{Neg_{f,a,y}} \quad (3.29)$$

$$\Rightarrow \frac{B^-_{f,a,y}}{Neg_{f,a,y}} = \frac{1.25 \times B^+_{f,a,y}}{HIV_{f,a,y}} \quad (3.30)$$

where $a = \{20-24, ..., 44-49\}$.

Substituting equation 3.30 in equation 3.23 gives

$$\frac{B^+_{f,a,y}}{Neg_{f,a,y}} + \frac{1.25 \times B^+_{f,a,y}}{HIV_{f,a,y}} = \frac{Pop_{f,a,y}}{Neg_{f,a,y}} \times ASFR_{f,a,y} \quad (3.31)$$

$$\Rightarrow \frac{B^+_{f,a,y}(HIV_{f,a,y} + 1.25 \times Neg_{f,a,y})}{HIV_{f,a,y} \times Neg_{f,a,y}} = \frac{Pop_{f,a,y}}{Neg_{f,a,y}} \times ASFR_{f,a,y} \quad (3.32)$$

$$\Rightarrow B^+_{f,a,y} = \frac{HIV_{f,a,y} \times Pop_{f,a,y} \times ASFR_{f,a,y}}{HIV_{f,a,y} + 1.25 \times Neg_{f,a,y}} \quad (3.33)$$

Combining the information in equations 3.28 and 3.33, the number of children born to HIV infected mothers was computed using the formula:

$$HIV\_births_{f,a,y} = \begin{cases} \frac{1.5 \times HIV_{f,a,y} \times Pop_{f,a,y} \times ASFR_{f,a,y}}{1.5 \times HIV_{f,a,y} + Neg_{f,a,y}} & a = \{15-19\} \\ \frac{HIV_{f,a,y} \times Pop_{f,a,y} \times ASFR_{f,a,y}}{HIV_{f,a,y} + 1.25 \times Neg_{f,a,y}} & a = \{20-24, ..., 45-49\} \end{cases} \quad (3.34)$$

where $HIV\_births_{f,a,y}$ denotes the number of children born to HIV-infected women aged a in year y.

After calculating the number of children born to HIV infected women in each age group, the formula

$$HIV\_births_{y} = \sum_{a=15-19}^{45-49} HIV\_births_{f,a,y} \quad (3.35)$$

was employed to calculate the total number of children born to all HIV infected women in a given year y.

Finally, the number of children infected with HIV through MTCT in any given year was calculated using the formula

$$HIV + \_births_{y} = HIV \_births_{y} \times PTR \tag{3.36}$$

where PTR denotes the perinatal transmission rate, which is defined as the percentage of children born to HIV-infected mothers who are infected themselves.

It has been documented that children acquire HIV infections from their mothers during gestation or birth or after birth through breastfeeding (The UNAIDS Reference Group on Estimates, Models and Projections, 2003). Based on a review of studies on MTCT, the UNAIDS Reference Group on Estimates, Models and Projections reports that in developing countries where a significant amount of transmission may occur through breastfeeding, the PTR lies between 25% and 48% in the absence of programs to prevent MTCT such as treatment with nevirapine (NVP), or zidovudine (ZDV) and NVP, or some other treatment or infant feeding options (The UNAIDS Reference Group on Estimates, Models and Projections, 2003; Stover, 2005). The UNAIDS/WHO approach is to use a value of 32% for the PTR in SSA countries (The UNAIDS Reference Group on Estimates, Models and Projections, 2003; Stover, 2005). Other studies have used a rate of 30% (Adetunji, 2000) or 35% (Zaba et al., 2003) for countries in SSA. In this study we used all the three proposed transmission rates (i.e., 30%, 32% and 35%) inorder to generate alternative estimates of the number of children infected with HIV via MTCT in the abscence of interventions to prevent MTCT. Our assumption is that these three transmission rates are equally likely to arise in Malawi.

Beginning 2002, PMTCT services have been provided to a certain proportion of HIV infected pregnant women in Malawi. According to the Malawi HIV and AIDS Monitoring and Evaluation Report 2005, 2198 and 2719 HIV positive pregnant women received NVP in 2003 and 2004 respectively. We did not find the exact number of HIV infected women that received NVP in 2002. However, we assume it to be around 840, which is the number of

pregnant women that tested positive in facilities providing PMTCT services (Ministry of Health, Lighthouse Trust (Lilongwe) and CDC (Malawi), 2006). In our final estimates of the number of children infected with HIV via MTCT in Malawi we took into account the HIV infected pregnant women that received NVP and used the default transmission rates from AIM for women receiving NVP presented in Table 3.8 below.

Table 3.8: PTR for HIV infected pregnant women receiving Nevirapine.

Base transmission rate (no intervention)	30%	32%	35%
Transmission rate with intervention (NVP)	16%	24%	28%

Source: Spectrum software version 2.39.

http://www.unaids.org/en/HIV_data/Epidemiology/episoftware.asp.

Accessed on 15 August, 2007.

3.1.6 Estimating the number of HIV infected children dying before the age of five years

It has been reported that children who are infected with HIV via MTCT generally progress to AIDS faster than adults (The UNAIDS Reference Group on Estimates, Models and Projections, 2003). The median time from birth to AIDS have been reported to range from one year to 6.3 years based on a number of studies cited by The UNAIDS Reference Group on Estimates, Models and Projections (2003). It has been reported that several of those studies found that some children (about 40%) progress to AIDS within a few months while the rest take considerably longer. A UNAIDS review of the available evidence suggests that the survival of the infected children is best described by a rapid progression from infection to death for some children and much slower progression for others (UNAIDS, 2001 cited by The

UNAIDS Reference Group on Estimates, Models and Projections, 2003). On the basis of this available evidence, The UNAIDS Reference Group on Estimates, Models and Projections (2002) has developed procedures for estimating the proportion of children who are infected with HIV via MTCT who will die from HIV-related causes y years after birth. This study adopted those procedures to estimate the number of children dying due to HIV/AIDS before their fifth birthday in Malawi during the period 2000 to 2004.

According to The UNAIDS Reference Group on Estimates, Models and Projections' procedures, the shape of the survival curve for HIV-infected children up to the age of 15 is specified by the following double Weibull function:

$$S(y) = 1 - [p(1 - exp(-(\beta_1 y)^{\alpha_1})) + (1 - p)(1 - exp(-(\beta_2 y)^{\alpha_2}))] \tag{3.37}$$

where $S(y)$ represents the fraction of children who have not died from HIV-related causes y years after birth, p is the proportion of children who progress to death rapidly, α_1, β_1, α_2 and β_2, are parameters of the component Weibull curves describing mortality amongst the group of children that progress to death rapidly and the group of children that progress to death slowly respectively (Zaba et al., 2003). An analysis conducted by The UNAIDS Reference Group on Estimates Models and Projections (2002) found that the parameter values that gave the best fit to a wide range of net survival data measured in clinic and community based cohorts were $p = 0.6$, $\alpha_1 = 0.9$, $\beta_1 = 0.9$, $\alpha_2 = 10.0$ and $\beta_2 = 0.1$. These parameter values are the ones that were used in this study in estimating the number of HIV-infected children who would die before the age of five years in Malawi during the period in question. Figure 3.1 shows the curve of the cumulative proportion of the HIV-infected children that progress to AIDS death y years after birth using the stated parameters. The curve indicates that over a third of infected children would die before their first birthday, nearly two thirds by age five and none of them would survive past the age of 15.

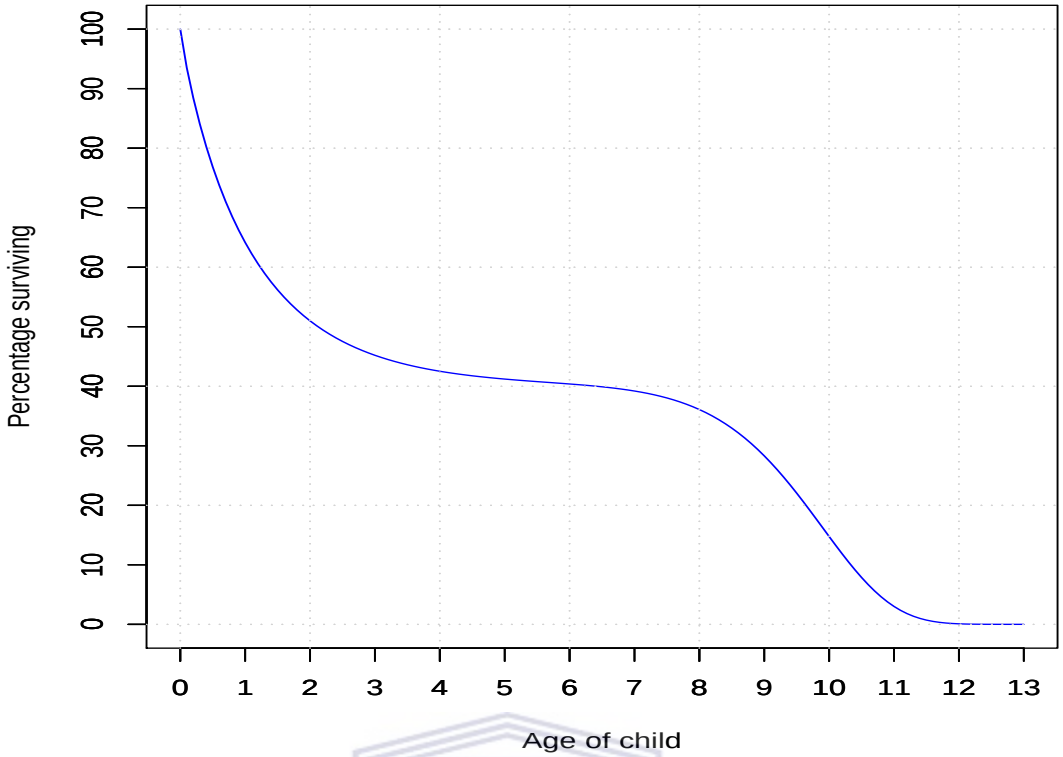

Figure 3.1: Survival distribution of HIV-infected children.

Source: The UNAIDS Reference Group on Estimates Models and Projections (2002).

3.1.7 Estimating the proportion of under-five mortality in Malawi during the period 2000 to 2004 that is directly attributable to HIV/AIDS

We adopted the approach by Walker et al. (2002) to move from the estimates of the total number of HIV infected children dying before the age of five years during the period 2000 to 2004 computed by the procedures described above to estimates of the proportion of under-five mortality directly attributable to HIV/AIDS in Malawi from 2000 to 2004. First, we computed estimates of U5MR in HIV-infected children by dividing the estimated total number of HIV infected children dying before the age of five years from 2000 to 2004 by the estimated total number of children infected with HIV through MTCT from 2000 to

2004. Second, we computed estimates of U5MR for HIV-negative children by subtracting the estimates of U5MR in HIV-infected children from the 2004 Malawi DHS estimate of U5MR from all causes. Third, we used the computed estimates of U5MR without HIV/AIDS to compute estimates of the total number of HIV infected children dying before the age of five years from non-HIV causes from 2000 to 2004 since HIV infected children can also die from non-HIV related causes (Walker et al., 2002). Fourth, we subtracted estimates of the total number of HIV infected children dying before the age of five years from non-HIV causes from 2000 to 2004 from the estimates of total number of HIV infected children dying before the age of five years from 2000 to 2004 to obtain estimates of the total number of HIV infected children dying before the age of five years from HIV related causes from 2000 to 2004. Fifth, we computed estimates of U5MR due to HIV/AIDS from 2000 to 2004 by dividing the estimates of the total number of HIV infected children dying before the age of five years from HIV related causes from 2000 to 2004 by the estimated total number of children born to all women from 2000 to 2004. Lastly, we computed estimates of the proportion of U5MR attributable to HIV/AIDS in Malawi during the period 2000 to 2004 by dividing the estimates of U5MR due to HIV/AIDS from 2000 to 2004 by the 2004 Malawi DHS estimates of U5MR.

3.2 Data sources

The study mainly used secondary data collected by government departments and other institutions working on HIV/AIDS related issues in Malawi as well as data from relevant published studies and reports. Below we present the sources of data which formed the basis of the HIV/AIDS and demographic estimates and projections done in this study.

3.2.1 HIV prevalence data

Until recently, the most widely available source of epidemiological data on HIV prevalence in Malawi has been a routine ANC surveillance system. Since 1994, 19 sentinel ANC sites located in the urban and the rural areas in all the three regions (North, Central, and South) have been used to collect data on HIV prevalence every one or two years using consistent methodology in the same population group (MEASURE Evaluation, 2004; NSO and Macro International Inc., 2005). Therefore, data for setting assumptions about the prevalence of HIV among women in each age group from age 15 to age 49 from 1999 to 2005 were obtained from the Epidemiology Department of the Malawi Ministry of Health and Population.

3.2.2 Demographic data

The 1998 Malawi Population and Housing Census Analytic Report (NSO, 2002) was the source of the base year population for estimating the number of women of reproductive age for each year from 1999 to 2004. Information on ASFRs was obtained from the 2000 and 2004 Malawi DHSs.

3.3 Software

Most of the computations needed in this study were done using R version 2.4.1. R is a freely available language and environment for statistical computing and graphics which provides a wide variety of statistical and graphical techniques: linear and nonlinear modelling, statistical tests, time series analysis, classification, clustering, and many more others. More information about R and instruction for downloading a copy is available on the R home page (http://www.r-project.org). Analysis of the HIV prevalence data was done using SPSS version 14. This thesis document was typeset in LaTeX using MiKTeX 2.5

installation downloaded from http://sourceforge.net/projects/miktex/ and TeXnicCenter editor downloaded from http://sourceforge.net/projects/texniccenter/.

Chapter 4

Results

This chapter presents estimates of the proportion of under-five mortality directly attributed to HIV/AIDS in Malawi. First, the chapter presents estimates of HIV prevalence among women of reproductive age from 1999 to 2005. Second, it presents estimates of the number of women of reproductive age in Malawi from 1999 to 2004. In the third part the chapter presents estimates of the number of women of reproductive age infected with HIV. The fourth and fifth parts present estimates of the number of children born to all women and estimates of the number of children infected with HIV through MTCT respectively. The sixth part presents estimates of the number of HIV infected children dying before the age of five years. At the end, the chapter presents estimates of the proportion of under-five mortality directly attributed to HIV/AIDS in Malawi during the period 2000 to 2004.

4.1 Estimates of HIV prevalence among women of reproductive age

In this section we present estimates of HIV prevalence among women of reproductive age in Malawi from 1999 to 2005. We present ANC sentinel surveillance results first and end the section with final estimates of HIV prevalence among women of reproductive age in Malawi.

4.1.1 ANC sentinel surveillance sites in Malawi, 1999 to 2005

Since 1999, ANC HIV surveillance in Malawi has been conducted every two years in 19 sites in all the three regions of the country shown in Figure 4.1. Eight of the sites are classified as rural clinics, Eight as semi-urban clinics and three as urban clinics (see Table 4.1). As stated earlier, in this study we reclassified the ANC sentinel sites into urban and non-urban sites. Based on our classification of the sentinel sites, the numbers of women sampled in the ANC surveillance surveys by site category in Malawi from 1999 to 2005 are shown in Table 4.2. Although Table 4.2 shows that the total numbers of women sampled in non-urban sites were consistently more than the total numbers of women sampled in urban sites, the women sampled in the former were predominantly from semi-urban sites. For instance in 2003 the 69.2% of women sampled in the non-urban sites comprised 48.9% of women from semi-urban sites.

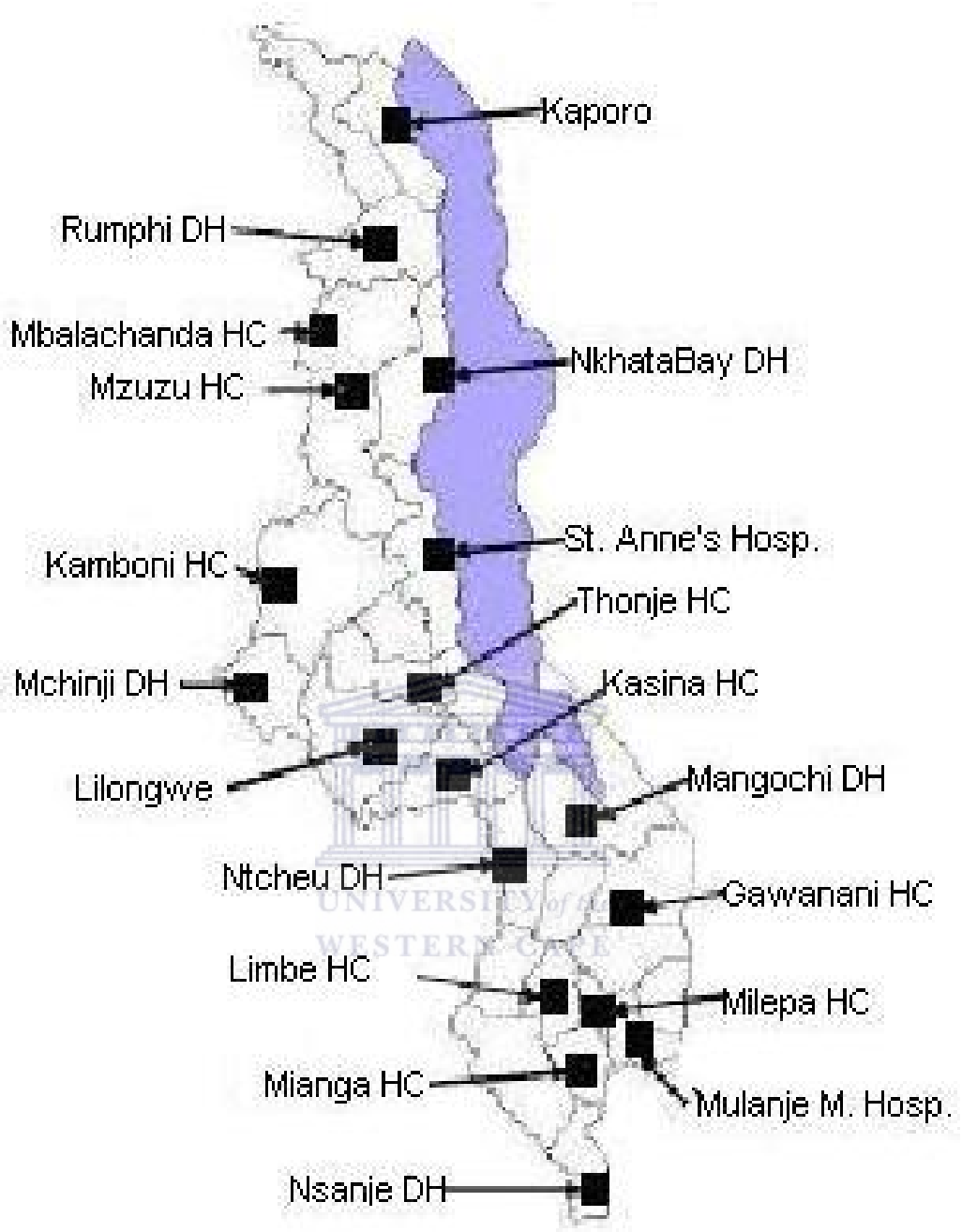

Figure 4.1: ANC sentinel surveillance sites in Malawi, 1999 to 2005

Source: NAC (2003b)

Note: Limbe Health Centre and Mzuzu Health Centre replaced Queen Elizabeth Central Hospital and St. John's Mission Hospital respectively which were used in 1999 and 2001.

Table 4.1: Classification of ANC sentinel surveillance sites in Malawi, 1999 to 2005.

Sentinel site	Region	Category
Kaporo Health Centre	North	Rural
Mbalachanda Health centre	North	Rural
Rumphi District Hospital	North	Semi-urban
Nkhata-Bay District Hospital	North	Semi-urban
Mzuzu Health Centre	North	Urban
Kamboni Health Centre	Centre	Rural
Thonje Health Centre	Centre	Rural
Kasina Health Centre	Centre	Rural
Mchinji District Hospital	Centre	Semi-urban
St. Anne's Mission Hospital	Centre	Semi-urban
Ntcheu District Hospital	Centre	Semi-urban
Lilongwe Central Hospital	Centre	Urban
Gawanani Health Centre	South	Rural
Milepa Health Centre	South	Rural
Mianga Health Centre	South	Rural
Mangochi District Hospital	South	Semi-urban
Mulanje Mission Hospital	South	Semi-urban
Nsanje District Hospital	South	Semi-urban
Limbe Health Centre	South	Urban

Source: NAC (2003c)

Table 4.2: Trends in the number of women sampled in ANC sentinel surveillance surveys in Malawi from 1999 to 2005 by site category.

Sentinel site	1999		2001		2003		2005	
category	Number	%	Number	%	Number	%	Number	%
Urban	1 901	27.6	1 853	25.1	2 460	30.8	2 564	28.6
Non-urban	4 984	72.4	5 521	74.9	5 517	69.2	6 390	71.4
Total	6 885	100	7 374	100	7 977	100	8 954	100

4.1.2 Age patterns of women sampled in ANC surveillance surveys in Malawi, 1999 to 2005

As evident in Table 4.3, the age pattern of women recruited in all the surveys in urban and non-urban sites from 1999 to 2005 was very similar. In both urban and non-urban sites, the samples comprised of relatively young women in their prime years of sexual activity. Women aged less than 30 years constituted over 75% of the samples in both categories with at least 55% of the women being aged between 15 and 24 years.

4.1.3 Age specific HIV prevalence among women sampled in ANC sentinel surveillance surveys

Age specific HIV prevalence among women aged 15-49 sampled in ANC surveillance surveys in Malawi from 1999 to 2005 for aggregated urban and non-urban sites are presented in Tables 4.4 and 4.5 respectively. As can be noted from these tables, HIV prevalence remained

Table 4.3: Age patterns of women sampled in ANC surveillance surveys in Malawi, 1999 to 2005.

Panel A:Urban Sites								
	1999		2001		2003		2005	
Age group	Number	%	Number	%	Number	%	Number	%
<15	4	0.2	5	0.3	2	0.1	8	0.8
15-19	378	19.9	354	19.2	481	19.6	487	19.1
20-24	816	43.1	781	42.5	1079	44.1	1057	41.5
25-29	420	22.2	440	23.9	565	23.1	628	24.7
30-34	191	10.1	190	10.3	251	10.3	279	11.0
35-39	76	4.0	62	3.4	60	2.5	72	2.8
40-49	9	0.5	7	0.4	9	0.4	14	0.5
50+	1	0.1	-	-	1	0.0	1	0.0
Total	1895	100	1839	100	2448	100	2546	100
Panel B:Non-urban Sites								
	1999		2001		2003		2005	
Age group	Number	%	Number	%	Number	%	Number	%
<15	8	0.2	13	0.2	13	0.2	5	0.1
15-19	1 153	23.5	1 203	22.1	1 133	20.7	1 294	20.4
20-24	1 913	39.0	1 977	36.3	2 124	38.8	2 324	36.6
25-29	990	20.2	1 204	22.1	1 157	21.1	1 408	22.2
30-34	499	10.2	647	11.9	641	11.7	854	13.4
35-39	258	5.3	313	5.7	319	5.8	326	5.1
40-49	84	1.7	92	1.7	84	1.5	134	2.1
50+	2	0.0	2	0.0	7	0.1	10	0.2
Total	4 907	100	5 451	100	5 478	100	6 355	100

above 10% across all age groups in both aggregated urban and non-urban sites during the entire period from 1999 to 2005. The confidence intervals in these tables suggest that HIV

prevalence in the youngest women (15-19 age group) remained significantly lower than that in the older women throughout the period 1999 to 2005. Furthermore, for both aggregated urban and non-urban sites, HIV prevalence figures peaked in the 25-29 and 30-34 age groups throughout the period 1999 to 2005 as the confidence intervals for HIV prevalence figures in the two age groups indicate no statistical significant differences.

Table 4.4: Age specific HIV prevalence for women sampled in ANC surveillance surveys in aggregated urban sites in Malawi, 1999 to 2005.

	1999				2001			
Age group	Total sampled	Number HIV+	% HIV+	95% CI	Total sampled	Number HIV+	% HIV+	95% CI
15-19	378	77	20.4	16.6-24.7	354	41	11.6	8.6-15.4
20-24	816	203	24.9	22.0-27.9	781	187	23.9	21.1-27.1
25-29	420	118	28.1	24.0-32.6	440	118	26.8	22.9-31.2
30-34	191	59	30.9	24.8-37.8	190	48	25.3	19.6-31.9
35-39	76	22	28.9	19.9-40.1	62	18	29.0	19.2-41.4
40-49	9	2	22.2	5.3-55.7	7	1	14.3	1.14-58.23
	2003				2005			
Age group	Total sampled	Number HIV+	% HIV+	95% CI	Total sampled	Number HIV+	% HIV+	95% CI
15-19	481	78	16.2	13.2-19.8	487	62	12.7	10.1-16.0
20-24	1 079	225	20.9	18.5-23.4	1 057	198	18.7	16.5-21.2
25-29	565	138	24.4	21.1-28.1	628	156	24.8	21.6-28.4
30-34	251	75	29.9	24.5-35.8	279	82	29.4	24.3-35.0
35-39	60	12	20.0	11.7-31.9	72	17	23.6	15.2-34.7
40-49	9	3	33.3	11.7-64.9	14	1	7.1	<0.001-33.5

Table 4.5: Age specific HIV prevalence for women sampled in ANC surveillance surveys in aggregated non-urban sites in Malawi, 1999 to 2005.

	1999				2001			
Age group	Total sampled	Number HIV+	% HIV+	95% CI	Total sampled	Number HIV+	% HIV+	95% CI
15-19	1 153	210	18.2	16.1-20.6	1 203	141	11.7	10.0-13.7
20-24	1 913	495	25.9	24.0-27.9	1 977	370	18.7	17.1-20.5
25-29	990	281	28.4	25.7-31.3	1 204	287	23.8	20.8-25.6
30-34	499	113	22.6	19.2-26.5	647	137	21.2	18.2-24.5
35-39	258	47	18.2	14.0-23.4	313	59	18.8	14.9-23.6
40-49	84	13	15.5	9.1-24.8	92	12	13.0	7.5-21.6
	2003				2005			
Age group	Total sampled	Number HIV+	% HIV+	95% CI	Total sampled	Number HIV+	% HIV+	95% CI
15-19	1 133	167	14.7	12.8-16.9	1 294	121	9.4	7.9-11.1
20-24	2 124	410	19.3	17.7-21.0	2 324	356	15.3	13.9-16.8
25-29	1 157	246	21.3	19.0-23.7	1 408	283	20.1	18.1-22.3
30-34	641	144	22.5	19.4-25.9	854	151	17.7	15.3-20.4
35-39	319	53	16.6	12.9-21.1	326	53	16.3	12.6-20.7
40-49	84	16	19.0	12.0-28.8	134	21	15.7	10.4-22.8

An examination of trends in the age specific HIV prevalence among the women sampled in ANC surveillance surveys in Malawi during the period 1999 to 2005 indicated that HIV prevalence in younger age groups declined but remained almost stable in old women. As depicted in Figures 4.2 and 4.3 there was a general downward trend in HIV prevalence between 1999 and 2005 in the 15-19, 20-24 and 25-29 age groups in both the aggregated urban and non-urban sites. However, in both sentinel site categories the decline was more pronounced in the 15-19 and 20-24 age groups. As Table 4.4 shows, the numbers of women

aged 40-49 sampled in the ANC surveillance surveys in the urban sites were very small, therefore the trends in HIV prevalence in this age group should be interpreted with caution. The trendline of HIV prevalence for women aged 40-49 in urban sites shown in Figure 4.2 might not be a true representation of reality. Thus, the peak shown in Figure 4.2 does not necessarily mean HIV prevalence in urban areas in Malawi was highest among women aged 40-49 compared to women in the younger age groups in 2003.

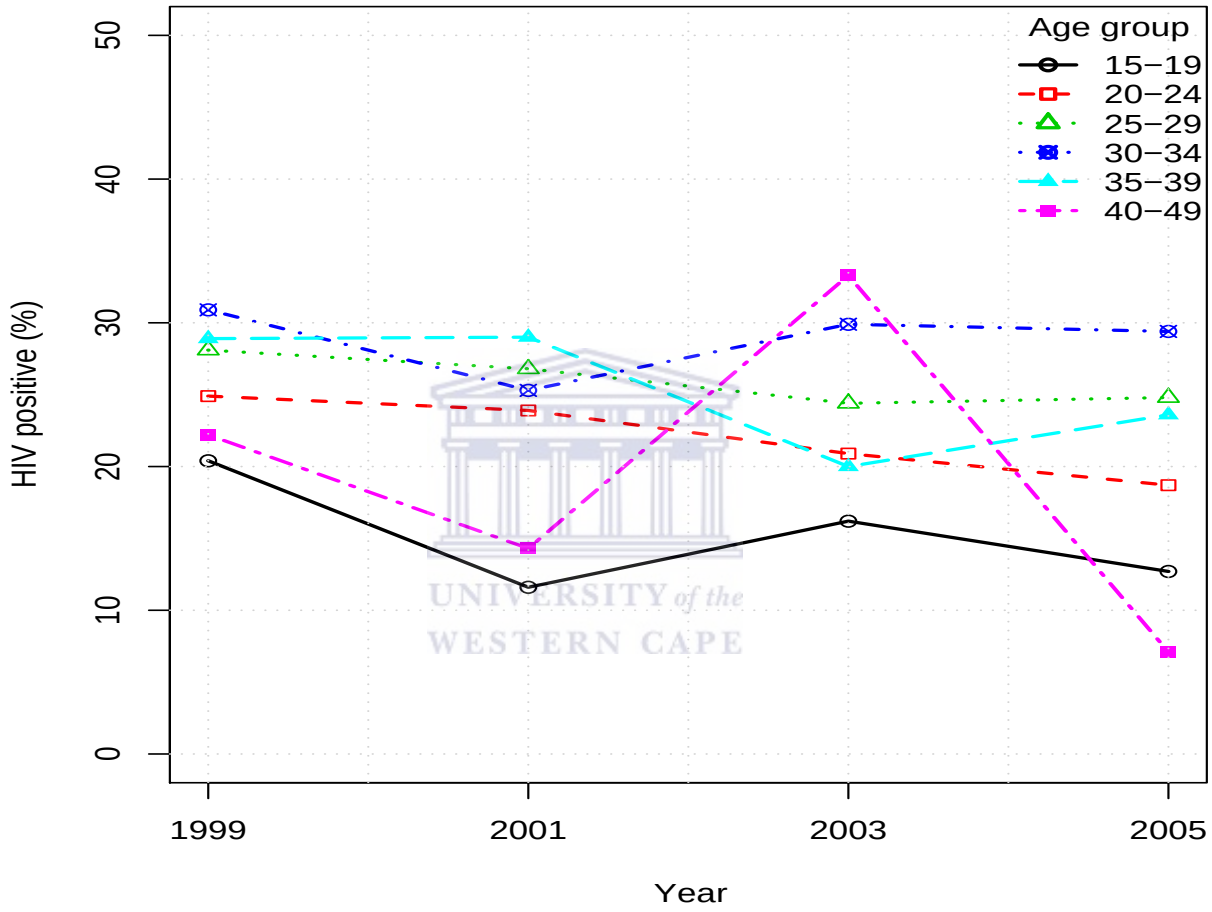

Figure 4.2: Age specific HIV prevalence in aggregated urban sites.

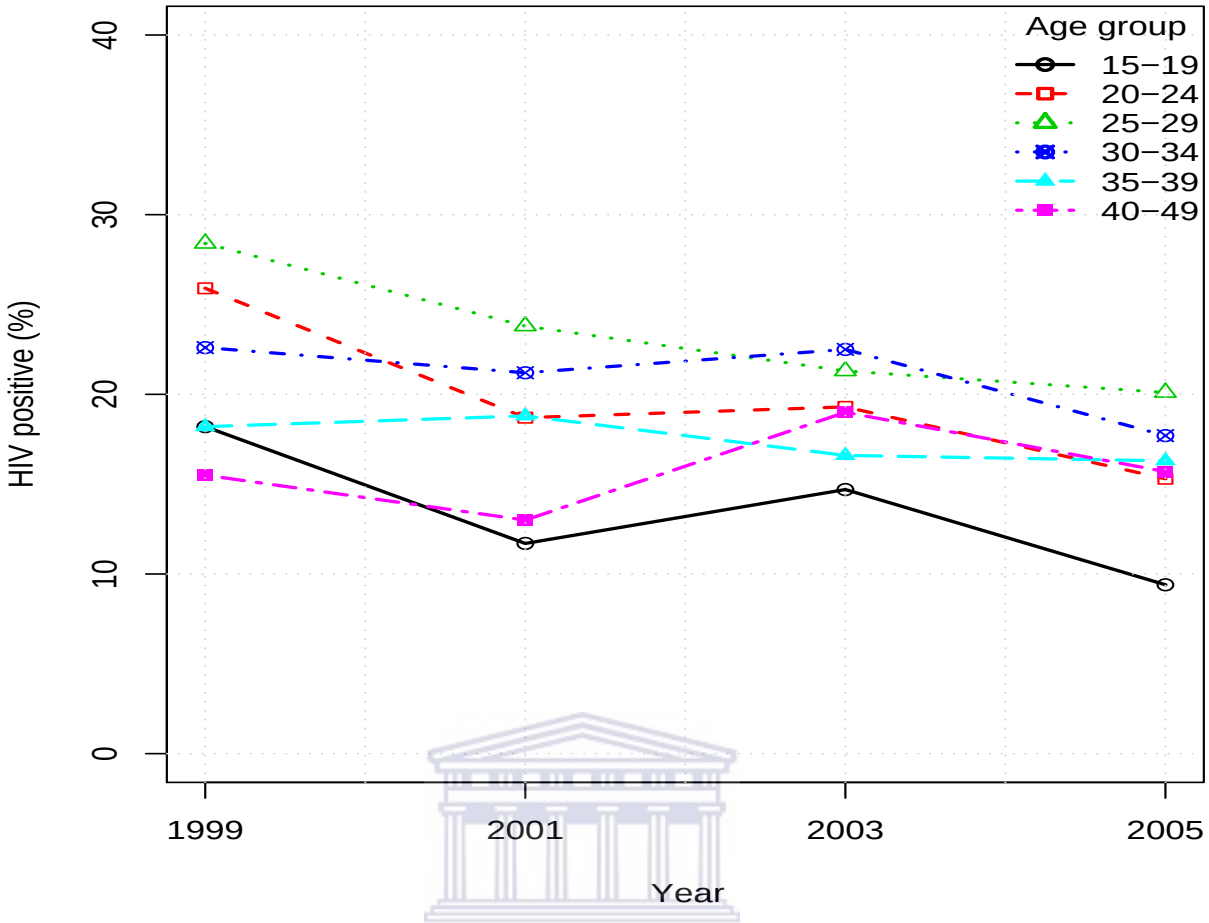

Figure 4.3: Age specific HIV prevalence in aggregated non-urban sites.

4.1.4 Adjusted age specific HIV prevalence for non-urban sites

Because the sites we classified as non-urban are located in small towns and large rural settlements with higher levels of economic activity and mobility and probably associated with higher HIV prevalence and may therefore over-estimate HIV prevalence in most remote areas, consistent with the UNAIDS/WHO approach, we adjusted down the age specific HIV prevalence figures in non-urban sites presented in Table 4.5 by 20%. The adjusted age specific HIV prevalence figures for the aggregated non-urban sites are presented in Table 4.6.

Table 4.6: Age specific HIV prevalence for aggregated non-urban sites in Malawi from 1999 to 2005 adjusted for representativeness.

	HIV prevalence (%)			
Age group	1999	2001	2003	2005
15-19	14.6	9.4	11.8	7.5
20-24	20.7	15.0	15.4	12.2
25-29	22.7	19.0	17.0	16.1
30-34	18.1	17.0	18.0	14.2
35-39	14.6	15.0	13.3	13.0
40-49	12.4	10.4	15.2	12.6

4.1.5 National estimates of age specific HIV prevalence among women based on ANC surveillance data

Applying the estimates of the percentages of female populations in urban and rural areas to the estimates of age specific HIV prevalence for the aggregated urban and non-urban sites presented in Tables 4.4 and 4.6 respectively, yielded preliminary estimates of national age-specific HIV prevalence for women in Malawi from 1999 to 2005 based on ANC surveillance data presented in Table 4.7.

Estimates of national age specific HIV prevalence among women based on the ANC surveillance data for the years 2000, 2002 and 2004 were linearly interpolated from the HIV prevalence figures presented in Table 4.7. The interpolated estimates of age specific HIV prevalence together with the age specific HIV prevalence figures in Table 4.7 formed the final national estimates of age specific HIV prevalence among women based on ANC

Table 4.7: Preliminary estimates of the national age specific HIV prevalence among women in Malawi from 1999 to 2005 based on ANC surveillance data.

	HIV prevalence (%)			
Age group	1999	2001	2003	2005
15-19	15.5	9.8	12.6	8.5
20-24	21.5	16.7	16.5	13.6
25-29	23.6	20.4	18.4	17.8
30-34	20.0	18.3	20.0	16.8
35-39	16.5	17.0	14.3	14.7
40-49	13.4	10.8	17.3	11.9

surveillance data presented in Table 4.8.

Table 4.8: Final estimates of the national age specific HIV prevalence among women in Malawi from 1999 to 2004 based on ANC surveillance data

	HIV prevalence (%)						
Age group	1999	2000	2001	2002	2003	2004	2005
15-19	15.5	12.6	9.8	11.2	12.6	10.6	8.5
20-24	21.5	19.1	16.7	16.6	16.5	15.1	13.6
25-29	23.6	22.0	20.4	19.4	18.4	18.1	17.8
30-34	20.0	19.2	18.3	19.1	20.0	18.4	16.8
35-39	16.5	16.8	17.0	15.7	14.3	14.5	14.7
40-49	13.4	12.1	10.8	14.1	17.3	14.6	11.9

As depicted in Figure 4.4, the final estimates of national age specific HIV prevalence among women in Malawi from 1999 to 2005 based on the ANC surveillance data suggest that the trajectory of HIV prevalence across age groups was almost similar in all the years except 2003. With the exception of the 40-49 age group whose prevalence figures were affected by small sample sizes as indicated earlier, HIV prevalence rates were lowest among women aged 15-19 years and peaked among women aged 25-29 years. Figure 4.4 also reveals that there was a substantial decline in national HIV prevalence among women in the younger age groups (15-19, 20-24 and 25-29).

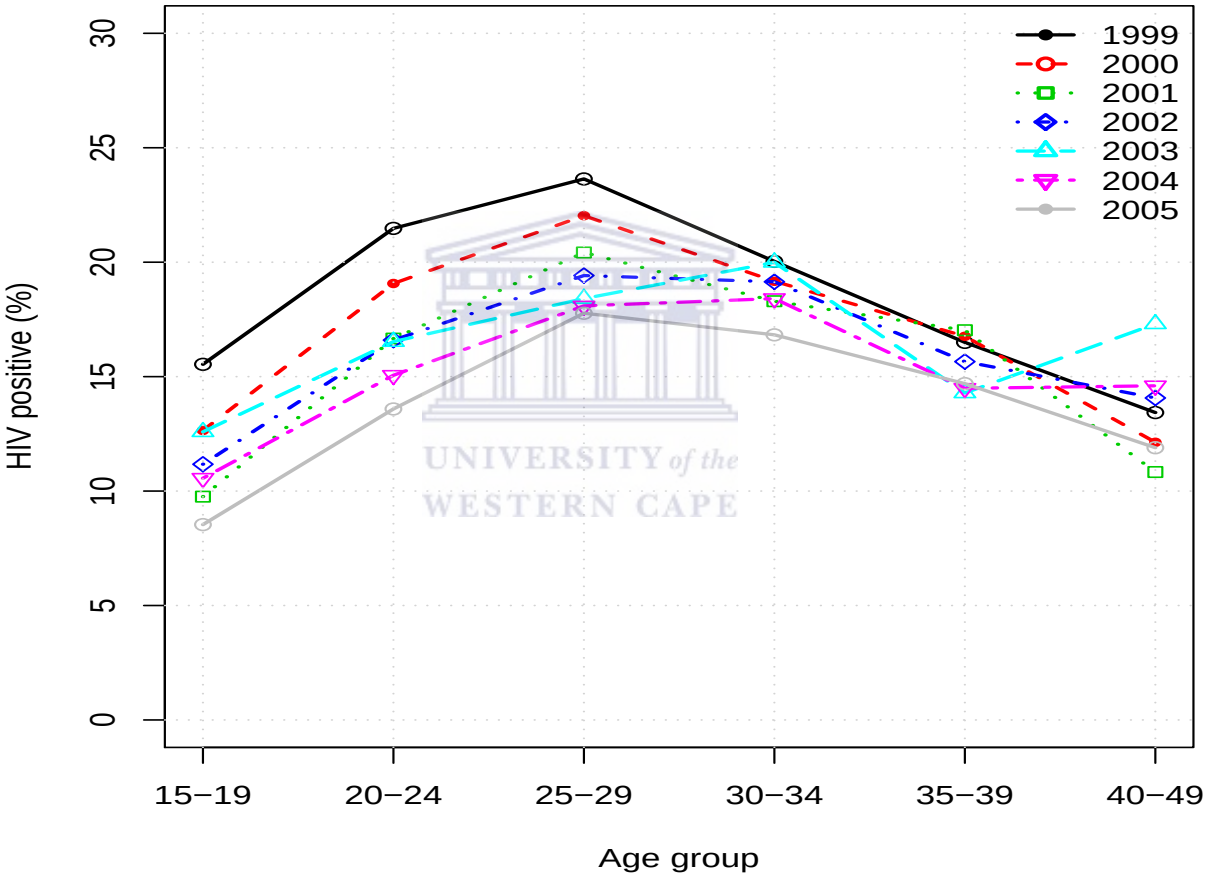

Figure 4.4: National estimates of age specific HIV prevalence among women based on ANC data.

4.1.6 Final national estimates of age specific HIV prevalence among women based on ANC surveillance data and 2004 Malawi DHS results

For the first time Malawi has national population-based HIV prevalence estimates for women and men derived from the 2004 Malawi DHS which included HIV testing. The age specific national HIV prevalence estimates for women of reproductive age derived from the 2004 Malawi DHS are presented in Table 4.9.

Table 4.9: Estimates of age specific HIV prevalence among females aged 15-49 in Malawi derived from 2004 Malawi DHS

Age group	Number tested	HIV prevalence (%)
15-19	500	3.7
20-24	661	13.2
25-29	477	15.5
30-34	382	18.1
35-39	257	17.0
40-49	408	15.9

Source: NSO and ORC Macro (2005).

Note: Numbers for the 40-49 age group were computed by author based on the original numbers in the 40-44 and 45-49 age groups in the 2004 Malawi DHS report.

A comparison was made between the national estimates of age specific HIV prevalence among females aged 15-49 in Malawi for the year 2004 derived from the 2004 Malawi DHS and

those based on the ANC surveillance data. According to NSO and ORC Macro (2005), the 2004 Malawi DHS was conducted from October 2004 to January 2005 while the 2005 ANC surveillance was conducted over a period of eight weeks starting on 1 August 2005 (NAC 2005). Therefore, appropriate HIV prevalence estimates from the ANC surveillance data that could be compared to the HIV prevalence estimates derived from the 2004 Malawi DHS were computed as the average of the estimates of HIV prevalence based on ANC surveillance data for the years 2004 and 2005 presented in Table 4.8. Figure 4.5 illustrates the comparison analysis of the computed HIV prevalence estimates from the ANC surveillance data and the HIV prevalence estimates from the 2004 Malawi DHS. As can be noted from Figure 4.5, estimates of HIV prevalence by age based on the ANC surveillance data differ from estimates of HIV prevalence for the general population derived from the 2004 Malawi DHS. For the 15-19, 20-24 and 25-29 age groups, estimates of HIV prevalence based on the ANC surveillance data are higher than those obtained from the 2004 Malawi DHS and there is a reversed relationship when comparing the 30-34, 35-39 and 40-49 age groups. This cross-over effect, although with different magnitudes, has been observed in most studies comparing estimates of HIV prevalence from ANC surveillance data and HIV prevalence in the general population (Fylkesnes et al., 1998; WHO and UNAIDS 2003). For this study, the magnitudes of the differences between the estimates of HIV prevalence by age based on ANC surveillance data and those derived from the 2004 Malawi DHS are presented in Table 4.10 as ratios of ANC HIV prevalence to general population HIV prevalence.

The estimates of age specific ratios of ANC HIV prevalence to general population HIV prevalence presented in Table 4.10 were used to further adjust the estimates of HIV prevalence by age based on ANC surveillance data presented in Table 4.8 to obtain final estimates of national HIV prevalence by age for all women of reproductive age in Malawi for the years 1999 to 2005. This yielded estimates of national HIV prevalence by age for women of reproductive age in Malawi for the years 1999 to 2005 presented in Table 4.11.

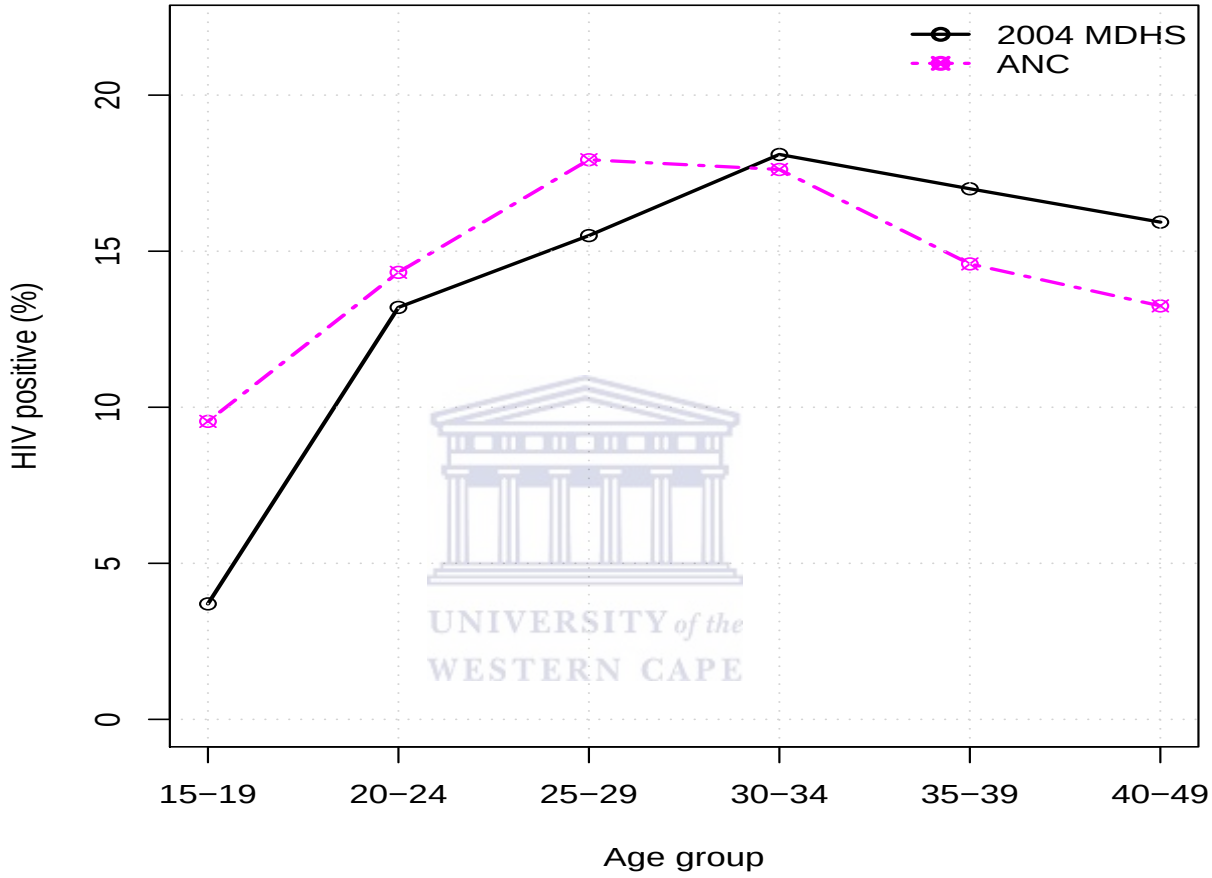

Figure 4.5: Comparison between estimates of age specific HIV prevalence among women aged 15-49 in Malawi in 2004 based on 2004 Malawi DHS and ANC data.

Table 4.10: Estimates of ratios of ANC HIV prevalence to general population HIV prevalence

Age group	Ratio of ANC HIV prevalence to general population HIV prevalence
15-19	2.58
20-24	1.09
25-29	1.16
30-34	0.97
35-39	0.86
40-49	0.83

Table 4.11: Final estimates of age specific national HIV prevalence among women of reproductive age in Malawi, 1999 to 2005

	HIV Prevalence (%)						
Age group	1999	2000	2001	2002	2003	2004	2005
15-19	6.0	4.9	3.8	4.3	4.9	4.1	3.3
20-24	19.8	17.6	15.4	15.3	15.2	13.9	12.5
25-29	20.4	19.0	17.7	16.8	15.9	15.6	15.4
30-34	20.6	19.7	18.8	19.7	20.5	18.9	17.3
35-39	19.2	19.5	19.8	18.2	16.6	16.9	17.1
40-49	16.2	14.6	13.0	16.9	20.8	17.6	14.3

4.2 Estimates of women of reproductive age

Four different sets of estimates of women of reproductive age in Malawi for the period 1999 to 2004 were made. The estimates were obtained by projecting the age smoothed population of females presented in Table 4.12 which was obtained from the analytic report of the 1998 census (NSO, 2002) using four different MLT systems as outlined in the methodology section (section 3.1.2). The first set of estimates was done using survival ratios derived from the WHO MLT system, the second using survival ratios derived from the United Nations Far East MLT system, the third using survival ratios derived from the north family of Coale-Demeny MLT system and the fourth using survival ratios derived from the south family of Coale-Demeny MLT system. Tables 4.13 to 4.20 present the estimates of women of reproductive age in Malawi for the years 1999 to 2004 based on these four MLT systems.

Table 4.12: Age smoothed population of females in Malawi in 1998.

Age group	Population size	Age group	Population size
0-4	835 780	40-44	193 647
5-9	726 525	45-49	153 393
10-14	623 625	50-54	112 069
15-19	552 501	55-59	91 901
20-24	514 183	60-64	80 856
25-29	428 291	65-69	73 642
30-34	304 987	70-74	69 004
35-39	238 958	75 & over	66 943

Source: NSO, 2002.

Table 4.13: Estimates of women of reproductive age in Malawi from 1999 to 2001 based on WHO MLT system.

	1999		2000		2001	
Age group	Population size	% of total	Population size	% of total	Population size	% of total
15-19	560 239	23.06	570 221	23.05	582 307	23.11
20-24	517 703	21.31	519 534	21.00	520 961	20.68
25-29	440 324	18.12	450 606	18.21	459 068	18.22
30-34	317 056	13.05	331 614	13.40	347 113	13.78
35-39	241 113	9.92	243 394	9.84	246 608	9.79
40-44	195 764	8.06	197 740	7.99	199 623	7.92
45-49	157 459	6.48	160 807	6.50	163 545	6.49
Total	2 429 658	100.00	2 473 916	100.00	2 519 225	100.00

Table 4.14: Estimates of women of reproductive age in Malawi from 2002 to 2004 based on WHO MLT system.

	2002		2003		2004	
Age group	Population size	% of total	Population size	% of total	Population size	% of total
15-19	596 143	23.23	611 441	23.38	627 702	23.54
20-24	523 636	20.41	528 742	20.22	536 189	20.11
25-29	465 737	18.15	470 768	18.00	473 939	17.77
30-34	361 661	14.09	374 011	14.30	384 478	14.42
35-39	251 714	9.81	259 146	9.91	269 409	10.10
40-44	201 451	7.85	203 304	7.77	205 138	7.69
45-49	165 842	6.46	167 838	6.42	169 676	6.36
Total	2 566 184	100.00	2 615 250	100.00	2 666 531	100.00

Table 4.15: Estimates of women of reproductive age in Malawi from 1999 to 2001 based on UN Far East MLT system.

	1999		2000		2001	
Age group	Population size	% of total	Population size	% of total	Population size	% of total
15-19	558 298	22.84	566 582	22.63	577 195	22.51
20-24	517 928	21.19	519 635	20.76	520 586	20.30
25-29	444 097	18.17	457 705	18.29	468 995	18.29
30-34	322 037	13.18	341 768	13.65	362 691	14.14
35-39	245 240	10.03	251 911	10.06	259 845	10.13
40-44	198 283	8.11	203 167	8.12	208 360	8.13
45-49	158 026	6.47	162 384	6.49	166 582	6.50
Total	2 443 909	100.00	2 503 152	100.00	2 564 254	100.00

Table 4.16: Estimates of women of reproductive age in Malawi from 2002 to 2004 based on UN Far East MLT system.

	2002		2003		2004	
Age group	Population size	% of total	Population size	% of total	Population size	% of total
15-19	589 768	22.44	603 972	22.42	619 517	22.42
20-24	522 421	19.88	526 281	19.53	532 715	19.28
25-29	477 963	18.19	484 708	17.99	489 191	17.70
30-34	382 848	14.57	400 830	14.88	416 470	15.07
35-39	270 145	10.28	283 403	10.52	299 870	10.85
40-44	213 916	8.14	219 924	8.16	226 157	8.18
45-49	170 796	6.50	175 167	6.50	179 730	6.50
Total	2 627 857	100.00	2 694 285	100.00	2 763 650	100.00

Table 4.17: Estimates of women of reproductive age in Malawi from 1999 to 2001 based on Coale-Demeny north MLT system.

	1999		2000		2001	
Age group	Population size	% of total	Population size	% of total	Population size	% of total
15-19	559 574	22.79	568 674	22.52	579 654	22.33
20-24	520 125	21.19	523 769	20.75	526 384	20.28
25-29	446 241	18.18	461 991	18.30	475 373	18.31
30-34	323 622	13.18	345 064	13.67	367 820	14.17
35-39	246 492	10.04	254 431	10.08	263 659	10.16
40-44	199 529	8.13	205 632	8.14	212 018	8.17
45-49	159 441	6.49	165 173	6.54	170 693	6.58
Total	2 455 024	100.00	2 524 734	100.00	2 595 601	100.00

Table 4.18: Estimates of women of reproductive age in Malawi from 2002 to 2004 based on Coale-Demeny north MLT system.

	2002		2003		2004	
Age group	Population size	% of total	Population size	% of total	Population size	% of total
15-19	592 147	22.19	605 843	22.09	620 473	22.00
20-24	529 624	19.85	534 683	19.49	541 907	19.22
25-29	486 339	18.23	494 975	18.05	501 087	17.77
30-34	389 897	14.61	409 840	14.94	427 409	15.16
35-39	275 309	10.32	290 014	10.57	308 071	10.93
40-44	218 739	8.20	225 887	8.24	233 274	8.27
45-49	176 170	6.60	181 744	6.63	187 488	6.65
Total	2 668 225	100.00	2 742 986	100.00	2 819 709	100.00

Table 4.19: Estimates of women of reproductive age in Malawi from 1999 to 2001 based on Coale-Demeny South MLT system.

	1999		2000		2001	
Age group	Population size	% of total	Population size	% of total	Population size	% of total
15-19	559 888	22.78	569 420	22.50	580 951	22.30
20-24	520 317	21.17	524 165	20.71	526 996	20.23
25-29	446 653	18.17	462 778	18.28	476 491	18.29
30-34	324 190	13.19	346 203	13.68	369 535	14.18
35-39	247 101	10.05	255 644	10.10	265 476	10.19
40-44	200 099	8.14	206 784	8.17	213 762	8.20
45-49	159 899	6.50	166 115	6.56	172 142	6.61
Total	2 458 147	100.00	2 531 109	100.00	2 605 353	100.00

Table 4.20: Estimates of women of reproductive age in Malawi from 2002 to 2004 based on Coale-Demeny South MLT system.

	2002		2003		2004	
Age group	Population size	% of total	Population size	% of total	Population size	% of total
15-19	594 122	22.16	608 629	22.05	624 296	21.98
20-24	530 465	19.78	535 775	19.41	543 373	19.13
25-29	487 736	18.19	496 603	17.99	502 962	17.71
30-34	392 181	14.63	412 671	14.95	430 749	15.16
35-39	277 745	10.36	293 107	10.62	311 850	10.98
40-44	221 088	8.24	228 861	8.29	236 873	8.34
45-49	178 150	6.64	184 282	6.68	190 597	6.71
Total	2 681 487	100.00	2 759 928	100.00	2 840 700	100.00

4.2.1 Comparison of estimates of women of reproductive age in Malawi from 1999 to 2004

As can be noted from Tables 4.13 to 4.20, throughout the years the estimates based on all the four MLT systems indicate that about 75% of the women in the 15-49 age group in Malawi were less than 35 years old. Furthermore, as shown in Figure 4.6, the WHO MLT system produced the lowest estimates of the total population of women aged 15-49 in Malawi from 1999 to 2004 and the highest estimates were obtained from the south family of Coale-Demeny MLT system. In addition, comparison between the four sets of estimates of the total population of women aged 15-49 in Malawi from 1999 to 2004 derived from the four MLT systems and estimates done by the Malawi National Statistical Office and the National AIDS Commission revealed that there were no huge differences between the estimates derived from the north family of Coale-Demeny MLT system and those done by the National AIDS Commission (see Figure 4.7). Figure 4.7 further indicates that there were also no huge differences between estimates derived from the south family of Coale-Demeny MLT system and those done by the Malawi National Statistical Office.

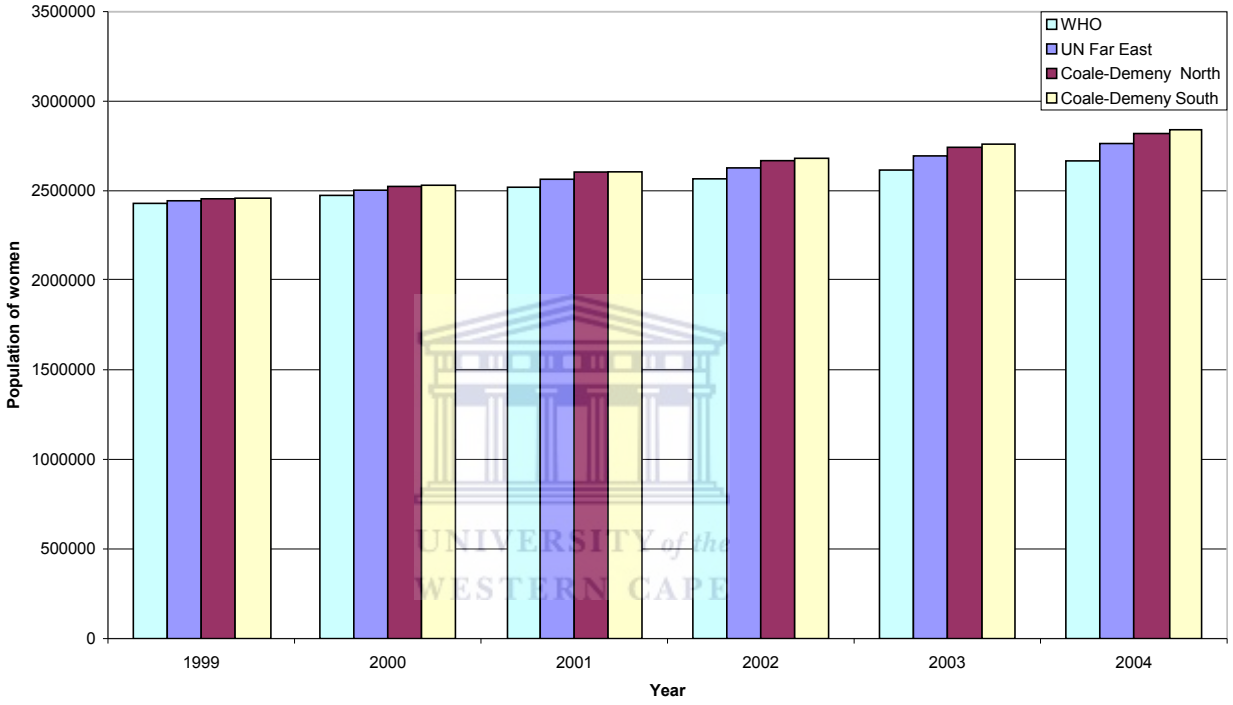

Figure 4.6: Comparison of estimates of total women population aged 15-49 in Malawi from 1999 to 2004.

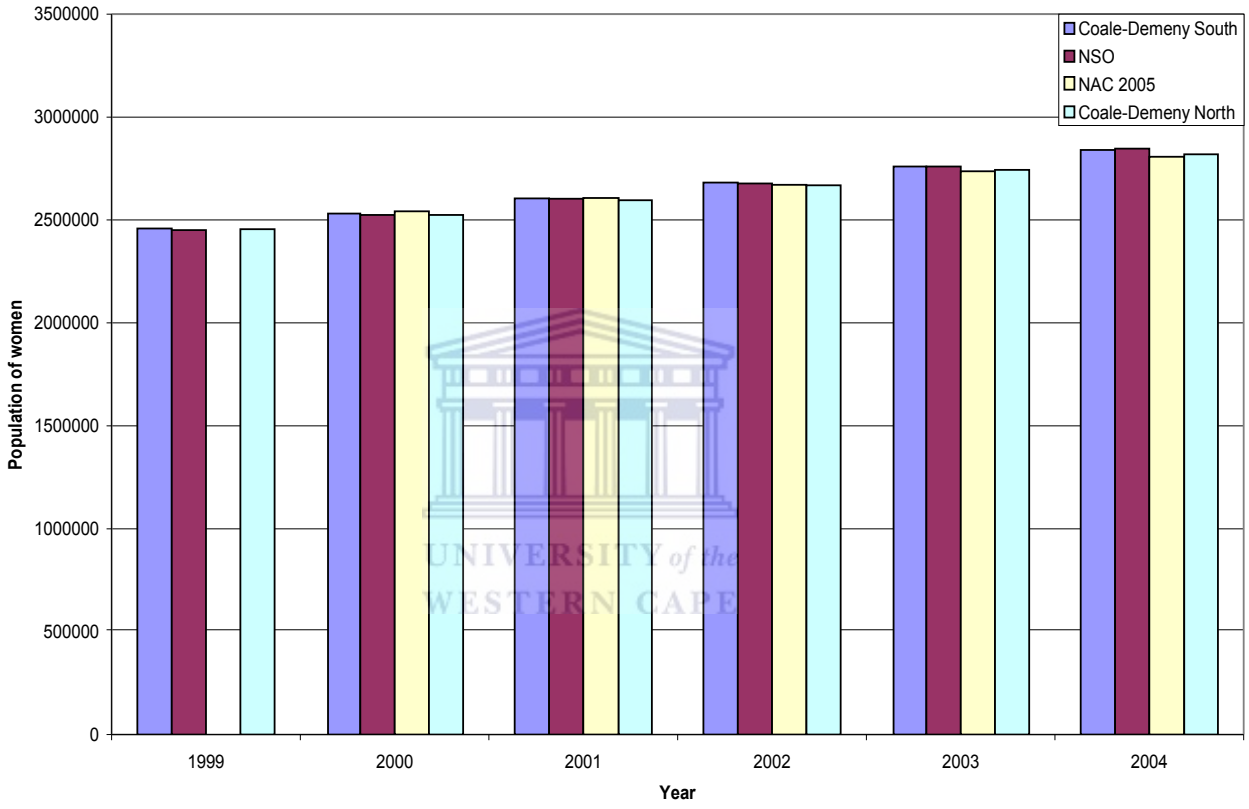

Figure 4.7: Comparison of estimates of women aged 15-49 in Malawi from 1999-2004

4.3 Estimates of the number of HIV infected women

Estimates of the number of women aged 15-49 infected with HIV were made by applying the age specific estimates of HIV prevalence presented in Table 4.11 to the estimates of the total population of women aged 15-49 in Malawi presented in Tables 4.13 to 4.20. A range of the obtained estimates are presented in Tables 4.21 to 4.24. Interestingly, the estimates of the number of women aged 15-49 infected with HIV presented in Tables 4.21 to 4.24 yield estimates of HIV prevalence for adult females (age 15-49) in Malawi for the years 2000 to 2004 that diverge only very narrowly from those presented in Table 4.25, which were produced by NAC (2005) using the Spectrum package in combination with the Estimation and Projection Package. The differences between the estimates of HIV prevalence for adult females in Malawi from 2000 to 2004 obtained in this study and NAC (2005)'s estimates range from 0.6 to 2.1 percentage points with the estimates obtained in this study being lower than NAC (2005)'s estimates in all the years as shown in Figure 4.8.

Table 4.21: Estimates of the number of HIV infected women in Malawi for estimates of women based on WHO MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	33 734	27 947	22 016	25 809	29 826	25 690
20-24	102 470	91 304	79 994	80 085	80 544	74 411
25-29	89 973	85 814	81 049	78 173	74 919	74 115
30-34	65 264	65 294	65 241	71 130	76 823	72 718
35-39	46 342	47 530	48 918	45 910	43 126	45 478
40-44	31 619	28 848	26 004	34 081	42 307	36 017
45-49	25 432	23 460	21 304	28 057	34 927	29 791
Total HIV-infected women (15-49)	394 834	370 197	344 526	363 245	382 472	358 220
% HIV-infected women (15-49)	16.3	15.0	13.7	14.2	14.6	13.4

Table 4.22: Estimates of the number of HIV infected women in Malawi for estimates of women based on UN Far East MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	33 618	27 769	21 823	25 533	29 462	25 355
20-24	102 515	91 322	79 936	79 899	80 169	73 929
25-29	90 743	87 166	82 802	80 225	77 138	76 500
30-34	66 289	67 293	68 169	75 298	82 331	78 769
35-39	47 135	49 194	51 544	49 272	47 163	50 620
40-44	32 026	29 640	27 142	36 190	45 765	39 707
45-49	25 524	23 690	21 700	28 895	36 452	31 556
Total HIV-infected women (15-49)	397 850	376 074	353 116	375 312	398 480	376 436
% HIV-infected women (15-49)	16.3	15.0	13.8	14.3	14.8	13.6

Table 4.23: Estimates of the number of HIV infected women in Malawi for estimates of women based on Coale-Demeny North MLT system.

Age Group	1999	2000	2001	2002	2003	2004
15-19	33 694	27 871	21 916	25 636	29 553	25 394
20-24	102 950	92 048	80 827	81 001	81 449	75 204
25-29	91 182	87 983	83 928	81 631	78 772	78 360
30-34	66 615	67 942	69 133	76 684	84 182	80 838
35-39	47 376	49 686	52 300	50 214	48 263	52 004
40-44	32 227	30 000	27 618	37 006	47 006	40 957
45-49	25 752	24 097	22 235	29 804	37 820	32 918
Total HIV infected women (15-49)	399 796	379 627	357 957	381 976	407 045	385 675
% HIV-infected women (15-49)	16.3	15.0	13.8	14.3	14.8	13.7

Table 4.24: Estimates of the number of HIV infected women in Malawi for estimates of women based on Coale-Demeny South MLT system.

Age Group	1999	2000	2001	2002	2003	2004
15-19	33 713	27 908	21 965	25 722	29 689	25 550
20-24	102 988	92 118	80 920	81 130	81 615	75 408
25-29	91 266	88 133	84 125	81 865	79 031	78 654
30-34	66 732	68 167	69 455	77 133	84 763	81 469
35-39	47 493	49 923	52 661	50 658	48 778	52 642
40-44	32 319	30 168	27 845	37 404	47 625	41 589
45-49	25 826	24 235	22 424	30 139	38 349	33 464
Total HIV infected women (15-49)	400 337	380 652	359 395	384 051	409 850	388 776
% HIV-infected women (15-49)	16.3	15.0	13.8	14.3	14.9	13.7

Table 4.25: Estimates of national HIV prevalence among women of reproductive age in Malawi from 1999 to 2005 by NAC(2005)

	HIV Prevalence (%)					
Age Group	2000	2001	2002	2003	2004	2005
15-49	16.1	15.9	15.7	15.5	15.4	15.4

Source: Computed by author from NAC(2005)'s report.

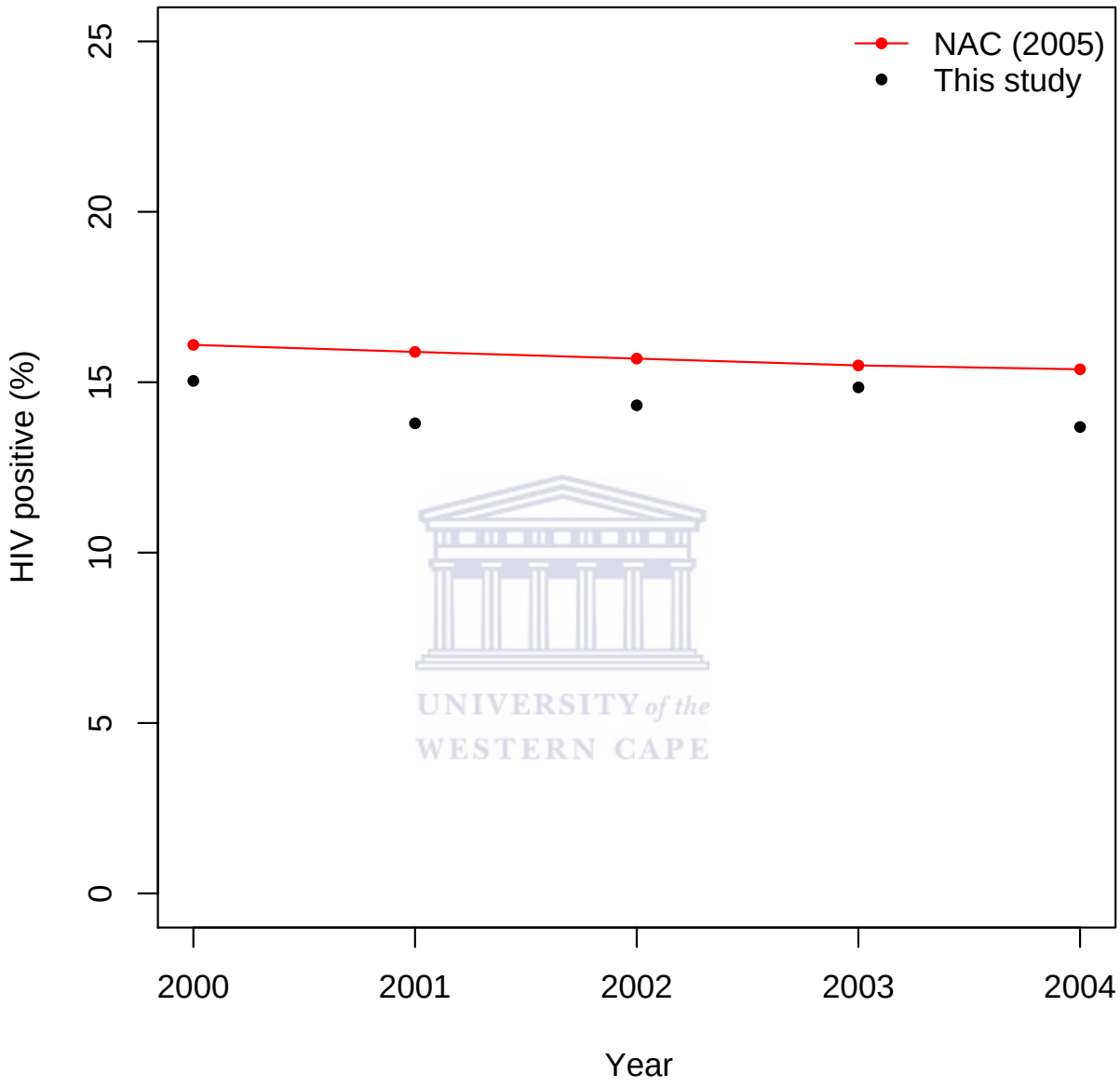

Figure 4.8: Comparison of this study's estimates of HIV prevalence for adult females in Malawi with NAC (2005)'s estimates from 2000 to 2004

4.4 Estimates of the number of children

Estimates of the number of children born to all women of reproductive age in Malawi from 1999 to 2004 were based on ASFRs derived from the 2000 and 2004 Malawi DHSs presented in Table 4.26. An examination of the ASFRs presented in Table 4.26 reveals that fertility slightly declined between 2000 and 2004 in all age groups except the 30-34 age as shown in Figure 4.9.

Table 4.26: Age-specific fertility rates (per 1 000 women) in Malawi in 2000 and 2004.

	Age Group						
	15-19	20-24	25-29	30-34	35-39	40-44	45-49
2000 MDHS	172	305	272	219	167	94	41
2004 MDHS	162	293	254	222	163	80	35

Source: NSO and ORC Macro (2001; 2005).

As we required estimates of ASFRs for all the years starting from 1999 up to 2004 in order to compute estimates of the number of children born to all women during this period, we assumed a constant annual rate of change in ASFRs between 2000 and 2004 and applied linear interpolation to the ASFRs presented in Table 4.26 above to derive estimates of ASFRs for the missing years. Table 4.27 shows the computed estimates of ASFRs together with those in Table 4.26. The set of ASFRs presented in Table 4.27 are the ones that were used in computing estimates of the number of children born to all women in Malawi during the period from 1999 to 2004.

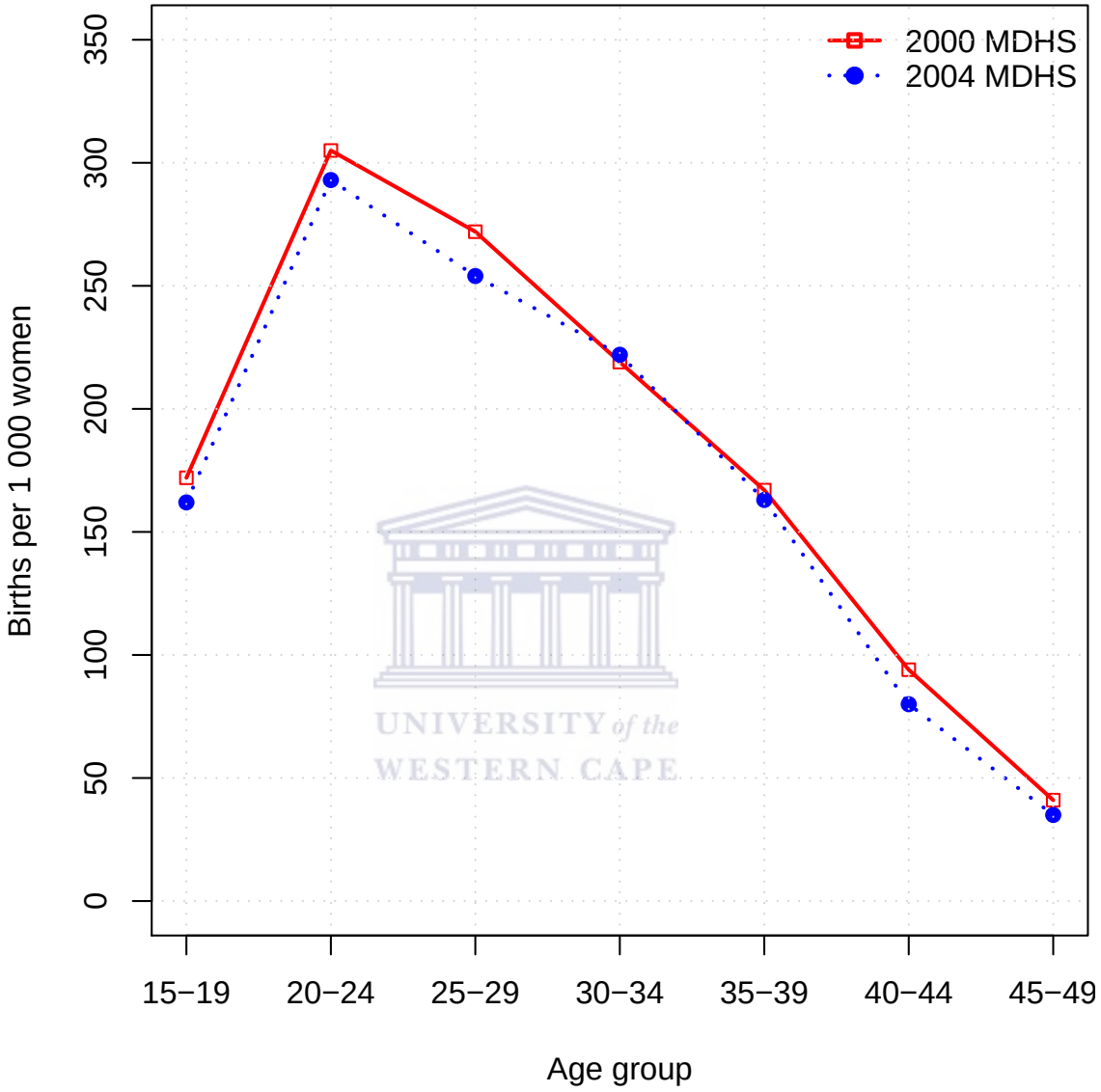

Figure 4.9: Comparison of age-specific fertility rates (per 1 000 women) in Malawi in 2000 and 2004.

Table 4.27: Estimates of age-specific fertility rates (per 1 000 women) for all women in Malawi from 1999 to 2004.

Age group	1999	2000	2001	2002	2003	2004
15-19	174	172	170	167	164	162
20-24	308	305	302	299	296	293
25-29	276	272	268	263	258	254
30-34	218	219	220	220	221	222
35-39	168	167	166	165	164	163
40-44	98	94	90	87	84	80
45-49	42	41	40	38	36	35

Estimates of ASFRs presented in Table 4.27 were applied to the estimates of the total population of women aged 15-49 in Malawi presented in Tables 4.13 to 4.20 and yielded a range of estimates of number of children born to all women in Malawi from 1999 to 2004 presented in Tables 4.28 to 4.31.

Estimates of the number of children born to all women followed a similar pattern as estimates of the total number of women of reproductive age. The highest numbers of births were those based on estimates of women using the south family of Coale-Demeny MLT system and the lowest were those based on the UN Far East MLT system. As evident in Figure 4.10, the estimates of the annual number of births to all women in Malawi based on the three MLTs are almost comparable to the estimates produced by UNICEF (2005, 2004, 2003 and 2002).

Table 4.28: Estimates of the number of births to all women in Malawi from 1999 to 2004 for estimates of women based on WHO MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	97 482	98 078	98 992	99 556	100 276	101 688
20-24	159 453	158 458	157 330	156 567	156 508	157 103
25-29	121 529	122 565	123 030	122 489	121 458	120 381
30-34	69 118	72 623	76 365	79 565	82 656	85 354
35-39	40 507	40 647	40 937	41 533	42 500	43 914
40-44	19 185	18 588	17 966	17 526	17 078	16 411
45-49	6 613	6 593	6 542	6 302	6 042	5 939
Total births	513 887	517 552	521 162	523 538	526 518	530 790

Table 4.29: Estimates of the number of births to all women in Malawi from 1999 to 2004 for estimates of women based on UN Far East MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	97 144	97 452	98 123	98 491	99 051	100 362
20-24	159 522	158 489	157 217	156 204	155 779	156 085
25-29	122 571	124 496	125 691	125 704	125 055	124 255
30-34	70 204	74 847	79 792	84 227	88 583	92 456
35-39	41 200	42 069	43 134	44 574	46 478	48 879
40-44	19 432	19 098	18 752	18 611	18 474	18 093
45-49	6 637	6 658	6 663	6 490	6 306	6 291
Total births	516 710	523 109	529 372	534 301	539 726	546 421

Table 4.30: Estimates of the number of births to all women in Malawi from 1999 to 2004 for estimates of women based on Coale-Demeny North MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	97 366	97 812	98 541	98 889	99 358	100 517
20-24	160 198	159 750	158 968	158 358	158 266	158 779
25-29	123 163	125 662	127 400	127 907	127 704	127 276
30-34	70 550	75 569	80 920	85 777	90 575	94 885
35-39	41 411	42 490	43 767	45 426	47 562	50 216
40-44	19 554	19 329	19 082	19 030	18 975	18 662
45-49	6 697	67 72	6 828	6 694	6 543	6 562
Total births	518 939	527 384	535 506	542 081	548 983	556 897

Table 4.31: Estimates of the number of births to all women in Malawi from 1999 to 2004 for estimates of women based on Coale-Demeny South MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	97 421	97 940	98 762	99 218	99 815	101 136
20-24	160 258	159 870	159 153	158 609	158 589	159 208
25-29	123 276	125 876	127 700	128 275	128 124	127 752
30-34	70 673	75 818	81 298	86 280	91 200	95 626
35-39	41 513	42 693	44 069	45 828	48 070	50 832
40-44	19 610	19 438	19 239	19 235	19 224	18 950
45-49	6 716	6 811	6 886	6 770	6 634	6 671
Total births	519 467	528 446	537 107	544 215	551 656	560 175

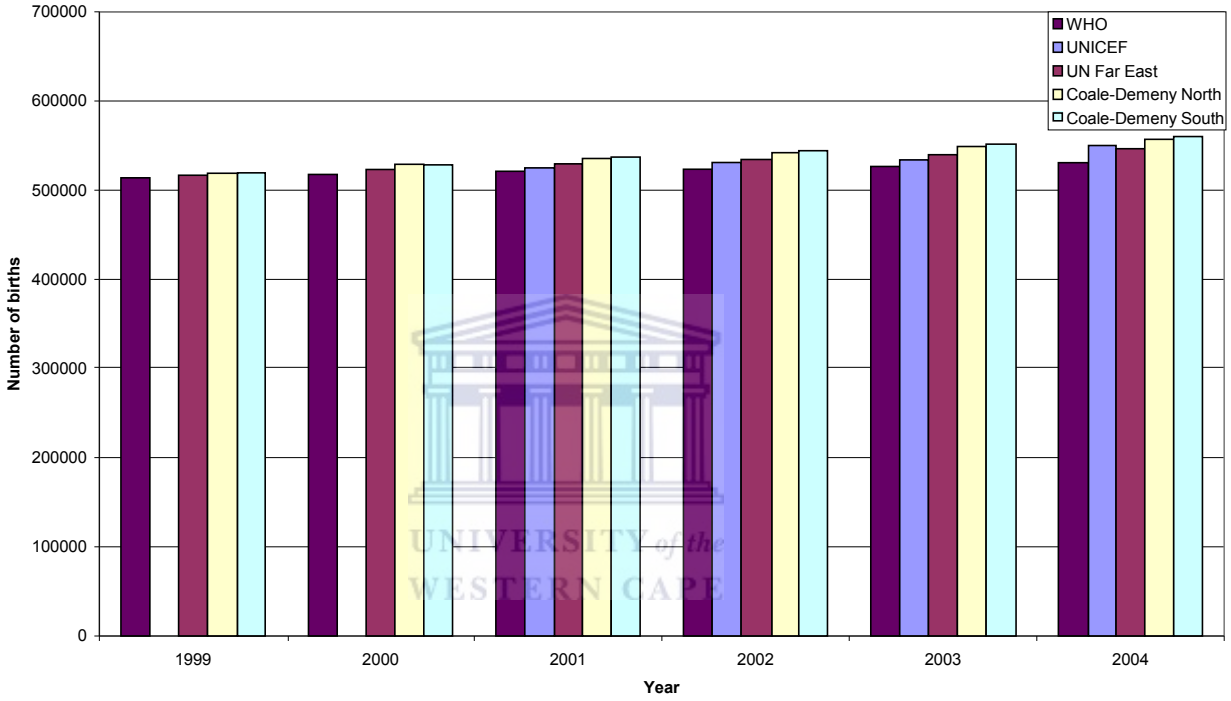

Figure 4.10: Comparison of estimates of the number of births to all women in Malawi from 1999 to 2004.

4.5 Estimates of the number of children infected with HIV through mother-to-child transmission

Estimates of the number of children infected with HIV through MTCT started with estimates of the number of children born to all HIV infected women. Assuming that fertility among 15-19 years old women is 50% higher among HIV-positive than HIV-negative women and that fertility among women 20-49 years old is 20% lower among HIV-positive women than HIV-negative women we applied equation 3.34 outlined in the methodology section (section 3.1.5) and estimates of ASFRs for all women in Malawi from 1999 to 2004 presented in Table 4.27 to estimates of HIV-infected women presented in Tables 4.21 to 4.24 and estimates of HIV-negative women to obtain estimates of number of births to HIV-infected women. The estimated numbers of children born to HIV-infected women in Malawi from 1999 to 2004 are presented in Tables 4.32 to 4.35.

Table 4.32: Estimates of the number of births to HIV-infected women in Malawi from 1999 to 2004 for estimates of women based on WHO MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	8 547	7 038	5 510	6 328	7 163	6 117
20-24	26 289	23 090	19 939	19 761	19 672	17 940
25-29	20 712	19 413	18 013	17 019	15 972	15 546
30-34	11 871	11 908	11 931	13 031	14 164	13 422
35-39	6 477	6 608	6 765	6 290	5 853	6 138
40-44	2 562	2 235	1 922	2 455	2 966	2 389
45-49	883	793	700	883	1 050	865
Total births	77 341	71 085	64 780	65 767	66 840	62 417

Table 4.33: Estimates of the number of births to HIV-infected women in Malawi from 1999 to 2004 for estimates of women based on UN Far East MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	8 518	6 993	5 462	6 260	7 075	6 038
20-24	26 301	23 094	19 924	19 715	19 581	17 824
25-29	20 890	19 718	18 403	17 466	16 445	16 047
30-34	12 057	12 273	12 466	13 795	15 180	14 539
35-39	6 588	6 839	7 128	6 750	6 401	6 831
40-44	2 595	2 296	2 006	2 607	3 209	2 634
45-49	886	800	713	909	1 095	916
Total births	77 835	72 013	66 102	67 502	68 986	64 829

Table 4.34: Estimates of the number of births to HIV-infected women in Malawi from 1999 to 2004 for estimates of women based on Coale-Demeny North MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	8 537	7 019	5 485	6 286	7 097	6 047
20-24	26 412	23 278	20 147	19 987	19 893	18 131
25-29	20 991	19 903	18 653	17 772	16 793	16 437
30-34	12 116	12 391	12 643	14 049	15 521	14 921
35-39	6 622	6 908	7 232	6 879	6 550	7 018
40-44	2 611	2 324	2 042	2 666	32 96	2 717
45-49	894	814	731	938	1 137	955
Total births	78 183	72 637	66 933	68 577	70 287	66 226

Table 4.35: Estimates of the number of births to HIV-infected women in Malawi from 1999 to 2004 for estimates of women based on Coale-Demeny South MLT system.

Age group	1999	2000	2001	2002	2003	2004
15-19	8 542	70 28	5 497	6 307	7 130	6 084
20-24	26 422	23 296	20 170	20 019	19 934	18 180
25-29	21 010	19 937	18 697	17 823	16 848	16 499
30-34	12 138	12 432	12 702	14 131	15 628	15 038
35-39	6 638	6 941	7 282	6 940	6 620	7 104
40-44	2 618	2 337	2 058	2 694	3 339	2 759
45-49	897	819	737	948	1 152	971
Total births	78 265	72 790	67 143	68 862	70 651	66 635

Estimates of the number of children infected with HIV through MTCT were then computed by applying PTRs to the estimates of the total numbers of children born to HIV-infected women in Malawi from 1999 to 2004 presented in Tables 4.32 to 4.35. Three scenarios of PTRs in the absence of any intervention (PTR equal to 30%, PTR equal to 32% and PTR equal to 30%) were considered together with their corresponding default values from AIM for HIV infected pregnant women who received Nevirapine presented in Table 3.8. The final estimates of the number of children infected with HIV through MTCT in Malawi from 1999 to 2004 under the three scenarios are presented in Tables 4.36 to 4.39.

Table 4.36: Estimates of the number of children infected with HIV through MTCT in Malawi from 1999 to 2004 for estimates of women based on WHO MLT system.

Base transmission rate	1999	2000	2001	2002	2003	2004
30%	23 202	21 326	19 434	19 612	19 744	18 344
32%	24 749	22 747	20 730	20 978	21 213	19 756
35%	27 069	24 880	22 673	22 960	23 240	21 656

Table 4.37: Estimates of the number of children infected with HIV through MTCT in Malawi from 1999 to 2004 for estimates of women based on UN Far East MLT system.

Base transmission rate	1999	2000	2001	2002	2003	2004
30%	23 350	21 604	19 831	20 133	20 388	19 068
32%	24 907	23 044	21 153	21 533	21 900	20 528
35%	27 242	25 205	23 136	23 567	23 991	22 500

Table 4.38: Estimates of the number of children infected with HIV through MTCT in Malawi from 1999 to 2004 for estimates of women based on Coale-Demeny North MLT system.

Base transmission rate	1999	2000	2001	2002	2003	2004
30%	23 455	21 791	20 080	20 456	20 778	19 487
32%	25 019	23 244	21 419	21 877	22 316	20 975
35%	27 364	25 423	23 427	23 943	24 447	22 989

Table 4.39: Estimates of the number of children infected with HIV through MTCT in Malawi from 1999 to 2004 for estimates of women based on Coale-Demeny South MLT system.

Base transmission rate	1999	2000	2001	2002	2003	2004
30%	23 480	21 837	20 143	20 541	20 888	19 610
32%	25 045	23 293	21 486	21 969	22 432	21 106
35%	27 393	25 476	23 500	24 043	24 574	23 132

4.6 Estimates of the number of HIV infected children dying before the age of five years during the period 2000 to 2004

We computed estimates of the total number of children infected with HIV through MTCT that died before attaining the age of five years during the period 2000 to 2004 in Malawi by applying the survival curve of children infected with HIV through MTCT presented by equation 3.37 in the methodology section (section 3.1.6) to the estimates of the numbers of children infected with HIV through MTCT during the period 2000 to 2004 presented in Tables 4.36 to 4.39. We assumed an even distribution in the number of children infected

with HIV through MTCT in each year and started by computing estimates of the average number of children infected with HIV through MTCT per month in each year from 2000 to 2004. Thereafter, applying the survival curve of children infected with HIV through MTCT presented by equation 3.37 to the monthly estimates of the number of children infected with HIV through MTCT we obtained estimates of the total number of children infected with HIV through MTCT that died before their fifth birthday in Malawi during the period 2000 to 2004 presented in Table 4.40. As shown in Table 4.40, for all the three scenarios of PTRs, the south family of Coale-Demeny MLT system yielded the highest estimates of the total number of under-five deaths among HIV-infected children in Malawi during the period 2000 to 2004.

Table 4.40: Estimates of the total number of children infected with HIV through MTCT dying before the age of five years during the period 2000 to 2004 in Malawi.

	MLT			
Base transmission rate	WHO	UN Far East	Coale-Demeny North	Coale-Demeny South
30%	45 193	46 359	47 076	47 267
32%	48 388	49 624	50 385	50 586
35%	52 963	54 321	55 152	55 386

4.7 Estimates of under-five mortality directly attributable to HIV/AIDS in Malawi during the period 2000 to 2004

The process of estimating the proportion of under-five mortality that is directly attributable to HIV/AIDS in Malawi during the period 2000 to 2004 involved computing estimates of a correction for competing causes of mortality among HIV-infected children and estimates of U5MR due to HIV/AIDS as described in the methodology section (section 3.1.7). Using the 2004 Malawi DHS U5MR estimate of 133 deaths per 1000 live births and the results presented in Tables 4.29 to 4.31 and 4.40 we obtained estimates of U5MR due to HIV/AIDS and the proportion of under-five mortality directly attributable to HIV/AIDS in Malawi during the period 2000 to 2004 presented in Table 4.41. As Table 4.41 shows, about 11.7% to 13.8% of under-five deaths that occured in Malawi during the period 2000 to 2004 were due to paediatric HIV-infection contracted through MTCT. Thus, on average HIV/AIDS directly caused about 12.7% of under-five mortality in Malawi during the period 2000 to 2004.

On the one hand, the results presented in Table 4.41 indicate that the U5MR due to HIV/AIDS and the proportion of under-five mortality directly attributable to HIV/AIDS depends on the PTR. A low PTR yields a low U5MR due to HIV/AIDS as well as proportion of under-five mortality directly attributable to HIV/AIDS. On the other hand, the results presented in Table 4.41 indicate that the type of MLT used has no effect on the estimates of U5MR due to HIV/AIDS and the proportion of under-five mortality directly attributable to HIV/AIDS. The minor differences in the estimates of U5MR due to HIV/AIDS and the proportion of under-five mortality directly attributable to HIV/AIDS for the same PTR across the MLTs are due to rounding.

Table 4.41: Estimates of U5MR due to HIV/AIDS and proportion of under-five mortality attributable to HIV/AIDS in Malawi during the period 2000 to 2004.

MLT	Base transmission rate	U5MR (per 1000) due to HIV/AIDS	Proportion of under-five mortality attributable to HIV/AIDS
WHO	30%	15.26	11.47%
	32%	16.37	12.30%
	35%	17.94	13.49%
UN Far East	30%	15.34	11.53%
	32%	16.44	12.36%
	35%	18.03	13.56%
Coale-Demeny North	30%	15.36	11.55%
	32%	16.46	12.38%
	35%	18.05	13.57%
Coale-Demeny South	30%	15.36	11.55%
	32%	16.46	12.38%
	35%	18.06	13.58%

4.8 HIV/AIDS, PMTCT programs and U5MR reduction goals in Malawi

In this section we present results on how HIV/AIDS directly affected progress towards reaching overall under-five mortality reduction goals in Malawi. The section also presents results on the potential contribution of PMTCT programs currently being implemented in Malawi towards reaching the country's overall under-five mortality reduction goals.

We assessed how HIV/AIDS directly affected progress towards reaching overall under-five mortality reduction goals in Malawi by comparing estimates of U5MR due to non-HIV/AIDS causes during the period 2000 to 2004 with an estimate of the level of U5MR needed to be achieved by 2004 if Malawi was on track towards reaching the under-five mortality reduction MDG. As shown in Figure 4.11, after discounting the direct effects of HIV/AIDS, U5MR in Malawi during the period 2000 to 2004 is below the level it was required to have reached had the country been on track towards reaching the overall under-five mortality reduction MDG depicted by the dotted horizontal line.

To assess the potential contribution PMTCT programs currently being implemented in Malawi would make towards reaching Malawi's overall under-five mortality reduction goals we discounted an estimated number of under-five deaths that would be averted in Malawi during the period 2000 to 2004 if there was 100% coverage of PMTCT services from the estimated number of under-five deaths from all causes computed using the 2004 Malawi DHS estimate of U5MR from all causes in Malawi during the period 2000 to 2004. We then computed an estimate of U5MR with 100% PMTCT coverage which we again compared with the level of U5MR needed to be achieved by 2004 if Malawi was on track towards reaching the under-five mortality reduction MDG. In our analysis we only considered a 100% coverage of treatment with NVP as it is the only established PMTCT service available in Malawi at the time of conducting this study (Malawi HIV and AIDS Monitoring and Evaluation Report 2005). As Figure 4.11 further shows, a 100% coverage of treatment with Nevirapine

for PMTCT could have reduced the U5MR in Malawi during the period 2000 to 2004 to almost the level needed for being on track towards reaching the overall under-five mortality reduction MDG only if the PTR was 30%.

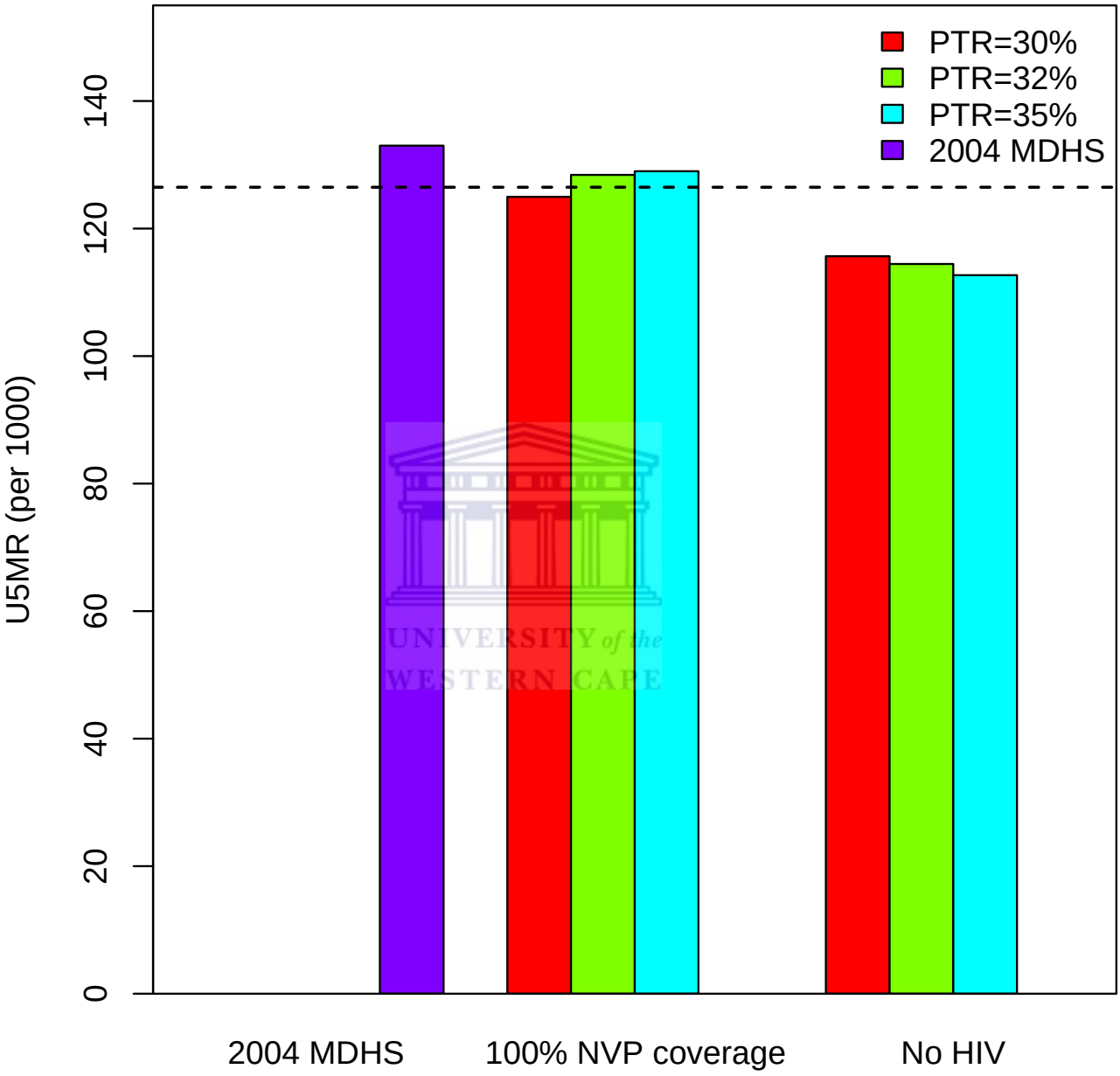

Figure 4.11: HIV/AIDS, PMTCT programs and U5MR reduction goals in Malawi assuming a PTR of 30%.

Chapter 5

Discussion and conclusions

This study has estimated the proportion of under-five mortality that is directly attributable to HIV/AIDS in Malawi during the period 2000 to 2004. The steps involved in deriving the estimates included estimating HIV prevalence among women of reproductive age using ANC surveillance survey data and HIV prevalence results from the 2004 Malawi DHS, estimating the number of women of reproductive age, estimating the number of HIV infected women, estimating the total number of births in each year, estimating the total number of children infected with HIV through MTCT, and estimating the U5MR due to HIV/AIDS. To a large extent, the study adopted the methods and procedures recommended by UNAIDS and WHO that are implemented in DemProj and AIDS Impact Model computer packages. To account for uncertainties in the estimates, the study used survival ratios from four sets of MLTs deemed to fit the Malawian mortality experience and three sets of PTR assumed to arise in SSA countries by other researchers (Stover, 2005; The UNAIDS Reference Group on Estimates, Models and Projections, 2003; Zaba et al., 2003; Walker et al., 2002; Adetunji, 2000).

Because there were only few data points for HIV prevalence from the ANC surveillance surveys we did not derive smoothed national estimates of HIV prevalence for women of

reproductive age in Malawi during the period 2000 to 2004. Nevertheless, using widely used and recommended procedures, considerable efforts were made to adjust the HIV prevalence data from the ANC surveillance surveys to derive plausible estimates of HIV prevalence in women of reproductive age in Malawi.

The finding that estimates of national HIV prevalence for women aged 15 to 49 derived in this study are lower than those produced by NAC (2005) suggests that estimates of the proportion of under-five mortality that is directly attributable to HIV/AIDS in Malawi during the period 2000 to 2004 obtained in this study may be slightly lower than those that could be based on NAC (2005)'s national HIV prevalence estimates. However, since the differences between this study's estimates of national HIV prevalence and those produced by NAC (2005) are very small the conclusions drawn from the findings of this study would not be significantly altered if estimates of national HIV prevalence for women of reproductive age in Malawi during the period 2000 to 2004 were derived from those produced by NAC (2005).

The finding that the estimates of the number of women of reproductive age obtained in this study are very close to those produced by NAC (2005) and NSO (2000) also indicates that the estimates obtained in this study are within plausible bounds as far as the number of women of reproductive age in Malawi are concerned. The small difference between the estimates of the number of births in each year obtained in this study and those produced by UNICEF (2005, 2004, 2003 and 2002) is a further indication that the estimates of the number of births in Malawi during the period 2000 to 2004 obtained in this study are within plausible bounds.

Although the estimates of national HIV prevalence for women of reproductive age may be affected by the small numbers of women sampled in ages 40 years and above in ANC surveillance surveys, owing to low fertility in such women (NSO and ORC Macro, 2005) we expect very little effect on the estimates of the proportion of under-five mortality that is directly attributable to HIV/AIDS. Furthermore, although our estimates of the proportion of under-five mortality that is directly attributable to HIV/AIDS in Malawi during the

period 2000 to 2004 may differ from those that may be produced by other researchers and scientists owing to varying demographic and epidemiological assumptions, we believe that the results obtained in this study cannot greatly diverge from those that can be produced using the WHO/UNAIDS recommended methods and procedures, particularly those implemented in the Spectrum package (Ghys et al., 2004). This claim is supported by fact that to a large extent this study used methods and procedures similar to those implemented in the Spectrum package and there are small differences between the estimates of some of the parameters needed to compute estimates of the proportion of under-five mortality that is directly attributable to HIV/AIDS obtained in this study and those produced by other researchers and experts using similar methods and procedures as illustrated in the results section.

Taking the value 133 per 1 000 from 2004 Malawi DHS as an estimate of U5MR from all causes in Malawi during the period 2000 to 2004, the main finding of this study is that the proportion of under-five mortality that is directly attributable to HIV/AIDS in Malawi during this period ranges from 11.53% to 13.58%. These proportions correspond to PTRs ranging from 30% to 35% respectively. These estimates are slightly above the estimate of 8.9% produced by Walker et al. (2002) for 1999 and 11.4% produced by Zaba et al. (2003) for 2001. Since this study used approaches that are to a great extent similar to those used by Walker et al. (2002) in estimating the proportion of under-five mortality that is directly attributable to HIV/AIDS, although Walker et al. (2000)'s estimates cover single years, this study's finding suggests a possible slight increase in the direct contribution of HIV/AIDS towards under-five mortality in Malawi during the period 2000 to 2004 compared to previous years. Although Zaba et al. (2003) used a different approach from the one used in this study, this study's results can also be compared to their results since it has been found that MLT assumptions do not affect estimates of the proportion of under-five mortality attributable to HIV/AIDS. Since Zaba et al. (2003), although again their estimates are for single years, used a PTR of 35% which corresponds to an estimated proportion of under-five mortality dirrectly attributable to HIV/AIDS of 13.57% from this study, the same conclusion that the proportion of under-five mortality directly attributable to HIV/AIDS in Malawi slightly

increased during the period 2000 to 2004 compared to the previous years can also be drawn.

From this study's assessment of how HIV/AIDS directly affected progress towards reaching overall under-five mortality reduction goals in Malawi it has been noted that HIV/AIDS significantly hampered the achievement of the level of U5MR needed for Malawi to be on track towards reaching the overall under-five mortality reduction MDG. This finding indicates that averting HIV/AIDS related deaths among children below the age of five years could help in bringing down the overall under-five mortality in Malawi to targeted levels.

A distinct feature of this study is that apart from providing insights on how HIV/AIDS negatively affected the achievement of overall under-five mortality reduction goals in Malawi it has also attempted to assess the potential contribution of scaling up coverage of PMTCT services currently being provided in Malawi towards achieving the country's overall under-five mortality reduction goals. The finding that 100% coverage of treatment with Nevirapine to prevent MTCT of HIV infection would not have greately contributed towards reaching overall under-five mortality reduction goals in Malawi during the period 2000 to 2004 confirms that only a comprehensive set of PMTCT services which comprise primary prevention of HIV infection among women of reproductive age, prevention of unintended pregnancies among HIV-infected women, prevention of MTCT transmission of HIV infection from HIV-infected mothers to their infants and the provision of appropriate treatment, care and support to HIV-infected mothers and their infants and families would significantly contribute towards reaching overall under-five mortality reduction goals (UNICEF, UNAIDS, WHO and UNFPA, 2004). Thus, in order to make substantial contributions to the country's overall under-five mortality reduction goals, Malawi should intensify its efforts in all the four key components of a comprehensive PMTCT program. Although Malawi has made substantial progress in putting in place various HIV prevention programmes, as argued by the Global HIV Prevention Working Group (2007), findings from the 2004 Malawi DHS (NSO and ORC Macro, 2005) and the first behavioural surveillance survey conducted in Malawi in 2004 (NAC et al., 2004) that a number of people in Malawi still do not have accurate and comprehensive knowledge of HIV and others still engage in high risk behaviour, means that individuals and communities in Malawi have not yet been reached with the level of prevention coverage

needed to have a major impact. The same argument holds for the majority of people who still remain unaware of their HIV status. Malawi also needs to intensify coverage and availability of HIV testing and counselling services. Furthermore, Malawi also needs to improve on coverage and availability of contraception services especially among HIV-infected women as a way of preventing unintended pregnancies among HIV-infected women.

According to NSO and ORC Macro (2005), the other four communicable diseases: pneumonia, diarrhea, malaria and measles reported to be the leading causes of deaths in children under the age of five years in developing countries by Bryce et al. (2005) and WHO (2005a) also make a substantial contribution to Malawi's under-five mortality. Therefore, attainment of under-five mortality reduction targets in Malawi requires both expansion of coverage and availability of a comprehensive set of PMTCT services as well as strengthening of efforts to address these other major causes of under-five mortality.

Like other studies that have attempted to estimate the direct impact of HIV/AIDS on child mortality this study does not capture the many indirect effects of HIV/AIDS on under-five mortality in Malawi (Walker et al., 2002; Adetunji, 2000). Therefore, due to the additional indirect effects, the overall contribution of HIV/AIDS towards under-five mortality in Malawi during the period 2000 to 2004 is without doubt greater than obtained in this study.

In summary, there are two main conclusions drawn from the findings of this study. One main conclusion is that HIV/AIDS has significantly hampered achievement of Malawi's overall under-five mortality reduction targets. The other main conclusion is that attainment of further reductions in Malawi's under-five mortality requires both expansion of coverage and availability of a comprehensive set of PMTCT services and strengthening of efforts to address the other major causes of under-five mortality. However, since putting in place a comprehensive set of PMTCT services alongside strengthening efforts to address the other major causes of under-five mortality would require huge financial resources, taking into account Malawi's economic situation, we argue that the attainment of further substantial reductions in Malawi's under-five mortality in the years to come depend on financial support from the country's international donors. Unless more financial support become available to

effectively address HIV/AIDS and the other major causes of under-five mortality, Malawi's under-five mortality will continue to be one of the highest in the world in the years to come.

Appendix

R Code

This section presents R code used to compute the estimates presented in this thesis. The code was written in a number of text files. The code in one file is linked to the code in another file by the "source" statement. All statements beginning with # are comments explaining what the code is doing.

code for estimating proportion of urban population code file name: U_R_popn.txt

```
#reading the table containing the urban and rural populations as recorded in 1987 and
1998 census reports.
urb_rural<-read.table("urban_rural_prop.txt", header=FALSE)
#combine age groups 40-44 and 45-49
urb_rural_40_49<- urb_rural[6,]+urb_rural[7,]
#creating a data table containing the urban and rural populations with age groups
40-44 and 45-49 combined
urb_rural_15_49<-rbind(urb_rural[1:5,],urb_rural_40_49)
names(urb_rural_15_49)<-c("urban_1987", "rural_1987",
"urban_1998", "rural_1998")
Age<-c("15-19", "20-24", "25-29", "30-34", "35-39", "40-49")
row.names(urb_rural_15_49)<-Age
```

```
#computing proportion urban in 1987 and 1998
prop_urban87<-urb_rural_15_49$urban_1987/(urb_rural_15_49$urban_1987
+urb_rural_15_49$rural_1987)
prop_urban98<-urb_rural_15_49$urban_1998/(urb_rural_15_49$urban_1998
+urb_rural_15_49$rural_1998)
prop_urban87_98<-cbind(prop_urban87,prop_urban98)
row.names(prop_urban87_98)<-Age
#computing annual proportion urban change 1987-1998
prop_urban_87_98_ac<-cbind((prop_urban87_98[,2]-prop_urban87_98[,1])/(1998-
1987))
#create a function for estimating age specific proportion urban population for any year
from 1987
prop_urban<-function(y) # y is any year <=1987
{interval<-(y-1987)
prop_urban<-prop_urban87_98[,1] +interval*prop_urban_87_98_ac
cbind(prop_urban)
}
#creating a function for estimating age specific proportion rural population for any
year from 1987
prop_rural<-function(y) # y any year <=1987
{prop_rural<-1-prop_urban(y)
cbind(prop_rural)
}
```

code for adjusting HIV prevalence in non-urban sites for representativeness

code file name: ANC_NON_URBAN_80.txt

```
# The code in this file was used to generate the results in Table 4.6 on page 62
#reading the file containing the unadjusted HIV prevalence in aggregated non-urban
sites
NON_URBAN<-read.table("ANC_NON_URBAN.txt", header=FALSE)
Age<-c( "15-19","20-24","25-29","30-34","35-39","40-49")
year<-c(1999,2001,2003,2005)
NON_URBAN_0.8<-NON_URBAN*0.8
names(NON_URBAN_0.8)<-year
row.names(NON_URBAN_0.8)<-Age
```

code for estimating unadjusted national HIV prevalence

code file name: HIV_NATION.txt

```
#reading in the code containing the adjusted age specific HIV prevalence rates for
aggregated rural sites.
source("ANC_NON_URBAN_80.txt")
# reading the age specific HIV rates for aggregated urban sites
URBAN<-read.table("ANC_URBAN.txt", header=FALSE)
#reading the code for calculating proportion urban and rural.
source("U_R_popn.txt")
#creating a data frame containing age specific proportion urban
for the years (1999,2001,2003,2005)
prop_urban_99_05<-cbind()
for (i in seq(1999,2005,2))
{urban_prop<-prop_urban(i)
prop_urban_99_05<-cbind(prop_urban_99_05,urban_prop)
}
prop_urban_99_05<-data.frame(prop_urban_99_05)
```

```
names(prop_urban_99_05)<-year
#creating a data frame containing age specific proportion rural for
the years 1999,2001,2003,2005
prop_rural_99_05<-1-prop_urban_99_05
prop_rural_99_05<-data.frame(prop_rural_99_05)
names(prop_rural_99_05)<-year
#calculating estimates of national HIV prevalence for the years
1999,2001,2003,2005 presented in Table 4.7 on page 63
HIV_NATION<-(prop_urban_99_05*URBAN)
+(prop_rural_99_05*NON_URBAN_0.8)
#calculating estimates of HIV prevalence for the years 2000, 2002 and 2004
HIV_NATION_2000<-0.5*(HIV_NATION[1]+HIV_NATION[2])
HIV_NATION_2002<-0.5*(HIV_NATION[2]+HIV_NATION[3])
HIV_NATION_2004<-0.5*(HIV_NATION[3]+HIV_NATION[4])
#creating a data frame containing estimates of HIV prevalence for 2000, 2002 and 2004
HIV_NATION2<-cbind(HIV_NATION_2000,HIV_NATION_2002,HIV_NATION_2004)
names(HIV_NATION2)<-c("2000","2002", "2004")
#creating a data frame containing all the estimates of HIV prevalence from 1999 to
2005 presented in Table 4.8 on page 63
HIV_NATION_ALL<-array(,dim=c(6,7))
HIV_NATION_ALL<-data.frame(HIV_NATION_ALL)
i=seq(1,7,2)
j=seq(2,6,2)
HIV_NATION_ALL[,i]<-HIV_NATION
HIV_NATION_ALL[,j]<-HIV_NATION2
names(HIV_NATION_ALL)<-1999:2005
row.names(HIV_NATION_ALL)<-Age
HIV_ANC_1999<-HIV_NATION_ALL[,1]
names(HIV_ANC_1999)<-Age
HIV_ANC_1999.table<-as.table(HIV_ANC_1999)
```

code for combining HIV prevalence rates for age groups 40-44 and 45-49 from the 2004 Malawi DHS report

code file name: HIV_DHS.txt

```
#The code in this file was used to generate the results presented in Table 4.9 on page 65. #creating a vector for number tested
number_tstd <-c(500,661,477,382,257,235,173)
Age<-c( "15-19","20-24","25-29","30-34","35-39","40-49")
#creating a vector containing the age specific prevalence rates for 2004 Malawi DHS report
HIV_2004MDHS<-c(3.7,13.2,15.5,18.1,17.0,17.9,13.3)
#computing numbers HIV positive in each age group
number_postv<-(number_tstd*HIV_2004MDHS)/100
# rounding the elements in number_postv to whole numbers
number_postv.rounded<-round(number_postv)
#adding the numbers positive in age groups 40-44 and 45-49
number_postv_40_49<-number_postv.rounded[length(number_postv.rounded)] +
number_postv.rounded[length(number_postv.rounded)-1]
#adding the numbers tested in age groups 40-44 and 45-49
number_tstd_40_49<-number_tstd[length(number_tstd)]
+ number_tstd[length(number_tstd)-1]
# calculating percentage positive in 40-49 age group
percnt_postv_40_49<-(number_postv_40_49/number_tstd_40_49)*100
#creating a vector containing the age specific HIV prevalence rates for 2004 Malawi DHS with age groups 40-44 and 45-49 combined
HIV_2004MDHS_comb<-c(HIV_2004MDHS[-c((length(HIV_2004MDHS)-1),
length(HIV_2004MDHS))],percnt_postv_40_49)
#assigning names to the elemnts in HIV_2004MDHS_comb
names(HIV_2004MDHS_comb)<-Age
```

#converting HIV_2004MDHS_comb into a table.

#This makes it possible to plot the HIV prevalence rates with the age groups on the horizontal axis

HIV_2004MDHS_comb.table<-as.table(HIV_2004MDHS_comb)

code for estimating final national HIV prevalence

code file name: ANC_VS_DHS.txt

#The code in this file was used to produce the graph in Figure 4.5 on page 67 and to compute estimates of ratios of ANC HIV prevalence to general population HIV prevalence presented in Table 4.10 on page 68 and final national estimates of HIV prevalence adjusted using 2004 Malawi DHS results presented in Table 4.11 on page 68

#sourcing the code in HIV_NATION.txt and HIV_VS_DHS.txt

source("HIV_NATION.txt")

source("HIV_VS_DHS.txt")

#compute second HIV prevalence estimates for ANC for 2004

HIV_2004_ANC2<-1/2*(HIV_NATION_ALL[,6]+HIV_NATION_ALL[,7])

#computing the ratios of ANC to DHS estimates

ANC_2_DHS <-cbind(HIV_2004_ANC2/HIV_2004MDHS_comb.table)

#compute final estimates of national HIV prevalence by age for the years 1999 to 2005

HIV_NATION_FINAL<-HIV_NATION_ALL/ANC_2_DHS

code for computing survival ratios corresponding to the projected life expectancy at birth values presented in Table 3.7 on page 41

code file name: survival_cal.txt

#reading the file containing survival ratios for a particular model life table

survival_table<-read.table("cdnorth.txt", header=TRUE)

#cdnorth.txt contains female survival ratios from the north family of Coale-Demeny model life table system

#converting survival_table into a dataframe

```
survival_table.frame<-data.frame(survival_table)
#calculating survival ratios corresponding to life expectancy at birth values of 43.23, 43.77, 44.33, 44.90
#start by finding the difference between survival ratios for life expectancy values of 40 and 45
life_exp40_45<-survival_table.frame$X45-survival_table.frame$X40
#divide the difference into 500 equal units
unit_life_exp40_45<-life_exp40_45/500
#Now calculate survival ratios for life expectancy at birth value of 43.23, 43.77, 44.33 and 44.90
life_exp43.23<-survival_table.frame$X40+(323*unit_life_exp40_45)
life_exp43.77<-survival_table.frame$X40+(377*unit_life_exp40_45)
life_exp44.33<-survival_table.frame$X40+(433*unit_life_exp40_45)
life_exp44.90<-survival_table.frame$X40+(490*unit_life_exp40_45)
#calculating survival ratios corresponding to life expectancy at birth values of 45.47, 46.03, 46.60 in a similar manner as above
life_exp45_50<-survival_table.frame$X50-survival_table.frame$X45
unit_life_exp45_50<-life_exp45_50/500
life_exp45.47<-survival_table.frame$X45+(47*unit_life_exp45_50)
life_exp46.03<-survival_table.frame$X45+(103*unit_life_exp45_50)
life_exp46.60<-survival_table.frame$X45+(160*unit_life_exp45_50)
#putting the 7 sets of survival ratios together
survival_ratios<-cbind(life_exp43.23,life_exp43.77,life_exp44.33,life_exp44.90,
life_exp45.47,life_exp46.03,life_exp46.60)
#extracting from survival_ratios the survival ratios of the age group(5-9, 10-14,...,45-49)
survival_ratios5_49<-survival_ratios[8:16,]
#making survival_ratios5_49 a dataframe
survival_ratios5_49<-data.frame(survival_ratios5_49)
year<-1998:2004
```

names(survival_ratios5_49)<-year

code for estimating the number of women of reproductive age in Malawi from 1999 to 2004

code file name: proj_pop.txt

#The code in this file was used to obtain estimates of women of reproductive age in Malawi from 1999 to 2004 presented in Tables 4.15 to 4.20 on pages 71 to 73. The code presented here is for estimates based on Coale-Demeny North model life table system

years<-1998:2004

duration<-length(years)

ages<-5:49

age_width<-length(ages)

#creating a matrix with zeros

proj_matrix<-rep(0,duration*age_width)

dim(proj_matrix)<-c(age_width,duration)

#converting the zero matrix into a data frame

proj_matrix.frame<-data.frame(proj_matrix)

names(proj_matrix.frame)<-years

row.names(proj_matrix.frame)<-ages

#reading base line population data from base_pop.csv

base_pop<-read.csv("base_pop2.csv", header=TRUE)

#base_pop.csv contains the age-smoothed female population aged 5 to 49 in Malawi in 1998 which has been separated into single years using the Beers formulae.

#creating a function for finding five year pop groups from age 5 to age 49

pop5ages<-function(x)

{five<-c()

a=1

b=5

```
for (i in 1:9)
{total5<-sum(x[a:b])
five<-c(five,total5)
a=a+5
b=b+5
}
five}
#creating a data frame containing population in five year age groups
pop5y_grps<-function(x)
{five_y_grps<-cbind()
for (i in x)
{sum5ages<-pop5ages(i)
five_y_grps<-cbind(five_y_grps,sum5ages)
} five_y_grps
}
#sourcing file containing survival ratios
source("survival_cal.txt")
#converting five year survival ratios into single year survival ratios
#creating a function that converts five year survival ratios into single year survival ratios by taking the fifth root
five_year2single_year_survival<-function(x)
{x ^ (1/5)}
#converting the survival ratios in survival_cal.txt into single years
survival_ratios5_49_singles1<-five_year2single_year_survival(survival_ratios5_49)
#creating a function that replicates 5 times each 5 year survival ratio that has been converted to single year survival ratio
five_year2single_year_survival_X5<-function(x)
{a=length(x)
b=rep(5,a)
g=rep(x,b)
```

```
g}
survival_ratios5_49_singles2
<-five_year2single_year_survival_X5(survival_ratios5_49_singles1)
dim(survival_ratios5_49_singles2)<-dim(proj_matrix)
survival_ratios5_49_singles2.frame<-data.frame(survival_ratios5_49_singles2)
names(survival_ratios5_49_singles2.frame)<-years
row.names(survival_ratios5_49_singles2.frame)<-ages
for (i in 1:7)
{if (i==1)
{proj_matrix.frame[i:45,i]=base_pop[,2] }
else {proj_matrix.frame[i:45,i]=proj_matrix.frame[(i-1):(45-1),
(i-1)]*survival_ratios5_49_singles2[(i-1):(45-1),(i-1)]}
}
#obtaining population age 15-49 in 5 year groups
pop15_49<-pop5y_grps(proj_matrix.frame)[3:9,]
pop15_49.frame<-data.frame(pop15_49)
names(pop15_49.frame)<-years
#rounding to whole numbers
pop15_49_final<-round(pop15_49.frame)
# creating a function for calculating total population aged 15-49
total_pop<-function(x)
{total<-c()
for (i in x)
{a=sum(i)
total<-c(total,a)}
names(total)<-names(x)
total
}
pop15_49_final_total<-total_pop(pop15_49_final)
```

code for estimating the number of HIV-infected women

code file name: POP_INF.txt

```
# The code in this file was used to obtain estimates of the number of HIV-infected women in Malawi from 1999 to 2004 presented in Tables 4.22 to 4.25 on pages 79 to 81. The code presented here is for estimates based on Coale-Demeny North model life table system
#sourcing code in proj_pop.txt
source("proj_pop.txt")
#extracting population in 1999 to 2004
pop99_04<-pop15_49_final[,-1]
# sourcing code for final estimates of national HIV prevalence rates
source("ANC_VS_DHS.txt")
HIV_rates<-HIV_NATION_FINAL[1:6]
#this code gives HIV rates with the rate for 40-49 applied to age groups 40-44 and 45-49
HIV_rates2<-c()
for (i in HIV_rates)
{
rate<-i
rate2<-c(i,i[length(i)])
HIV_rates2<-cbind(HIV_rates2,rate2)
} HIV_rates2.frame<-data.frame(HIV_rates2)
names(HIV_rates2.frame)<-c("1999","2000","2001","2002","2003","2004")
row.names(HIV_rates2.frame)<-c("15-19","20-24","25-29","30-34","35-39","40-44","45-49")
#computing number of women aged 15-49 infected with HIV
inf_w<-round((pop99_04*HIV_rates2.frame)/100)
names(inf_w)<-c("infw_1999","infw_2000","infw_2001",
"infw_2002","infw_2003","infw_2004")
row.names(inf_w)<-row.names(HIV_rates2.frame)
```

```
#computing total number of HIV infected women
inf_w_total<-total_pop(inf_w)
#computing HIV prevalence in 15-49 age group in 1999 to 2004
HIV_prev_adult<-inf_w_total/pop15_49_final_total[-1]*100
#comparing estimates of HIV prev for female adults with spectrum estimates by NAC
NAC_female_HIV_15_49<-c(409171,414190,419204,424074,431723,443463)
NAC_female_15_49_total<-c(2542202,2606648,2671371,2737315,2807144,2881101)
NAC_prev_adult<-(NAC_female_HIV_15_49/NAC_female_15_49_total)*100
names(NAC_prev_adult)<-names(HIV_NATION_FINAL)[-1]
NAC_VS_CHO<-NAC_prev_adult[-6]-HIV_prev_adult[-1]
```

code for estimating age-specific fertility rates in Malawi from 1999 to 2004

code file name: ASFR.txt

```
# The code in this file was used to produce the graph in Figure 4.9 on page 84 and to
obtain estimates of age-specific fertility rates in Malawi from 1999 to 2004 presented
in Table 4.27 on page 85.
Ages<-c("15-19","20-24","25-29","30-34","35-39","40-44","45-49")
ASFR_2000<-c(172,305,272,219,167,94,41)
names(ASFR_2000)<-Ages
ASFR_2004<-c(162,293,254,222,163,80,35)
names(ASFR_2004)<-Ages
ASFR_2000.table<-as.table(ASFR_2000)
ASFR_2004.table<-as.table(ASFR_2004)
#calculating estimates of ASFR annual rate of change between 2000 and 2004.
ASFR_2000_2004<-ASFR_2000.table-ASFR_2004.table
ASFR_2000_2004_year_change<-ASFR_2000_2004/4
ASFR00_04<-c(ASFR_2000.table)
for (i in 1:4)
```

```
{
ASFR<-round(ASFR_2000.table-(i*ASFR_2000_2004_year_change))
ASFR00_04<-cbind(ASFR00_04,ASFR)
}
#estimating ASFR for 1999
ASFR99<-round(ASFR_2000.table+ASFR_2000_2004_year_change)
# producing estimates of ASFR from 1999 to 2004
ASFR99_04<-cbind(ASFR99,ASFR00_04)
ASFR99_04.frame<-data.frame(ASFR99_04)
names(ASFR99_04.frame)<-c("ASFR1999", "ASFR_2000","ASFR_2001",
"ASFR_2002","ASFR_2003","ASFR_2004")
#row.names(HIV_rates2.frame)<-c("15-19","20-24","25-29","30-34","35-39","40-44","45-
49")
```


code for estimating number of births

code file name: births.txt

```
# The code in this file was used to obtain estimates of the number of births to both
all women of reproductive age and HIV-infected women.
#sourcing code in POP_INF.txt
source("POP_INF.txt")
#sourcing code in ASFR.txt
source("ASFR.txt")
#computing number of births to all women of reproductive age from 1999 to 2004
births99_04<-round((pop99_04/1000)*ASFR99_04.frame)
#computing total number of births to all women
births99_04_total<-total_pop(births99_04)
#computing births to HIV positive women
birth_inf15_19<-(1.5*(pop99_04[1,])*ASFR99_04.frame[1,]*(inf_w[1,]))/(1.5*inf_w[1,]
```

```
+ (pop99_04[1,]-inf_w[1,]))
birth_inf20_49<-((pop99_04[-1,])*ASFR99_04.frame[-1,]*(inf_w[-1,]))/(inf_w[-1,] +
1.25*(pop99_04[-1,]-inf_w[-1,]))
inf_w_births<-round(rbind(birth_inf15_19,birth_inf20_49)/1000)
inf_w_births_total<-total_pop(inf_w_births)
# Estimating the number of children infected with HIV through MTCT
# creating a vector for number of women receiving NVP from 1999 to 2004
nvp<-c(0,0,0,840,2198,2719)
inf_w_births_nvp<-nvp
names(inf_w_births_nvp)<-names(inf_w_births)
#computing number of children whose mothers did not receive NVP
inf_w_births_nvp_free<-inf_w_births_total-inf_w_births_nvp
#computing number of children infected via MTCT assuming PTR of 30% for no NVP
and 16% for NVP
inf_births30<-round((inf_w_births_nvp_free*0.3)+(inf_w_births_nvp*0.16))
#computing number of children infected via MTCT assuming PTR of 32% for no NVP
and 24% for NVP
inf_births32<-round((inf_w_births_nvp_free*0.32)+(inf_w_births_nvp*0.24))
#computing number of children infected via MTCT assuming PTR of 35% for no NVP
and 28% for NVP
inf_births35<-round((inf_w_births_nvp_free*0.35)+(inf_w_births_nvp*0.28))
#Estimates with 100% nvp coverage
inf_births30_nvp<-round(inf_w_births_total*0.16)
inf_births32_nvp<-round(inf_w_births_total*0.24)
inf_births35_nvp<-round(inf_w_births_total*0.28)
```

code for survival curve of HIV-infected children

code file name: child_HIV_survival.txt

```
# The code in this file was used to generate the survival curve of HIV-infected children and produce the graph in Figure 3.1 on page 48.
#creating a function for calculating the proportion of children dying due to HIV after t years since birth
children_dying<-function(t)
{p=0.6
a_1=0.9
a_2=10
b_1=0.9
b_2=0.1
d_t<-(p*(1-exp(-(b_1*t) ^ a_1))+(1-p)*(1-exp(-(b_2*t) ^ a_2)))
d_t}
#creating a function for calculating the proportion of children not dying due to HIV after t years since birth
children_surving<-function(t)
{1-children_dying(t)
}
t=seq(0,13,0.1)
survivors<-children_surving(t)
survival_table=cbind(t,survivors)
#plotting the survival distribution
plot(t,survivors*100, type="l", col=4, xlab="Age of child", lwd=1, ylab="Percentage Surviving")
axis(1, xaxp=c(0, 13, 13)) #specifies the interval in the x axis
axis(2, yaxp=c(0,100,10)) #specifies the interval in the y axis
grid(,lwd=1)
```

code for estimating the number of HIV-infected children dying before their fifth birthday during the period 2000 to 2004

code file name: cummulative_dying.txt

```
# The code in this file was used to compute estimates of the number of HIV-infected children dying before their fifth birthday during the period 2000 to 2004 presented in Table 4.40 on page 94. The code presented here is for PTR=30%
#calculating total number of children under five years dying due to HIV
#sourcing code for births
source("births.txt")
#sourcing code for survival curve of HIV-infected children
source("child_HIV_survival.txt")
#computing average number of children infected with HIV thru MTCT per month in each year from 2000 to 2004
average_inf_births<-round(inf_births30[-1]/12)
#for each year, replicating the average number of infected children 12 times so that the total should be equal to the total for that year
inf_births_monthly<-rep(average_inf_births, rep(12,length(average_inf_births)))
time<-59:0
prop_dying<-children_dying(time/12)
HIV_deaths<-round(average_inf_births*prop_dying)
total_HIV_deaths_00_04<-sum(HIV_deaths)
```

code for estimating the proportion of under-five mortality directly attributable to HIV/AIDS in Malawi during the period 2000 to 2004

code file name: cummulative_dying.txt

```
# This code is the second part of the code in cummulative_dying.txt and was used to produce estimates of U5MR due to HIV/AIDS and proportion of under-five mortality attributable to HIV/AIDS in Malawi during the period 2000 to 2004 presented in Table
```

4.41 on page 96. The code presented here is for PTR=30%

```
total_HIV_inf_births<-sum(inf_births30[-1])
total_births_00_04<-sum(births99_04_total[-1])
total_u5m_all_cause_00_04<-round(total_births_00_04*133/1000)
total_u5m_HIV_neg_00_04<-total_u5m_all_cause_00_04-total_HIV_deaths_00_04
u5mr_non_HIV<-total_u5m_HIV_neg_00_04/total_births_00_04*1000
#estimate of mortality in HIV-infected children adjusted for competing causes
total_HIV_deaths_adj<-
total_HIV_deaths_00_04-round(u5mr_non_HIV*total_HIV_deaths_00_04/1000)
HIV_u5mr_adj<-(total_HIV_deaths_adj/total_births_00_04)*1000
#estimate of HIV attributable under-five mortality
HIV_mort_PAF<-(HIV_u5mr_adj/133)*100
#estimates wth 100% nvp covearage
average_inf_births_nvp<-round(inf_births30_nvp[-1]/12)
#for each year, replicating the average number of infected children 12 times so that
the total should be equal to the total for that year
inf_births_nvp_monthly<-rep(average_inf_births_nvp,
rep(12,length(average_inf_births_nvp)))
HIV_deaths_nvp<-round(average_inf_births_nvp*prop_dying)
total_HIV_deaths_nvp_00_04<-sum(HIV_deaths_nvp)
nonvp_nvp<-total_HIV_deaths_00_04-total_HIV_deaths_nvp_00_04
total_u5m_all_cause_nvp_00_04<-total_u5m_all_cause_00_04-nonvp_nvp
u5mr_all_cause_nvp_00_04<-
(total_u5m_all_cause_nvp_00_04/total_births_00_04)*1000
```

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