HIV/AIDS impact on childhood mortality and childhood mortality measurement: from the perspective of Kenyan and Malawian DHS data

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Plagiarism declaration form

This research is my original work, produced with normal supervisory assistance from my supervisor. All the relevant sources of knowledge that I have used during the course of writing this dissertation have been fully credited using the Harvard convention for citation and referencing. Also, this dissertation has not been submitted for any academic or examination purpose at any other university.

Chifundo Kanjala

Date

Dedication

To my sweet mum, whose love is my inspiration.

Abstract

This study has two goals. The first is to assess the consistency of the childhood mortality trends constructed from the direct and the indirect methods of estimation in high HIV prevalence settings. The second goal is to assess the direct impact of HIV/AIDS on childhood mortality in Kenya and Malawi for the periods 1999 – 2003 and 2000 – 2004 respectively.

It is important to understand the impact of HIV on childhood mortality and childhood mortality measurement to ensure that child health planning and evaluation are correctly informed.

Trends of infant and under-five mortality are constructed for each country by applying the Brass Children Ever Born Children Surviving method to census and Demographic and Health Survey (DHS) data collected in the HIV/AIDS era (1992 – 2004). Trends of childhood mortality are also constructed using direct childhood mortality estimates obtained from applying the synthetic cohort life table analysis to DHS data.

To assess the impact of HIV on childhood mortality, the proportions of childhood mortality attributable to HIV (HIV PAF) in the five year periods leading to the Kenyan 2003 and the Malawian 2004 DHS are estimated using DHS birth histories data and results from African longitudinal studies involving paediatric HIV infection and survival.

The results from the trend analysis reveal that the trends of childhood mortality from the direct and the indirect methods applied to Kenyan and Malawian DHS data are different. While the direct estimates generally give well defined trends, the trends from the indirect estimates are erratic. However, being less erratic does not confirm the correctness of the trends from the direct method since it is possible for the trends to be biased to the same extent and in the same direction.

The HIV PAFs obtained are 5.3 per cent (Kenya) and 6.8 per cent (Malawi) for infant mortality and 14.3 per cent (Kenya) and 18.0 per cent (Malawi) for under-five mortality respectively. As expected, the impact of HIV is higher on under-five mortality than it is on infant mortality in both Kenya and Malawi. The results also suggest that Malawi had higher proportions of mortality attributable to HIV/AIDS compared to Kenya. The uncertainty surrounding the PAFs however makes it impossible to say the

difference is material. The PAFs are also lower than what would be expected. Since the methodology used has given inconsistent results of HIV PAF, it is recommended that further improvements be made to the estimates of HIV PAF and their sensitivity to changes in the inputs be assessed before they can be used for any decision making on HIV impact reduction.

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1. Introduction

1.1. Background

The analysis of trends of mortality under the age of 5 (childhood mortality) in Africa reveal that childhood mortality started declining in the second half of the twentieth century (2000). The speed of decline reduced from around the mid 1980s in many African countries. Some countries, for example Kenya, actually experienced a reversal of trends (Central Bureau of Statistics (CBS) [Kenya], Ministry of Health (MOH) [Kenya] and ORC Macro, 2004). As pointed out by Walker, Schwartlander and Bryce (2002), HIV/AIDS has often been singled out as the major contributor to these adverse trends. In addition to having an impact on the trends of childhood mortality, HIV/AIDS is also said to be affecting the measurement of childhood mortality (Ward and Zaba, 1999; Mahy, 2003).

It is important to understand the exact impact of HIV/AIDS on childhood mortality and its measurement to ensure the accurate measurement of childhood mortality in high HIV prevalence settings (estimated adult HIV prevalence greater than 5 per cent (Maher, Watt, Williams *et al.*, 2005)). Accurate measurement of childhood mortality is crucial since the childhood mortality estimates are used as indicators of general social development and health (Hill, 1991).

Ideally, childhood mortality estimates should be derived from vital registration systems and data on the population at risk from censuses or continuous population registers. However, vital registration in Africa is uniformly incomplete and inaccurate (United Nations, 1992; Cleland, 1996; Setel, Macfarlane, Szreter *et al.*, 2007; UNICEF, WHO, World Bank *et al.*, 2007).

The absence of reliable vital registration has been compensated for by indirect childhood mortality measurement using census data or direct childhood mortality estimates derived from detailed birth histories provided by women of reproductive age interviewed in household surveys.

The advent of the Human Immune Virus (HIV) which causes Acquired Immuno-deficiency Syndrome (AIDS) has led to the violation of the assumptions on which the methods used for childhood mortality measurement in Africa are based. This has mainly been due to the retrospective nature of the data (Ward and Zaba, 1999;

Mahy, 2003). Retrospective reporting of children's survival by mothers can only be done by mothers who are alive at the time of the interview. Mothers who die between giving birth and the time of the survey are not available to report on the death of their children. The exclusion of the mortality of the children of deceased mothers may bias childhood mortality estimates because these omitted children normally have higher mortality than children in the general population (Nakiyingi, Bracher, Whitworth *et al.*, 2003; Newell, Brahmbhatt and Ghys, 2004).

Research has confirmed that HIV/ AIDS impacts childhood mortality (Nicoll, Timaeus, Kigadye *et al.*, 1994; Adetunji, 2000; Hill, Cheluget, Curtis *et al.*, 2004). Efforts have also been made to quantify the impact of HIV/ AIDS on childhood mortality (Ward and Zaba, 1999; Zaba, Marston and Floyd, 2003; Marston, Zaba, Salomon *et al.*, 2005). However, more work still needs to be done to further our understanding of the impact of HIV/AIDS on childhood mortality and childhood mortality measurement.

This project contributes towards further understanding of the direct impact of HIV/AIDS on childhood mortality and its measurement.

The research has two aims. The first is to analyse the consistency of childhood mortality estimates derived from the direct method of childhood mortality measurement and those from the indirect method using data from Kenya and Malawi DHS surveys and censuses done during the period 1990 to 2004.

The second aim is to quantify the direct impact of HIV/AIDS on childhood mortality in the two above-mentioned countries in the five years before the Kenya 2003 DHS and the Malawi 2004 DHS.

The next chapter reviews the literature related to the project. It also specifies the gap in the body of knowledge the project intends to fill.

Chapter 3 gives the sources of the data used in this study and an appraisal of their quality. In chapter 4, the methodologies used to analyse the trends of childhood mortality are described and the results obtained are presented. Trends in infant mortality rates and under-five mortality rates from the direct and indirect methods are examined and a comparison is made between the trends suggested by the direct and the indirect methods. Chapter 5 presents the method used to assess the direct impact of HIV/AIDS on childhood mortality and the results obtained from applying the method to Kenyan and Malawian data. The last chapter (chapter 6) comprises of the discussion

of the results, the conclusions drawn from the data analysis and suggestions for future research.

2. Literature Review

2.1. Introduction

This chapter reviews the literature on childhood mortality measurement in high HIV prevalence settings prevailing in Africa. In particular the review will focus on the traditional methods of measuring childhood mortality used in Africa, some of the problems that arise from using these methods in high HIV prevalence settings and the new approaches to childhood mortality measurement developed for high HIV prevalence settings. The review will also point out the need for comparison of trends of childhood mortality estimates from the direct and the indirect methods in high HIV prevalence settings and the need for the use of relatively current, empirical and nationally representative data for assessing the impact of HIV on childhood mortality.

Section 1A in the Appendix provides selected definitions of some concepts related to childhood mortality and its measurement used (some repeatedly) in this chapter.

2.2. Measures of childhood mortality

Mortality under the age of five can be broken down into neonatal mortality, post-neonatal mortality, infant mortality and child mortality depending on the exact age at death of the child. However, the infant mortality rate (IMR) and the under-five mortality rate (U5MR) are the conventional measures of childhood mortality (Hill and Amouzou, 2006). These two are chosen because of their characteristics. IMR contributes the majority of under-five mortality (UNICEF, WHO, World Bank *et al.*, 2007). The mortality between age 1 and 5 is also substantial, especially in developing countries (Population Division United Nations Secretariat, 1990); this makes the IMR inadequate for fully describing of mortality in childhood.

The U5MR gives a good summary measure of mortality in childhood; it captures almost all deaths in children under the age of 18 (United Nations, 1992; UNICEF, WHO, World Bank *et al.*, 2007). However, it is also important to monitor the IMR because it captures increasingly larger proportions of U5MR as mortality of children below the age of five declines. Therefore, it is best to monitor both U5MR and IMR.

2.3. Data sources

The data for childhood mortality measurement in Africa come mainly from household surveys. These household surveys include Demographic and Health Surveys (DHS), Multiple Indicator Cluster Surveys (MICS) (UNICEF, WHO, World Bank *et al.*, 2007) and country-specific studies. MICS are usually conducted in countries that have not done DHS surveys (Mahy, 2003). The household surveys provide data for both direct and indirect mortality estimation.

The DHS data provide more detailed nationally representative birth histories data than MICS. MICS only collect birth histories for the last three births from the women interviewed. The quality of the DHS is considered the best of all household surveys in Africa (Zaba, Marston and Floyd, 2003) in terms of being relatively error free and nationally representative. Cluster sampling is used to obtain DHS samples. A typical DHS interviews some 7000 women (Korenromp, Arnold, Williams *et al.*, 2004).

Though census data are used for indirect childhood mortality estimation, data from this source are not as frequently available as they are needed (UNICEF, WHO, World Bank *et al.*, 2007). The censuses are normally done at ten year intervals.

Censuses aim to enumerate the entire population in a country. They also cover other socio-economic aspects of a population besides its demography. Thus, data on childhood mortality collected in censuses are less detailed compared with those from household surveys.

2.4. Methods for estimating childhood mortality

There are two main categories of childhood mortality estimation techniques. These are the direct and the indirect methods. These two categories are based on different assumptions and they have different data requirements. Detailed descriptions of these two methods are given below.

2.4.1. Direct childhood mortality estimation

There are three approaches to direct estimation of childhood mortality. These are: the vital statistics approach, the true cohort approach and the synthetic cohort approach (Rutstein and Rojas, 2006).

2.4.1.1. The vital statistics approach

The vital statistics approach uses childhood deaths recorded in vital registration systems and census data (or any other accurate estimates of the population) to estimate childhood mortality. Data recorded in a reliable vital registration system can solely be

used for estimation of IMR. This is done by dividing deaths occurring within a year of interest among children aged below one by the number of children born within that year (Population Division United Nations Secretariat, 1990).

However, to estimate U5MR, data from the vital registration system are used jointly with data from a national population census or data from a population register to closely approximate the population exposed to risk of death. The U5MR is estimated as the number of deaths below the age of five per 1000 births. Data from the vital registration system cannot be relied upon for estimating the population at risk for use in estimating the U5MR unless migration is captured in the vital registration system (UNICEF, WHO, World Bank *et al.*, 2007).

2.4.1.2. The true cohort approach

The second direct approach is the true cohort approach. Deaths to children of a specific birth cohort are divided by the number of births in that cohort- the estimates obtained do not refer to any particular period but rather to the mortality experiences of cohorts as they progress through life (Rutstein and Rojas, 2006).

A birth cohort has to be observed for the full duration of time for which estimates are required. For example, if under-five mortality estimates are required, a birth cohort has to be observed for the full five years. Therefore, there is need for a lot of time of observation which is usually not feasible and the longer the time horizon the more out of date are the results.

Though the time constraints associated with following a birth cohort from birth up to age five are not very serious (Population Division United Nations Secretariat, 1990), there is still the disadvantage that this approach does not allow more recent births to be included in the estimates since each person involved has to belong to the birth cohort of interest, and not later cohorts (Rutstein and Rojas, 2006).

The true cohort approach has been applied mainly in some African longitudinal surveys following birth cohorts usually for periods of up to two years (Crampin, Floyd, Glynn *et al.*, 2003). In some studies, the periods of follow up have however gone up to five years (Spira, Lepage, Msellati *et al.*, 1999).

2.4.1.3. The synthetic cohort approach

The third approach is to use synthetic cohorts. The survival experiences of children at different ages collected during a cross-sectional survey are assumed to be an approximation of what a real cohort would experience if the mortality rates prevailing

during the survey period were to remain unchanged over a specified time period (Preston, Heuveline and Guillot, 2001).

The data needed for the synthetic cohort approach are the date of birth of each child, the sex of the child, the child's survival status at the time of the survey, the age at survey or date of death, whichever is applicable at the time of the survey (Rutstein and Rojas, 2006). The method also requires ages of the female respondents at the time of the survey.

The children are classified into age groups for estimation of probabilities of dying. The age groups are as follows: less than 1 month, 1 – 2 months, 3 – 5 months, 6 – 11 months, 12 – 23 months, 24 – 35 months, 36 - 47 months and 48 - 59 months (Rutstein and Rojas, 2006). Alternative grouping of the children into segments one month long were found to have no advantage over the grouping above. Using dates of births and date of either death or interview, whichever comes first, numbers of children dying in each of the above mentioned age groups and specific five year periods before the survey are determined. The number of events of interest (deaths) in each of the age groups and the time periods mentioned above are then calculated. The numbers of deaths in each of the given age segments are divided by the numbers of survivors at the beginning of each of the appropriate age intervals.

After obtaining the probabilities of dying within each of the segments given above, probabilities of surviving are calculated as complements of the probabilities of dying. The cumulative probabilities of dying at specific ages can then be calculated.

As mentioned before, specific mortality estimates of interest in this project are the IMR and the U5MR. For further details on calculation of the other childhood mortality measures (neonatal mortality rate and child mortality rate), the reader is referred to a more detailed report on childhood mortality estimation prepared by Rutstein and Rojas (2006).

Calculation of the IMR involves use of the cumulative probability of survival to 12 months; the product of survival probabilities up to 12 months is subtracted from 1. The result is then multiplied by 1000 to obtain the IMR.

The U5MR is obtained by first obtaining component survival probabilities for all ages from birth up to 59 months. A product of these survival probabilities is then calculated. This product is then subtracted from 1. The result is multiplied by 1000 to obtain the U5MR (Rutstein and Rojas, 2006).

2.4.2. Indirect childhood mortality estimation

The Brass children ever born children surviving method (Brass method) is an indirect childhood mortality estimation technique. The Brass method has been heavily relied upon in the past for estimating childhood mortality in developing countries where neither vital registration nor detailed birth histories from reproductive age women representative of the population have been available (Brass and Coale, 1968). It was also found to be extremely useful in illiterate populations because the input data come from very simple questions.

The Brass method requires data on the total number of children each female respondent in the age range 15-49 has ever borne, the number of those children who have died and the total number of female respondents in the age range 15-49 stratified by five year age groups (United Nations, 1983; Population Division United Nations Secretariat, 1990).

The assumptions made in applying the Brass method are that childhood mortality has been constant in the past or that it has been linearly changing; that there is negligible correlation between maternal and childhood mortality; that the childhood mortality being estimated can be described by the chosen model life table; and that the fertility of female respondents has been constant in the recent past (United Nations, 1983). Childhood mortality is required to have been constant in the past or steadily declining to ensure accurate allocation of estimates to time periods in the past (Feeney, 1980). The pattern of childhood mortality under investigation is required to be similar to a pattern displayed by the chosen model life table. This is required because an appropriate model life table is used for the conversion of proportions of children dead to estimates of childhood mortality rates. The same model life table used for converting the proportions surviving is also used for converting the estimates of mortality rates to common indexes for example, q(1) or q(5). The average parities of women aged 15-19, 20-24 and 25-29 are used to convert proportions of children dead to mortality estimates.

There are two variants of the Brass method which are used for indirect childhood mortality estimation. These are the Trussell version and the Palloni and Heligman version (Population Division United Nations Secretariat, 1990). The main difference between these two versions is in the model life tables used. The Trussell version uses the Princeton model life tables while the Palloni and Heligman version uses the United Nations model life tables for developing countries (Population Division United Nations Secretariat, 1990). The choice of the appropriate version to use depends on which model life tables describe the mortality in the population of interest more closely: if the Princeton model life tables are more suitable than the Trussell version becomes the appropriate version to use and vice versa (Population Division United Nations Secretariat, 1990)

Since the Trussell version is the one applied in this project, more details of this version are given. Further details on the Palloni and Heligman version can be in Population Division United Nations Secretariat (1990).

2.4.2.1. The Trussell version of the Brass method

Average parities of the female respondents (*P(i)*) are calculated first for each of the five year age groups spanning the 15 to 49 age range. This is done through dividing the number of children ever born by the number of women for each age group i where $i = 1$ refers to the 15-19 age group, 2 refers to the 20-24 age group, . . ., 7 refers to the 45-49 age group. The next to be calculated are proportions of children dead by age of mothers (*D(i)*). The *D(i)* values are calculated by dividing the number of children dead by the number of children ever born to women in the same age group. The next step involves converting the proportions of children dead to life table probabilities of dying at various childhood ages.

To convert the proportions of children dead to life table probabilities of dying by age x ($q(x)$), account is taken of the fertility pattern of the respondents in the past. The fertility pattern which determines the distribution of births in time and the exposure to the risk of death among the children, determines the childhood deaths that are observed (United Nations, 1983) - the earlier the birth the longer the exposure to the risk of dying. The multipliers used for the conversion are specific to model life tables. The equation relating the proportion dead to the probability of dying by exact age x is $q(x) = k(i) * D(i)$, where *D(i)* is the proportion of children dead for women in

age group i for *(i= 1, . . . ,7)* and $k(i) = a(i) + b(i) * \frac{P(1)}{P(2)} + c(i) * \frac{P(2)}{P(3)}$ is the multiplying factor which allows for the fertility pattern. The values of *k(i)* are determined by the average parity ratios *(P(1)/P(2))* and *(P(2)/P(3))* and the coefficients *a(i), b(i) and c(i).*

The coefficients were determined by regression analysis of model fertility schedules and the Princeton life tables (United Nations, 1983). A full list of the coefficients for each of the four families of model life tables constituting the Princeton model life table system are available in Manual X (United Nations, 1983).

The the approximate age at death *x*, takes the values 1, 2, 3, 5, 10, 15 and 20 for the 7 five-year age groups of women in the 15-49 age range (United Nations, 1983).

While constant mortality in the past would mean that the mortality estimates *(q(x))* apply to any time in the period for which the reported deaths pertain, linearly or steadily changing mortality would imply that the estimates refer to particular time points in the past (Feeney, 1980). Feeney (1980) devised a method to determine the points to which the estimates would refer when mortality is changing.

Based on the work by Feeney (1980), the equation used to estimate the number of years before the census or survey to which the mortality estimate *q(x)* refers (*t (i)*), is

$$t(i) = e(i) + f(i) * \frac{P(1)}{P(2)} + g(i) \frac{P(2)}{P(3)} ,$$

where *t(i)* is the number of years before the census or household survey to which *q(x)* from women in age group *i* refer, *P(i) (i=1, 2, 3)* is as defined before and *e(i), f(i)* and *g(i)* are coefficients derived from simulated cases using regression analysis (United Nations, 1983; Population Division United Nations Secretariat, 1990).

The date to which the *q(x)* estimates apply can be estimated by subtracting *t(i)* from the census or survey date.

The last stage in the indirect estimation procedure involves conversion of *q(x)* to common measures of childhood mortality, in this project, the various *q(x)* values are converted to q(1) and q(5) values. This is done using interpolation in model life tables (Population Division United Nations Secretariat, 1990). First, each estimated value of q(x) is allocated a level in the appropriate model life table family. This is done through linear interpolation between tabulated values of the *q(x)*. When the level is calculated, the value of q(1) and q(5) corresponding to the interpolated level are calculated.

When the *q(x)* values are converted to a common measure, trends of q(1) or q(5) are obtained since the age group of the respondents determines the values of *t(i)* obtained. Estimates from older respondents correspond to time periods further back in time as compared to those from the younger respondents.

The estimate pertaining to the point in time closest to the survey or census date is that derived from the youngest age group, the 15-19 age group. Results from this age group are however not reliable because the children born to teenage mothers have higher mortality as compared to children born to women in the general 15-49 population (United Nations, 1983). The standard practice is to present only results for ages 20 to 49 - the age range is assumed to give reliable estimates of childhood mortality.

2.5. Consistency and use of childhood mortality estimates in Africa

2.5.1. Consistency of estimates from direct and indirect methods

The literature on the consistency of the estimates derived from the two traditional methods of childhood mortality estimation is scanty mainly because sparseness of data. The few attempts made at checking the consistency of the methods are those by Preston (1985), Adetunji (1996) and United Nations (1992). Preston (1985) derived direct and indirect estimates of childhood mortality using world fertility survey (WFS) data collected in the developing countries in the 1970s and the early 1980s and concluded that the estimates derived from the direct method were generally more consistent than those from the indirect method.

In contrast to Preston (1985), Adetunji (1996) did not judge one method on the basis of the other, rather, he compared levels of infant mortality rates derived from the two methods using DHS data from African countries collected in the 1980s and 1990s. He derived direct and indirect estimates of IMR from the data and compared the estimates using statistical t-tests. He came to the conclusion that the direct and indirect methods gave estimates which were statistically different and that the differences were not entirely explained by errors in the data. He suggested that the differences could be due to intrinsic properties of the methods.

United Nations (1992) also considered the consistency of the estimates from the two methods of childhood mortality measurement. It was concluded that there is no one method that works well in all situations, thus the need for using the direct method in some situations for example, when the respondents are literate and are likely to give

accurate dates of vital events and to use the indirect method in situations where the available data for childhood mortality estimation are limited to just totals of children ever born and children surviving.

2.5.2. Use of the estimates from the direct and the indirect methods

The two traditional methods of childhood mortality measurement have been used for estimating levels and trends of childhood mortality in Africa (United Nations, 1992; Hill, Pande and Mahy, 1999; Ahmad, Lopez and Inoue, 2000; Rutstein, 2000; Garenne and Gakusi, 2006; Hill and Amouzou, 2006).

2.5.2.1. Trends in childhood mortality

The construction of the trends of childhood mortality has mainly focused on deriving a consistent series from direct and indirect estimates. This is especially true in the work by Hill and colleagues (United Nations, 1992; Hill, Pande and Mahy, 1999; Hill and Amouzou, 2006). Combining direct and indirect estimates in a single series requires understanding of the differences that exist between the estimates.

Other studies have relied more on the direct estimates derived from DHS data than on the indirect estimates derived from censuses or other general national surveys for construction of childhood mortality trends in Africa, only resorting to indirect estimates in times of need. i.e., when direct estimates were unavailable (Ahmad, Lopez and Inoue, 2000; Rutstein, 2000; Garenne and Gakusi, 2006).

The trends of childhood mortality in Africa constructed in the work just mentioned above show that it has been improving since the beginning of the second half of the twentieth century (Hill and Amouzou, 2006). The decline has mainly been attributed to improvements in health and health interventions in the form of expanding coverage of immunization programmes, prevention of malaria and provision of oral rehydration solutions to children suffering from diarrhoea (Ahmad, Lopez and Inoue, 2000).

The decline in childhood mortality was most rapid from the early 1970s up to the mid 1980s (Garenne and Gakusi, 2006; Hill and Amouzou, 2006). The period from the late 1980s onwards, however, saw the childhood mortality decline slowing down, worse still; stalling or even increasing in some African countries (Ahmad, Lopez and Inoue, 2000). These adverse trends of childhood mortality coincided with the advent of the HIV/AIDS epidemic among other negative conditions which included political instability, and economic downturns (Adetunji, 2000; Ahmad, Lopez and Inoue, 2000;

Garenne and Gakusi, 2006; Hill and Amouzou, 2006). HIV was assumed to be the main determinant of the worsening childhood mortality conditions.

The adverse childhood mortality conditions prevailing in most African countries from the mid 1980s fostered the need for research to determine the causal role of HIV in the levels and trends of childhood mortality (Walker, Schwartlander and Bryce, 2002). However, the traditional methods of childhood mortality measurement were found to be limited in their ability to answer questions on the exact role that HIV played in the overall trends of childhood mortality. This was due to the potential biases in the data and the unavailability prerequisite data for HIV impact assessment in Africa (Walker, Schwartlander and Bryce, 2002; Zaba, Marston and Floyd, 2003).

2.6. Problems with the traditional methods of childhood mortality measurement in high HIV prevalence settings prevailing in African countries

There are two major problems which are related to the use of the traditional childhood mortality estimation methods in high HIV prevalence settings. The first problem is the violation of some of the assumptions required in the application of these methods (Ward and Zaba, 1999; Mahy, 2003; Zaba, Marston and Floyd, 2003). The second problem, which surfaces when wanting to attribute cause to mortality, is the lack of national cause-specific childhood mortality data (Walker, Schwartlander and Bryce, 2002; Zaba, Marston and Floyd, 2003).

2.6.1. The violation of assumptions

The assumption that maternal and child mortality are independent is violated in high HIV prevalence settings. This assumption is violated because of mother-to-child transmission (vertical transmission) and the elevated mortality that results from HIV infection (Ward and Zaba, 1999). The infected women are more likely to die than the uninfected women in the period between giving birth and the survey or census. This leads to the under-representation of the children of the infected women in the survey. When the children of the infected women are under-represented, childhood mortality will be under-estimated since these children experience higher mortality than the children of the uninfected mothers, particularly since a proportion of them will be infected with HIV (Berhane, Begenda, Marum *et al.*, 1997; Brahmbhatt, Kigozi, Wabwire-Mangen *et al.*, 2006).

The assumption that the mortality of the children in the population of interest is similar to the mortality described by a model life table no longer holds since the model life tables mainly used (the Princeton or United Nations model life tables) were constructed without taking HIV/AIDS into account so they do not capture the additional deaths attributable to HIV/AIDS (Ward and Zaba, 1999; Mahy, 2003). The other assumption violated is that of independence between childhood mortality and maternal age. This is due to the fact that transmission of HIV from mother to child is age dependent. (Ward and Zaba, 1999; Walker, Stanecki, Brown *et al.*, 2003).

HIV also introduces errors in the time location of estimates. The coefficients used in estimating the time location estimates were estimated from model life tables that were constructed from HIV free data.

2.6.2. The absence of national cause-specific childhood mortality data

The evidence that AIDS is an important cause of childhood mortality is widely acknowledged (Adetunji, 2000; Crampin, Floyd, Glynn *et al.*, 2003; Nakiyingi, Bracher, Whitworth *et al.*, 2003; Ngweshemi, Urassa, Usingo *et al.*, 2003; Hill, Cheluget, Curtis *et al.*, 2004). However, the understanding of the exact contribution of HIV/AIDS to the overall level of childhood mortality is what remains limited. The contribution of HIV/AIDS is not clearly understood because the nationally representative data used for childhood mortality measurement in Africa are not cause of death specific. This makes it difficult to estimate the contribution of HIV/AIDS to overall childhood mortality.

2.7. Understanding the effect of HIV on childhood mortality

Methods which are robust to the violation of the assumptions highlighted in the previous section are required for accurate childhood mortality estimation in high HIV prevalence settings. However, it is not enough to have only methods which provide accurate overall childhood mortality estimates since observing overall mortality only cannot give a good picture of the impact of HIV on childhood mortality. The background mortality (mortality due to causes other than HIV/AIDS) may exaggerate or mask the impact of HIV (Zaba, Marston and Floyd, 2003). This happens since it is possible, depending on the level of prevalence, for overall mortality to keep declining due to reduction in non-AIDS mortality while HIV related deaths are stable or even increasing. There is therefore need to stratify childhood mortality by the HIV status of the child.

The need for understanding the effect of HIV on childhood mortality in high HIV prevalence settings has led to efforts being made towards verifying HIV prevalence as a covariate of childhood mortality (Adetunji, 2000; Hill, Cheluget, Curtis *et al.*, 2004), development of new approaches to measurement of childhood mortality and quantification of the impact of HIV on childhood mortality.

2.7.1. HIV prevalence as a covariate of childhood mortality

HIV prevalence has been included in regression relationships together with other potential covariates of childhood mortality (Adetunji, 2000; Hill, Cheluget, Curtis *et al.*, 2004) to check it as a covariate. Adetunji (2000) concluded that HIV was an important, but not the sole, cause of the adverse trends in childhood mortality in African countries. Hill, Cheluget, Curtis *et al* (2004), in the study they did to check whether there was any relationship between the reversal of the downward trends in childhood mortality in Kenya and the increases in HIV prevalence in the same country, found that HIV prevalence level was a significant covariate of childhood mortality in Kenya.

The results of longitudinal studies involving maternal HIV testing and child survival in Africa have been summarized well by Newell, Brahmbhatt and Ghys (2004) and Zaba (2003). These have indicated that the children of the HIV infected mothers have higher mortality than the children of the uninfected mothers. Some longitudinal studies have even gone further to stratify childhood mortality by both maternal and child HIV status (Berhane, Begenda, Marum *et al.*, 1997; Spira, Lepage, Msellati *et al.*, 1999; Taha, Kumwenda, Broadhead *et al.*, 1999; Newell, Coovadia, Borja *et al.*, 2004; Brahmbhatt, Kigozi, Wabwire-Mangen *et al.*, 2006; Marinda, Humphrey, Iliff *et al.*, 2007). The results from these studies indicated that the HIV infected children have the highest mortality of all children, followed by the uninfected children of the HIV infected mothers (the HIV exposed children). The children of the uninfected mothers have generally been shown to have the lowest mortality of the three groups of children. It has been concluded that HIV is indeed a covariate of childhood mortality.

Beyond establishing that HIV prevalence is a covariate, work has been done to measure the extent to which it impacts childhood mortality. This has been done by estimating the proportion of childhood mortality attributable to HIV/AIDS.

2.7.2. Proportion of childhood mortality attributable to HIV/AIDS

The effect of HIV on childhood mortality has been quantified using the population attributable fraction of childhood mortality (HIV PAF).

The HIV PAF is the proportion of population childhood mortality that is attributable to HIV/AIDS. The formula used to estimate HIV PAF is as given in Equation 2-1 below.

$$PAF = \frac{q_A(x) - q_U(x)}{q_A(x)}$$ **Equation 2-1**

where $q_A(x)$ is the overall childhood mortality up to exact age x and $q_U(x)$ is the mortality among HIV uninfected children.

Equation 2-1 shows the mortality estimates required for the estimation of HIV PAF. The components of the formula can be obtained using longitudinal data or from the new approaches to childhood mortality estimation (given in detail later).

Longitudinal studies that have estimated HIV PAF in Africa have tended to use overall mortality among all children involved in the studies and the mortality of the children of uninfected mothers thus including both direct and indirect effects of HIV/ AIDS on childhood mortality. (Crampin, Floyd, Glynn *et al.*, 2003; Ngweshemi, Urassa, Usingo *et al.*, 2003; Brahmbhatt, Kigozi, Wabwire-Mangen *et al.*, 2006). However to measure the direct impact of HIV/ AIDS on childhood mortality, the mortality of all uninfected children needs to be measured. The estimates of HIV PAF obtained from longitudinal data are presented in Table 2.1 below. These results show that childhood mortality could be improved by between 8 and 18 per cent if vertical transmission of HIV was completely eliminated in different African sub-populations.

These estimates are not nationally representative. They only apply to the districts in which the studies were done and include both the direct and the indirect effects of HIV/ AIDS. These shortcomings made it difficult to generalise the findings from these longitudinal studies (Ahmad, Lopez and Inoue, 2000).

Table 2.1 HIV PAF results from some African longitudinal studies

Country & data collection period	Source	HIV PAF (per cent)
Uganda (1994-1998)	(Brahmbhatt, Kigozi, Wabwire-Mangen *et al.*, 2006)	13.8
Malawi (1981-2000)	(Crampin, Floyd, Glynn *et al.*, 2003)	18
Tanzania (1994-1996)	(Ngweshemi, Urassa, Usingo *et al.*, 2003)	8
Uganda (1989-)	(Zaba, Marston, Nakiyingi *et al.*, 2003)	15.7

There are two main approaches that have been developed and used to provide national estimates of childhood mortality in high HIV prevalence settings prevailing in

most African countries. The childhood mortality estimates obtained from these methods have been used to derive national estimates of HIV PAF. These two approaches are described in detail in the next section.

2.8. New approaches to childhood mortality measurement

The approaches described below are termed "new" because they were devised to estimate childhood mortality in the presence of HIV/ AIDS. They used not to exist in the pre-AIDS era.

The two new approaches that have been mainly used to derive national estimates of childhood mortality stratified by child HIV status in sub-Saharan Africa are the method by Walker, Schwartlander and Bryce (2002) and the method by Zaba, Marston and Floyd (2003), hereafter referred to in short as the Walker method and the Zaba method respectively.

2.8.1. Walker method

Walker, Schwartlander and Bryce (2002) developed a method of measuring childhood mortality in high HIV prevalence settings (high HIV settings defined in Chapter 1)

In this method, a four-step process is used to produce estimates of the age specific mortality of HIV infected children and the proportion of all under-five deaths that are attributable to HIV/AIDS. The steps are described in detail below

2.8.1.1. Estimation of prevalence among females of reproductive age

The Walker method starts with HIV prevalence among women attending antenatal clinics at selected HIV prevalence sentinel surveillance sites. The point estimates of HIV prevalence from sentinel surveillance sites are entered into a epidemiological computer program developed by WHO called EPIMODEL (Schwartlander, Stanecki, Brown *et al.*, 1999) which implements a UNAIDS-developed HIV prevalence projection model. This prevalence projection model fits HIV/AIDS epidemic curves to point prevalence estimates. Details of how the model is fitted are given by Schwartlander, Stanecki, Brown *et al.* (1999).

2.8.1.2. Estimation of the numbers of infected and uninfected children

The prevalence rates for adults aged 15 - 49 are applied to the reproductive female population to get numbers of infected and uninfected women.

Appropriate fertility schedules from age specific fertility rates estimated by the United Nations Population Division, are then applied to the resulting estimated distributions of infected and uninfected women taking into account the effect of HIV on fertility. Fertility of infected women 20 years or older, is assumed to be 20 per cent lower than the fertility of the women of the same age in the national reproductive female population. The fertility of infected pregnant teenagers (15-19) is assumed to be 50 per cent higher compared to the 15-19 women in the general population. The teenage women who fall pregnant are assumed to be more sexually active and to be more exposed to unprotected sex than women in the general population (Walker, Stanecki, Brown *et al.*, 2003; Zaba, Whiteside and Boerma, 2004).

Vertical transmission rates are applied to the births from HIV positive women to estimate the proportion of births that gets infected. Account is taken of when the vertical transmission occurred since vertical transmission rates are known to vary depending on child's age at infection (De Cock, Fowler, Mercier *et al.*, 2000). The time periods at which vertical transmission occurs are: in utero or intrapartum, in the first 6 months after birth or after the first six months. The variation in the transmission rates is accounted for by grouping infected children into three cohorts depending on the timing of infection. The transmission rates are estimated as ranges for each of the three periods using results from work by De Cock, Fowler, Mercier *et al* (2000). The estimates of vertical transmission used are 15-30 per cent for children getting infected in utero or at birth (no transmission through breast milk), 25-35 per cent for children getting infected in the first six months after birth through early breastfeeding and 30-45 per cent for children getting infected after the first six months of life by late breastfeeding.

2.8.1.3. Survival from infection to death

Net survival of infected children from HIV/AIDS only in the time from infection to death is modeled by a double Weibull distribution on the basis of results from African studies involving vertical HIV transmission and survival (Walker, Schwartlander and Bryce, 2002).

Survival of children after infection is assumed to be either long or short term. Combinations of minimum and maximum transmission rates and long and short survival periods give four scenarios. The four scenarios are; minimum transmission - long survival, minimum transmission-short survival, maximum transmission-long survival and maximum transmission-short survival. Four estimates of mortality are

obtained for each year and each of the countries being considered. The mean value of the four estimates is used as the best estimate.

The results obtained are the numbers of children who die with the HIV infection.

2.8.1.4. Number of children dying of HIV/AIDS

To obtain the number of childhood deaths directly attributable to HIV/AIDS, the following steps are followed. First, the proportion of all childhood deaths due to causes other than HIV/AIDS is estimated by subtracting the number of deaths among infected children from the WHO all causes deaths and then dividing the difference by the WHO number of deaths from all causes. Second, this proportion is multiplied by the number of deaths among HIV infected children. The result is the number of HIV infected children who die of non-AIDS causes. Third, the number of the HIV positive children who die of causes other than AIDS is subtracted from the number of all the HIV infected children dying to obtain childhood deaths directly resulting from HIV/AIDS related causes.

After obtaining the estimated number of children dying of HIV/AIDS related causes, the proportion of all deaths that is directly attributable to HIV/AIDS is obtained by dividing the number of children dying of HIV/AIDS by the number of childhood deaths from all causes.

2.8.2. The Zaba method

2.8.2.1. Mortality of the uninfected children

The starting point for the Zaba method is childhood mortality corresponding to the period before the HIV/AIDS epidemic. Two time points, 10 years apart, are selected. Both points are required to be either in the pre- HIV/AIDS epidemic period or the later time point could be in the early years of the epidemic.

Since the logit transformations of mortality rates are linearly related (Zaba, Marston and Floyd, 2003), Brass parameters relating the logit transformations of infant and under-five mortality at the two chosen points are determined using an appropriate standard, say a UN model life table (Zaba, Marston and Floyd, 2003). The linear change in the parameters is extrapolated to an arbitrary point t in the future. The projected parameters are used in the relational logit model of mortality to estimate infant and under-five mortality. The equations explaining the extrapolation of the parameters are outlined in Zaba, Marston and Floyd (2003).

2.8.2.2. Gross mortality of the HIV infected children

The next estimate to be derived is the mortality of infected children from HIV/AIDS and non-HIV/AIDS causes, also called (by Zaba and colleagues) the gross mortality. This is done by assuming independence between HIV/AIDS related causes and non-HIV related causes and then using multiple decrement relationships. To derive the cumulative probability of surviving from birth to age x for infected children ($l_I(x)$), the net survival from HIV/AIDS only ($l_N(x)$) and the survival probability of the uninfected children ($l_U(x)$) are multiplied. The complement of $l_I(x)$ gives the gross mortality of infected children.

Since the net mortality due to HIV/AIDS related causes only is unobservable, it is modeled using a double Weibull distribution given in Equation 2-2. The double Weibull distribution was assumed to be suitable on the basis of studies done in Africa on mother to child transmission of HIV and child survival. Infected children are known to comprise of those who progress slowly and those who progress rapidly (The UNAIDS Reference Group, 2002). Children infected peri-partum tend to progress faster than those who get infected during breastfeeding (Spira, Lepage, Msellati *et al.*, 1999). The double Weibull distribution captures this pattern of mortality variation by having one component for the rapid progressors and another component for the slow progressors.

$$l_N(x) = \pi * e^{-(\lambda_1 * x)^{\mu_1}} + (1-\pi) * e^{-(\lambda_2 * x)^{\mu_2}} \qquad \textbf{Equation 2-2}$$

where π represents the proportion of infected children who rapidly progress to AIDS, while its complement (1- π) represents the slow progressors. λ_1 and μ_1 are the shape and scale parameters of the component Weibull curves representing those children who progress fast through the stages of the disease while λ_2 and μ_2 are the corresponding parameters of the Weibull curve representing the mortality among those children progressing slowly.

2.8.2.3. The overall childhood mortality

The overall mortality is estimated using the gross mortality of the HIV infected children and the mortality of the HIV uninfected children.

To get the mortality of all children in the population of interest, the proportion of all children who get infected is estimated by the product of the national estimate of

the HIV prevalence among pregnant women attending antenatal clinics (***p***) and the mother to child transmission rate of HIV (***v***). The prevalence used in this methodology was that recorded in sentinel surveillance sites and the mother to child transmission rate used is 35 per cent which is the mid-point of the range of vertical transmission in breastfeeding populations given in De Cock, Fowler, Mercier *et al* (2000). When this method was developed, prevention of mother-to-child transmission of HIV was only beginning to be implemented in most African countries so it was not considered in the estimation of vertical transmission rate. The developers of the method however give provision for adjusting the vertical transmission rate to accommodate PMTCT.

The proportion of all children infected ***h***, was estimated by $h = p^* v$ and uninfected children constituted $1 - h$. The overall mortality was estimated by $q_A(x)$ as given in Equation 2-3 below.

$$q_A(x) = h^* q_I(x) + (1-h)^* q_U(x) \qquad \textbf{Equation 2-3}$$

The overall mortality $q_A(x)$ and the mortality of uninfected children $q_U(x)$ were then used to estimate the HIV PAF using the formula in Equation 2-1.

2.9. Conclusion

The estimates derived from the traditional methods have shown a declining trend from 1960s to the mid 1980s. The period from around the mid 1980s onwards saw the speed of mortality decline reducing in some countries and stalling or even reversing in other countries. These adverse patterns in childhood mortality coincided with the advent of HIV/AIDS and other socio-economic problems.

AIDS was suspected to be responsible for the adverse trends (Korenromp, Arnold, Williams *et al.*, 2004). This resulted in the need to understand the importance of HIV in determining the levels and trends of childhood mortality. However, the violation of assumptions and the lack of cause-specific childhood mortality data have limited the usefulness of the traditional methods in assessing the impact of HIV. Hence, there was need for new approaches to childhood mortality measurement. Subsequently, efforts were made to understand how HIV affects childhood mortality. These included studies to confirm HIV prevalence as a covariate, to assess the impact of HIV/AIDS on childhood mortality measurement and also to estimate the proportion of childhood mortality attributable to HIV/AIDS.

The studies that have investigated the relationship between HIV/AIDS and childhood mortality in Africa have largely been longitudinal in nature. These studies were mainly done in sub-populations of countries, usually single districts (Crampin, Floyd, Glynn *et al.*, 2003; Nakiyingi, Bracher, Whitworth *et al.*, 2003; Ngweshemi, Urassa, Usingo *et al.*, 2003).

The mortality estimates derived from the data gathered in each of these longitudinal studies were not nationally representative because of the spatial variation of childhood mortality between regions within a country (Palamuleni, 2001; Zaba, Marston and Floyd, 2003). Despite not being nationally representative, the data revealed important characteristics of paediatric HIV infection and survival which have been used to inform construction of models which are the current sources of national estimates of the impact of HIV/AIDS on childhood mortality (The UNAIDS Reference Group, 2002; Walker, Schwartlander and Bryce, 2002; Zaba, Marston and Floyd, 2003; Johnson and Dorrington, 2005).

Although models such as the Walker method are good at bridging the gap between results from longitudinal studies and nationally representative estimates, they have the weakness of being complex and less transparent (Zaba, Marston and Floyd, 2003).

Although a significant amount of work has been done to improve our understanding of the way HIV affects childhood mortality and childhood mortality measurement in Africa, there still remains unaddressed issues concerning the impact of HIV on childhood mortality and childhood mortality measurement.

So far, trend analysis of childhood mortality has mainly focused on the construction of a consistent series of estimates from the direct and the indirect childhood mortality estimation methods. Little attention has been paid to the comparison of trends from these two methods to verify whether the two methods produce the same trend or not. It is important to verify whether the trends from the two methods are consistent especially in high HIV prevalence settings since there are suggestions that the indirect method is impacted more by HIV/AIDS than the direct method (Mahy, 2003).

No study in Africa so far has used DHS birth histories data from HIV negative women to derive childhood mortality estimates for uninfected children for use in estimating HIV PAF. These birth histories could be a good basis for the estimation of

mortality of uninfected children for use in HIV PAF estimation (Zaba, Marston and Floyd, 2003).

Chapter 4 addresses these two questions by providing a possible methodology for comparison of the childhood mortality trends and assessing the impact of HIV/AIDS on childhood mortality using DHS data involving HIV testing results and results from African longitudinal data on vertical HIV transmission and child survival.

3. Data

3.1. Introduction

This chapter presents the sources of the data used in this project and an assessment of their quality. Section 3.2 gives the background information on the two countries (Kenya and Malawi) from which the data were collected. Section 3.3 gives the data sources. Section 3.4 presents the assessment of data quality. Finally, section 3.5 gives the chapter conclusion.

3.2. Background information on Kenya and Malawi

3.2.1. Kenya

Comprehensive background information about Kenya is provided in DHS survey reports. The brief description of Kenya which follows has been mainly constructed from the information in the 2003 Kenyan DHS report (Central Bureau of Statistics (CBS) [Kenya], Ministry of Health (MOH) [Kenya] and ORC Macro, 2004).

Kenya is located in the eastern part of the African continent. It is bordered by the United Republic of Tanzania to the south, Uganda to the west, Ethiopia and Sudan to the north, Somalia to the north-east and the Indian Ocean to the south-east. The total land area of Kenya is 582 646 square kilometres. 80 per cent of the land area is either arid or semi arid. This non arable land is mainly used by nomadic pastoralists.

There are eight provinces in Kenya which are Central, Coast, Eastern, Nairobi, North-Eastern, Nyanza, Rift Valley and Western provinces.

The last Kenyan census in 1999 reported the Kenyan population as 28.7 million (Kenya National Bureau of Statistics, 2001). Projections reported by Population Reference Bureau put the Kenyan population at 36.9million as of mid 2007 (Population Reference Bureau, 2007) while the Kenyan Bureau of Statistics projected the population to 37.2 million in August 2006 (National AIDS Control Council and Office of the President Kenya, 2008).

3.2.2. Malawi

Malawi is a southern African country. It is bordered by the United Republic of Tanzania to the north and northeast, by Mozambique to the east, south and southwest and to the west and northwest by Zambia. The total area of Malawi is 118 484 square kilometers. The country is divided into three regions namely the Northern, Central and the

Southern regions. Demographic data in Malawi have mainly been collected through population censuses. The DHS surveys were started in 1992 (National Statistical Office (NSO) [Malawi] and Macro International Inc, 1994; National Statistical Office (NSO) [Malawi] and ORC Macro, 2005). The other data source is the 1996 Malawi knowledge, Attitudes and Practices in Health survey. As enumerated in 1998, the Malawian population was 9.9 million. the Malawian population was estimated as 13.1 for mid-2007 by the Population reference bureau (Population Reference Bureau, 2007). The National Statistical Office Malawi estimated population to be 13 187 632 by mid-2007 (National Statistical Office (NSO) [Malawi], 2008a). Childhood mortality in Malawi is among the highest in the world (Kabudula, 2007). The infant mortality and under five mortality reported by the National Statistical office for 2006 are 69 per thousand births and 118 per thousand births respectively (National Statistical Office (NSO) [Malawi], 2008b)

3.3. Data sources

Most of the data used in this project are from Demographic and Health Surveys (DHS). The DHS datasets used together with the periods of data collection are provided in Table 3.1 below. In addition to the DHS data, census data were also used. The census data used are from the Kenyan 1999 and the Malawian 1998 censuses. The reference nights for these censuses are 24/25 August and 1/2 September respectively.

Table 3.1 DHS datasets and data collection periods

Country	Data collection period	Mid-point of data collection period	Reference date of survey (in years)
Kenya	17 February to 15 August 1993	17 May	1993.4
	16 February to 29 July 1998	8 May	1998.4
	18 April to 15 September 2003	1 July	2003.5
Malawi	1 September to 10 November 1992	5 October	1992.8
	12 July to early November 2000	12 September	2000.7
	4 October 2004 to 31 January 2005	2 December 2004	2004.9

The reference dates of the DHS surveys in Table 3.1 above were obtained by expressing the mid-points of the data collection periods (column 3) in years. These reference dates were used (in Chapter 4) to estimate the mid-points of the five-year intervals by which IMR and U5MR are presented in DHS reports.

3.3.1. The Demographic and Health Surveys (DHS) data

The DHS program is based on nationally representative surveys with large sample sizes involving at least 5 000 households in Africa and other developing regions (Measure DHS Program, n.d.-b). The surveys are generally done every five years.

The DHS data are standardised to make comparison between countries possible. The standardised data files are called recode files (Croft, 1998). Documentation is made available of all the editing done to the data for users to see.

To make DHS estimates representative at district level in any country, some districts maybe over-sampled. Therefore; sample weights are used to account for the over-sampled districts and ensure that estimates are nationally representative. Nonetheless, sub-national estimates maybe unreliable.

3.3.1.1. Kenya DHS data

The Kenya DHS data used in this project are provided in Table 3.1 above. The datasets differ in the sampling frames used. The 1993 and 1998 Kenyan DHS used the Kenya 1989 census sampling frame. These two surveys excluded the North Eastern province and four other northern districts. The excluded population was about 4 per cent of the total population (National Council for Population and Development, Central Bureau of Statistics Kenya and Macro International Inc, 1998). The North Eastern province may have been excluded because the population is sparsely scattered and that it is predominantly nomadic as the inhabitants are constantly moving in search for pastures for their livestock. This makes it very difficult to locate women and identify their places of usual residence. The 2003 DHS used the Kenya 1999 census sampling frame and it also included all the parts of the country.

Each of the three Kenyan DHS surveys considered in this study used three questionnaires, a household questionnaire which was used to identify women aged 15 - 49 and men aged 15–54, a questionnaire for the women aged 15-49 and a questionnaire for males 15-54 (National Council for Population and Development, Central Bureau of Statistics Kenya and Macro International Inc, 1998).

3.3.1.2. Malawi DHS data

Table 3.1 provides Malawi DHS data used in this project. There are some features of the Malawian DHS surveys note mentioning pertaining to the sampling frames used and the sample sizes of the surveys. While the 1992 DHS used a sampling frame based on the Malawi 1987 population census, the 2000 and 2004 DHS used a sampling frame

based on the 1998 census. The 1992 sample of women of reproductive age was of size 4849. This sample was smaller than the later two DHS. The sample sizes for the 2000 and 2004 DHS were 13220 and 11698 respectively.

3.3.2. Census Data

The Kenyan census data used were obtained from the Integrated Public Use Microdata Series – International (IPUMS – International). The IPUMS International project is run by the University of Minnesota Population Center (Minnesota Population Center, 2007).

A five per cent sample of data from the 1999 Kenya census was accessed from IPUMS. A systematic sample of households was selected from a list of all the households included in the 1999 census. The sample size is 1 407 547 people and is self-weighting with an expansion factor of twenty. Field work for the census was done for seven days from 25 to 31 August 1999.

The 1998 Malawi census had the night of 1 September as its reference night. The data from 1998 census accessed for this study are in form of tables of population distributions by various socio-demographic characteristics. Neither the detail of the illogical responses and other errors found in the census data nor the way in which the errors were rectified was accessed.

3.4. Data quality

Demographic data are almost invariably subject to human error. It is therefore necessary to assess their quality before using them to at least identify or better still, rectify errors therein to minimize the risk of drawing erroneous conclusions from the data.

3.4.1. Assessment for errors common in DHS detailed birth histories data

There are errors which are commonly found in DHS birth histories data. These include missing dates of birth or ages at death for some of the children reported in the birth histories, misreported date of birth or age at death and omission of children who did not survive (Curtis, 1995). Misreporting the age at death for a deceased child normally occurs around age 1. Ages at death are either rounded up to 1 year for some children dying before turning 1 or rounded down for some children dying after age 1. These errors may distort levels, age patterns or trends of childhood mortality.

Missing dates of birth or ages at death are imputed using a hot deck procedure which involves identifying a child matching the child with missing information in other variables and using the date of birth or age at death of this child (Curtis, 1995).

Assessment of DHS data for misreporting of ages at death and omission of children who did not survive to survey dates is done for each DHS survey before presenting the childhood mortality results.

Kenyan DHS reports for the three surveys used in this study show that there was no significant misreporting of dates of births or dates of death or omission of dead children in the surveys (National Council for Population and Development (NCPD), central Bureau of Statistics (CBS) (Office of the Vice President and Planning and Development [Kenya]) and Macro International Inc. (MI), 1994; National Council for Population and Development, Central Bureau of Statistics Kenya and Macro International Inc, 1998; Central Bureau of Statistics (CBS) [Kenya], Ministry of Health (MOH) [Kenya] and ORC Macro, 2004).

Malawian 1992 and 2000 DHS reports did not indicate misreporting of dates of births or ages at death in the birth histories. No omission of dead children was reported for these two surveys (National Statistical Office (NSO) [Malawi] and Macro International Inc, 1994; National Statistical Office (NSO) [Malawi] and ORC Macro, 2001).

The Malawi 2004 DHS report stated that there was misreporting of dates of births. Births happening in the five-year period leading to the survey were reported to have occurred in the earlier five-year period (National Statistical Office (NSO) [Malawi] and ORC Macro, 2005). This transference of dates of births is said to be a result of interviewers trying to reduce their workload by pushing dates of births backwards. Pushing dates backwards eliminated the need to ask questions on child and maternal health required for children born within the latest five year period prior to a DHS survey. This transference of dates of births is said to lead to underestimation of mortality in the five-year period immediately prior to the survey and overestimation in the earlier five-year period.

Datasets were also assessed for general internal and external consistency by assessing age distributions of the women aged 15-49, their educational characteristics, parities and the interrelationships between these background characteristics. Anomalies identified are mentioned.

It must however be noted that consistency does not imply the absence of errors in the data. It is possible for datasets to pass consistency tests but nonetheless have errors.

3.4.2. The quality of Kenyan data

Table 3.2 gives the basic demographic indicators for women aged 15-49 in the Kenyan DHS surveys mentioned above and the 1999 Kenya census. Various background characteristics of these women are investigated below to check the consistency of the datasets used in this project.

Table 3.2 Basic demographic characteristics of Kenyan women aged 15-49 from various data sources

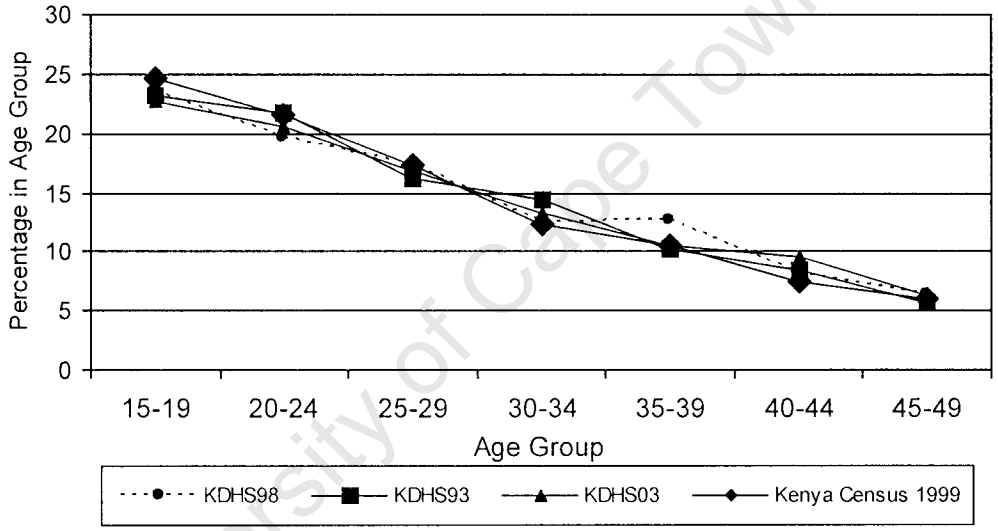
Background characteristics	1993 DHS			1998 DHS			1999 Census			2003 DHS		
	Weighted %	Weighted N	Unweighted N	Weighted %	Weighted N	Unweighted N	Weighted %	Weighted N	Unweighted N	Weighted %	Weighted N	Unweighted N
Age												
15-19	23.3	1754	1788	23.5	1851	1852	24.6	1700060	85003	22.6	1856	1820
20-24	21.7	1638	1605	19.6	1548	1542	21.6	1495180	74759	20.6	1691	1710
25-29	16.2	1221	1199	17.4	1371	1344	17.4	1205060	60253	16.9	1382	1400
30-34	14.4	1088	1112	12.5	986	977	12.3	849620	42481	13.3	1086	1116
35-39	10.2	768	743	12.6	991	999	10.5	725780	36289	10.6	871	859
40-44	8.5	638	653	8.1	637	643	7.5	519740	25987	9.6	788	780
45-49	5.8	434	440	6.3	497	524	6	417500	20875	6.4	521	510
Education												
None	17.9	1352	1297	11.5	909	1010	17.7	1221340	61067	12.7	1039	1291
Primary	57.6	4345	4449	59	4670	4719	62.8	4338100	216905	58	4734	4348
Secondary +	24.5	1844	1794	29.2	2302	2152	19.6	1353500	67675	29.4	2403	2556
Province												
Nairobi	6.7	507	367	9.8	770	419	8.8	609880	-	10.2	835	1169
Central	14.5	1094	1075	10.6	834	787	13.7	946020	-	14.4	1181	1314
Coast	9.5	717	1091	7.7	605	1226	8.8	609680	-	8.1	667	938
Eastern	18.6	1406	1044	17.6	1386	1186	16.1	1110080	-	16.2	1325	993
Nyanza	15.4	1158	1264	21.5	1690	1390	15.4	1062780	-	14.9	1222	1025
Rift-Valley	20.7	1562	1754	21.5	1696	1977	23.4	1618900	-	22.8	1872	1328
Western	14.5	1096	945	11.4	899	896	11.3	778200		11.3	927	991
North-Eastern	-	-	-	-	-	-	2.6	177400	-	2.0	168	437
Residence												
Urban	17.8	1339	1161	23.2	1830	1466	27.9	1926000	96300	25.1	2056	2751
Rural	82.2	6201	6379	76.8	6051	6415	72.1	4986940	249347	74.9	6139	5444
All women	100	7540	7530	100	7881	7881	100	6912940	6912940	100	8195	8195
TFR[1] (15-49)			5.40			4.70			4.70			4.90

[1] TFR stands for the Total Fertility Rate. This is defined as the average number of children a woman would give birth to in her life time if current age specific fertility was going to remain unchanged throughout her life time (Preston, Heuveline and Guillot, 2001)

3.4.2.1. Age distributions of Kenyan women aged 15-49

Age distributions for Kenyan women aged 15-49 are presented in Table 3.2 and in Figure 3.1 below. As would be expected, the figure shows declining percentages of women by age group. The age structure of the women in the childbearing ages as given by the data collected in the four undertakings are largely consistent other than the for the small difference in the 35-39 age group in the 1998 DHS.

Figure 3.1 Age distributions of Kenyan women aged 15-49, various data sources



3.4.2.2. Education levels of Kenyan women aged 15-49

Table 3.2 shows that the DHS women are generally more educated than the women in the 1999 census. Though the 1992 DHS and the 1999 census have similar percentages of women aged 15-49 with no schooling, the percentage of women with secondary or more education in the 1992 DHS is higher compared to the census. The percentages of women with primary and secondary education or more are similar in the three DHS surveys.

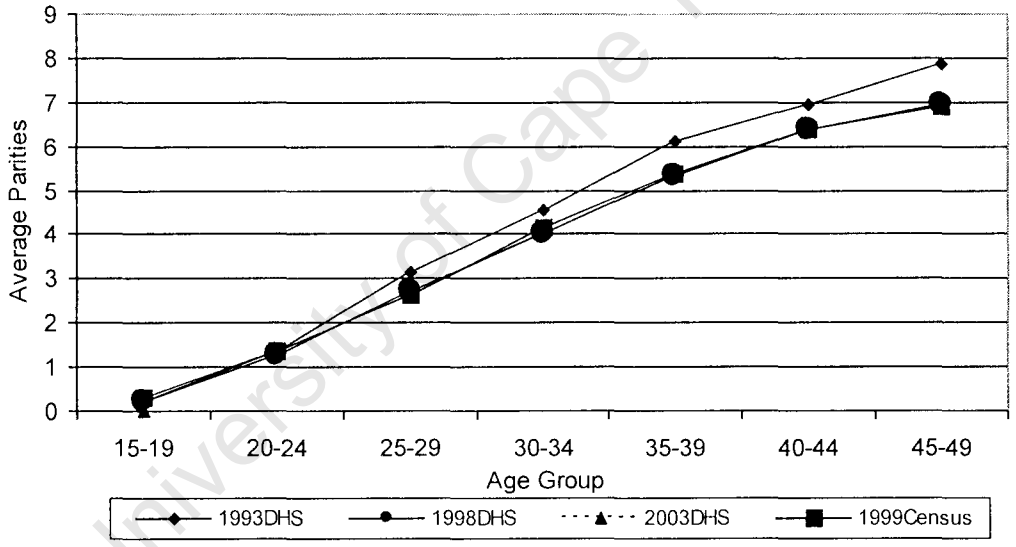
3.4.2.3. Parities of the Kenyan women aged 15-49

The relationship between average parities (average number of children ever born) and the ages of the women in the three DHS and the 1999 census was investigated. The

average parities are expected to increase with age since on average older women have more children than younger women.

A plot of these average parities against age of the 15-49 women shows an increasing trend (Figure 3.2). The average parities from the 1993 DHS data are significantly higher than from the later two DHS surveys and the 1999 census; this agrees with documented fertility declines in Kenya (Anyara and Hinde, 2005). The parities of Kenyan women in the 1998 DHS and 1999 census data are strikingly similar. The small differences between the average parities from the 1998 DHS, 1999 census and 2003 DHS are consistent with the hypothesis of a fertility stall suggested by (Bongaarts, 2005).

Figure 3.2 Average parities of Kenyan women (15-49), various data sources



The relationship between the average parities and the education level of the 15-49 women was also investigated. The level of education is known to have a negative effect on the average number of children ever born (Caldwell, 1980; Thomas and Muvandi, 1994; Lloyd, Kaufman and Hewett, 2000; Kravdal, 2002).

Table 3.3 below shows the relationship between average parities and education for Kenyan women of reproductive age. Generally there is a downward trend in the average parities with increasing education level.

Though showing a downward trend in fertility with increasing education level, the 15 – 19 age group shows a pattern that is different from that shown by the other older age groups.

Primary education is not very influential in reducing fertility; appreciable reduction is experienced from secondary level onwards.

Table 3.3 Average parities by education of Kenyan women (15-49), various sources

Age group	No school	Primary	Secondary +	No school	primary	Secondary +
	1993 DHS			1998 DHS		
15-19	0.4	0.2	0.1	0.6	0.2	0.8
20-24	1.9	1.6	0.8	1.8	1.5	0.8
25-29	3.9	3.5	2.3	3.4	3.2	1.8
30-34	5.3	4.7	3.6	5.2	4.4	3.1
35-39	6.4	6.4	4.8	5.8	5.6	4.4
40-44	7.0	7.2	5.3	7.3	6.4	4.8
45-49	8.2	7.8	4.4	6.9	7.4	5.3
	1999 Census			2003 DHS		
15-19	0.4	0.3	0.3	0.5	0.2	0.1
20-24	1.7	1.6	1.3	1.9	1.5	0.6
25-29	3.2	2.9	2.5	3.7	3.0	1.6
30-34	4.9	4.4	4.0	5.5	4.2	2.9
35-39	6.1	5.6	5.2	6.1	5.5	3.7
40-44	6.9	6.5	6.1	6.8	6.1	4.2
45-49	7.2	7.0	6.7	7.1	6.9	4.7

However, the parities corresponding to highest educated women aged 45-49 are not reliable due to data limitations, not many women of that age are educated up to university level.

3.4.2.4. Sex ratios of children ever born by Kenyan women aged 15-49

Sex ratios of children ever born to women of reproductive age were calculated to investigate differential reporting in the children ever born data with respect to the sex of the child. A sex ratio is defined as the number of males per 100 females.

These ratios are expected to be stable across age of the mothers (United Nations, 1983). (Garenne, 2004) showed that sex ratios at birth in eastern and southern Africa were stable over time and that they were significantly lower than the usually used value of 1.03 (United Nations, 1983) for sub-Saharan Africa.

The fact that the sex ratios at birth are generally constant over time and that women are expected to report the number of children they have given birth to regardless of whether these children are still alive or not at the time of enumeration

means that the sex ratios of children ever born are suppose to behave in the same way that sex ratios at birth behave unless there is differential reporting of children ever born with respect to sex. This differential is not evident in the sex ratios of the children ever born reported in Kenyan surveys and 1999 census. The ratios are stable with age of mother and are on average lower than 103 across age and time (Table 3.4)

Table 3.4 Sex ratios of children ever born to Kenyan women aged 15-49

Age group	1993 DHS	1998 DHS	1999 Census	2003 DHS
15-19	97.1	99.5	100.0	101.4
20-24	102.1	101.7	105.0	104.9
25-29	100.3	103.2	103.7	100.2
30-34	102.0	101.1	102.6	101.6
35-39	100.3	100.4	101.7	100.9
40-44	101.6	100.4	102.2	102.2
45-49	100.1	100.8	102.0	103.3
Overall	100.9	100.9	102.6	102.1

Sex ratios of children ever born from all the data sources have values between 100 and 105, besides those from the children ever born to teenage mothers in the 1993 and 1998 DHS surveys which are 97.1 and 99.5 (almost 100) respectively. Estimates from this age group of mothers are not very reliable since they are usually based on small numbers of events. The census data give satisfactory sex ratios; all but two of the ratios are between 102 and 105 thus according to the (United Nations, 1983) there is no evidence of omission of children of either of the two sexes.

Generally the assessment of Kenyan census and DHS data above has not identified serious flaws that can nullify the use of these data. Malawian data are considered in the next section.

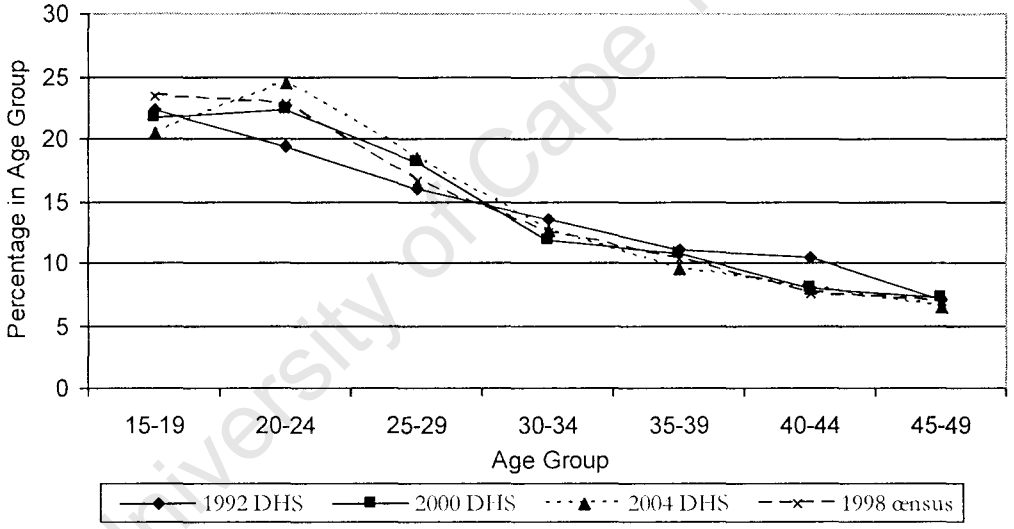
3.4.3. Malawi data

As was done for Kenya, background data for Malawian women aged 15-49 from the Malawian data sources used in this study were assessed for errors. These background data are provided in Table 3.5 below.

3.4.3.1. Age distributions of Malawian women aged 15-49 from various data sources

The age distributions for Malawian women aged 15-49 from the DHS surveys and census are shown in Figure 3.3 below. All the age distributions other than that from the 1992 DHS are very similar, the 2000 and 2004 survey seem to have had sampling problems as the 20-24 age group is larger than the 15-19 one.

Figure 3.3 Age distributions of Malawian women (15-49), various data sources



It also seems the 1992 data has errors since they show an age distribution which is different from the other three data sources.

Table 3.5 Basic demographic characteristics of Malawi women aged 15-49 from various sources

Background Characteristics	1992 DHS			1998 Census[2]		2000 DHS			2004 DHS		
	Weighted %	Weighted N	Unweighted N	Unweighted %	Unweighted N	Weighted %	Weighted N	Unweighted N	Weighted %	Weighted N	Unweighted N
Age											
15-19	22.3	1082	1105	23.4	560071	21.7	2867	2914	20.4	2392	2407
20-24	19.5	944	990	22.7	543922	22.4	2957	2998	24.5	2870	2824
25-29	16.0	777	804	16.7	398552	18.2	2401	2358	18.4	2157	2136
30-34	13.5	656	664	12.5	298161	11.8	1566	1574	12.6	1478	1492
35-39	11.1	537	517	10.3	245784	10.8	1424	1410	9.5	1117	1129
40-44	10.5	510	458	7.5	180542	8.0	1053	1052	8.0	935	940
45-49	7.5	343	311	7.0	166498	7.2	951	914	6.4	749	770
Education											
None	47.2	2287	1834	37.6	899121	27.0	3574	3372	23.4	2734	2823
Primary	48.5	2349	2622	53.0	1268470	61.8	8177	8219	61.1	7152	7189
Secondary+	4.4	212	382	9.4	225939	11.1	1468	1629	15.5	1811	1685
Region											
Northern	11.9	578	1442	12.4	294362	11.0	1453	2187	13.3	1552	1597
Central	38.6	1872	1606	40.9	947939	40.3	5321	4508	40.5	4734	4199
Southern	49.5	2398	1801	46.6	1151229	48.8	6446	6525	46.3	5412	5902
Residence				15.3							
Urban	12.3	594	1316	84.7	365906	15.9	2106	2871	17.8	2076	1640
Rural	87.7	4255	3533		2027624	84.1	11114	10349	82.2	9621	10058
All women	100	4849	4849	100	2393530	100	13220	13220	100	11698	11698
TFR (15-49)[3]			6.73		6.52			6.30			6.00

[2] The Malawian 1998 census data used are the un-weighted figures for the entire population. There is no information on under-coverage or over-coverage of the census since no post-enumeration survey was done to measure these.

[3] TFR defined in the same way done in Table 3.2.

3.4.3.2. Education of Malawian women aged 15-49

Educational attainment of Malawian women seems to be improving over time. The 1992 DHS had the highest level of women who have had no schooling. The percentage is consistently declining with time. The 2004 DHS has relatively more educated women than the other surveys (Table 3.5)

3.4.3.3. Average parities of Malawian women aged 15-49

Average parities of Malawian women increase with age of the mother in all the three surveys under consideration and also for the 1998 census (Figure 3.4)

Though one can not conclusively say there is no omission of children ever born with increasing age based only on the fact that the average parities are increasing with age, it seems the omissions if there are any do not significantly distort the expected trend relating parities to the age of the women under consideration. The average parities from the 1992 DHS are higher than those of the later surveys and the 1998 census this seems to support the fact that fertility in Malawi is declining (Mijoni, 2005).

Figure 3.4 Average parities of Malawian women (15-49), various data sources

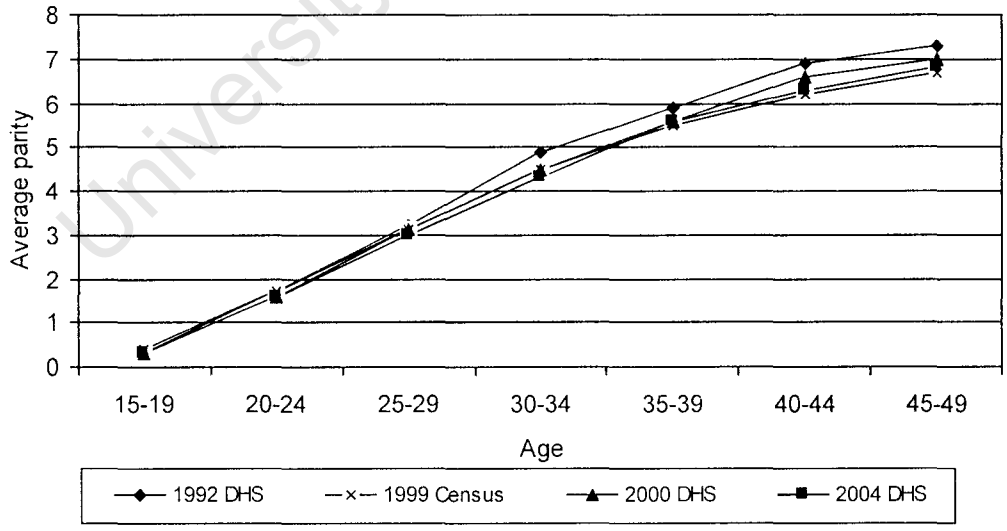


Figure 3.4 shows the relationship between the average parities of women and their educational attainment as suggested by the data collected in the three DHS surveys and the 1998 census. Generally there is a decrease in number of children ever born (average parities) as the educational attainment of the mother increases.

The pattern shown by the 15-19 age group is again different from that of the older age groups due to the small numbers involved especially at post secondary education levels, since not many female teenage mothers in Malawi have higher than secondary education and schooling only finishes at 18.

Further evidence of the problematic nature of the 1992 DHS data is shown by the odd distribution of average parities of the women aged 40-44 interviewed in this survey, this is largely due to very small sample sizes involved in these older age groups.

As was the case for Kenya, one cannot rely on the parities of the 45-49 women with higher than secondary education since the number in that category of women is very small.

Table 3.6 Average parities by education level of Malawian women (15-49), various sources

Age group	No school	Primary	Secondary +	No school	primary	Secondary +
	1992 DHS			1998 Census		
15-19	0.5	0.3	0.2	0.7	0.3	0.2
20-24	1.9	1.7	0.5	2.0	1.7	0.8
25-29	3.3	3.3	2.1	3.4	3.1	1.8
30-34	5.0	4.8	3.6	4.7	4.5	3.0
35-39	5.8	6.2	4.7	5.6	5.6	4.1
40-44	6.9	6.9	8.1	6.3	6.4	5.1
45-49	7.4	7.2	6.1	6.6	6.8	5.7
	2000 DHS			2004 DHS		
15-19	0.7	0.3	0.2	0.6	0.3	0.1
20-24	2.0	1.7	0.7	2.1	1.8	0.9
25-29	3.3	3.2	1.8	3.4	3.1	1.9
30-34	4.8	4.5	2.7	4.8	4.3	2.6
35-39	5.7	5.6	3.9	5.0	4.6	3.8
40-44	6.8	6.7	4.7	6.5	6.4	4.3
45-49	7.0	7.1	5.5	6.9	6.9	5.1

3.4.3.4. Sex ratios of children ever born by Malawian women aged 15-49

Sex ratios of children ever born are shown in Table 3.7 below. The sex ratios from the three DHS surveys presented in this table are on average below 103, this agrees, using the same reasoning used for Kenyan ratios earlier, with the conclusion drawn by Garenne (2004) that sex ratios at birth are below the value of 103 usually used for sub Saharan Africa. The sex ratios from the 1998 Malawian census are however too low, the

ratios are all below 100 and decrease with increasing age of mothers showing underreporting of male children ever born in the 1998 census. The degree of omission is increases with age of the mother.

Table 3.7 Sex ratios of children ever born to Malawian women age 15-49

Age group	1992 DHS	1998 census	2000 DHS	2004 DHS
15-19	98.3	99.4	104.6	95.7
20-24	103.4	99.2	101.8	102.6
25-29	103.4	98.4	101.3	101.4
30-34	103.1	97.9	102.5	102.8
35-39	97.5	96.8	101.4	102.0
40-44	98.6	96.3	102.8	101.8
45-49	104.9	95.4	101.7	103.5
Overall	101.3	97.4	102.3	101.4

3.5. Conclusion

The data appraisal done above has revealed that there are some inconsistencies in the data. The inconsistencies include differences in age distributions of the women in the reproductive age and transference of dates of births in the Malawi 2004 DHS mainly for deceased children.

The transference of dates of births in the Malawian data leads to underestimation of both IMR and U5MR in the five-year period leading to the survey.

The identified errors do not nullify use of these data for childhood mortality estimation; consideration of the effect of these errors will however be made in interpreting the results obtained from the analyses of these data.

4. Comparison of childhood mortality trends

4.1. Introduction

This chapter outlines the method used to compare the trends of childhood mortality estimates from the direct and the indirect methods. It also presents the results obtained. Section 4.2 gives the methods used to derive the direct and indirect estimates and the resulting childhood mortality rates. Then section 4.3 compares the trends. The last section (4.4) gives the conclusion.

4.2. Trends of direct and indirect estimates of childhood mortality

4.2.1. Direct childhood mortality estimates

An SPSS program used to derive childhood mortality rates presented in the DHS reports (Measure DHS Program, n.d.-a) was converted into a STATA 9.2 program. The STATA code (an illustration is provided in section 3A of the Appendix) was then shown to produce the same estimates as those presented in the DHS reports for all the DHS used at in this study. Table 4.1 and Table 4.2 provide the estimates as reported in the DHS reports and those from the STATA code used for the current study. The estimates derived from the STATA code are labelled as *calculated* while those from the DHS reports are given as *reported*. The columns labelled *Time* refer to the mid-points of the five-year periods before the survey to which the estimates pertain.

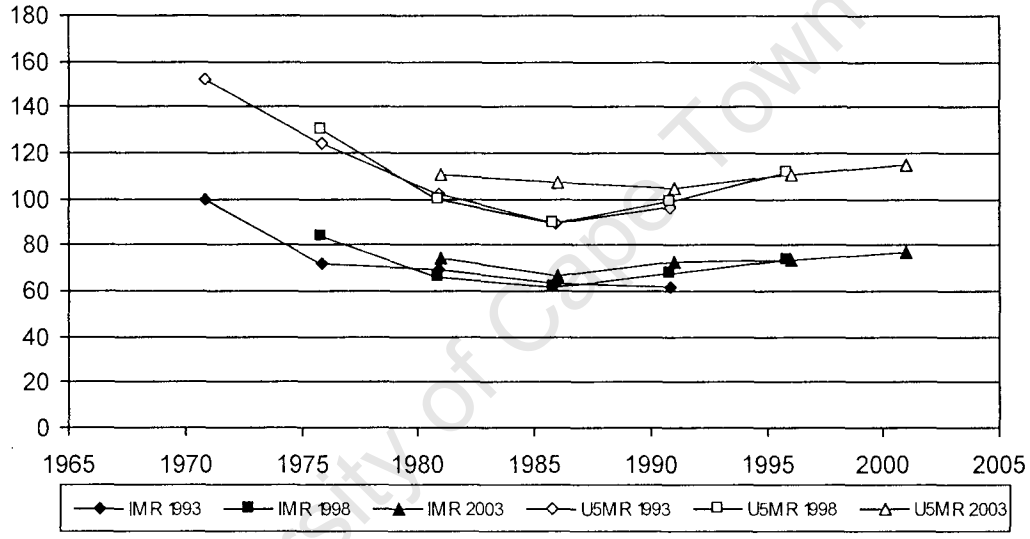
4.2.1.1. Derivation of the years to which direct estimates of childhood mortality refer

IMR and U5MR in DHS reports are provided by five year periods preceding the survey. These intervals could not be used in comparing childhood mortality trends from the direct and the indirect methods since the indirect estimates were tabulated by specific years. Instead of the five-year intervals, the mid-points of these intervals were used.

4.2.2. Kenya

The Kenya direct estimates of IMR were estimated for the period from 1970 to 2001. The resulting childhood mortality trends are shown in Figure 4.1 below. According to the DHS results, the IMR declined from around 100 deaths per thousand live births to about 60 deaths per 1000 live births in the period from 1970 to 1986. It then increased to a little less than 80 deaths per thousand live births by the time the 2003 DHS was done.

Figure 4.1 IMR and U5MR trends in Kenya from the direct method



Generally, the 1993 and 1998 Kenyan DHSes in Table 4.1 give highly consistent estimates for overlapping time periods besides the slight disagreement in their 1976 and 1991 estimates (Figure 4.1). However, the 2003 DHS has higher estimates for most of the overlapping period.

U5MR declined from around 160 deaths per 1000 live births in 1970 to less than 100 per 1000 live births in 1986. It then increased to almost 120 deaths per 1000 live births by the time of the 2003 DHS. As with the IMR, the 2003 data gives higher U5MR than the 1993 and the 1998 DHS data in the overlapping period. Childhood mortality estimates comparable to the 1993 and 1998 estimates were derived using 2003 data by excluding from the 2003 sample, areas that were not included in the earlier two surveys. The estimates obtained were identical to those obtained using all the 2003 data (Kenya DHS 2003). This suggests that the higher mortality estimates from the 2003 DHS in the overlapping are not due to different sampling frames but to other reasons.

Table 4.1 Direct childhood mortality estimates for Kenya

1993 DHS					1998 DHS					2003 DHS				
Time	IMR		U5MR		Time	IMR		U5MR		Time	IMR		U5MR	
	Reported	calculated	Reported	calculated		Reported	calculated	Reported	calculated		Reported	calculated	Reported	calculated
1970.9	-	99.9	-	152.4	1975.9	-	83.9	-	129.8	1981	-	74.6	-	111.0
1975.9	-	71.6	-	124.4	1980.9	-	66.3	-	99.6	1986	-	66.7	-	107.5
1980.9	68.9	68.9	101.8	101.8	1985.9	61.9	61.9	89.6	89.6	1991	73.0	72.6	105	105.0
1985.9	63.4	63.4	89.7	89.7	1990.9	67.7	67.7	98.9	98.9	1996	73.0	73.4	110.0	110.4
1990.9	61.7	61.7	96.1	96.1	1995.9	73.7	73.7	111.5	111.5	2001	77.0	77.2	115.0	114.6

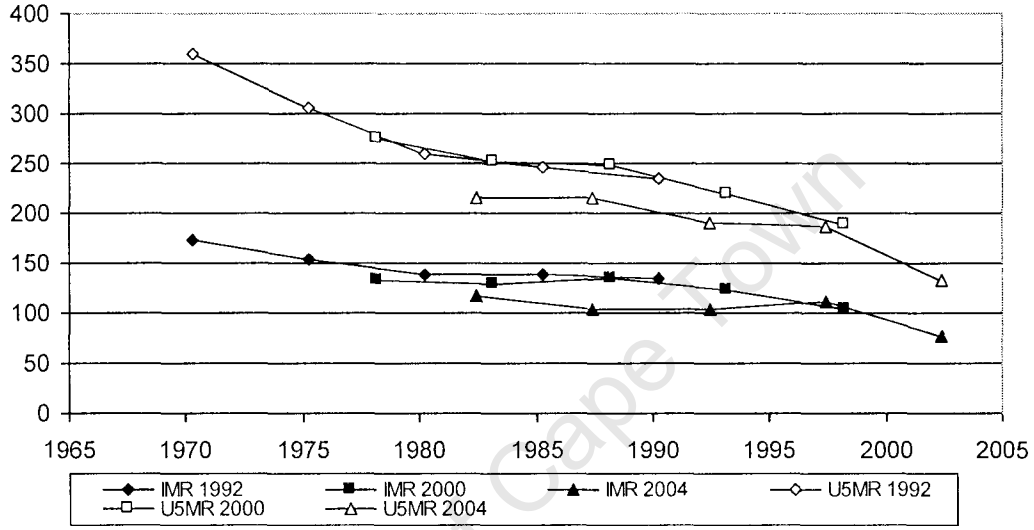
Table 4.2 Direct childhood mortality estimates for Malawi

1992 DHS					2000 DHS					2004 DHS				
Time	IMR		U5MR		Time	IMR		U5MR		Time	IMR		U5MR	
	Reported	calculated	Reported	calculated		Reported	calculated	Reported	calculated		Reported	calculated	Reported	calculated
1970.3	-	172.9	-	358.9	1978.2	-	133.0	-	276.0	1982.4		117.3	-	215.3
1975.3	-	153.1	-	306.0	1983.2	-	129.4	-	251.8	1987.4		104.4	-	214.6
1980.3	136.4	137.9	258.0	259.3	1988.2	135.5	135.5	247.4	247.4	1992.4	104.0	103.9	190.0	189.7
1985.3	137.5	137.9	246.3	246.6	1993.2	122.7	122.7	219.7	219.6	1997.4	112.0	112.5	187.0	186.8
1990.3	134.3	134.6	233.8	233.8	1998.2	103.8	103.8	188.6	188.6	2002.4	76.0	76.1	133.0	133.3

4.2.3. Malawi

The IMR and U5MR for Malawi estimated pertain to the period from 1970 to 2002. The results obtained are presented in Table 4.2 above. Figure 4.2 shows the childhood mortality trends constructed from these estimates.

Figure 4.2 IMR and U5MR trends in Malawi from the direct method



The IMR declined from 173 deaths per 1000 live births in 1970 to about 135 deaths per 1000 live births in the early 1980s. It plateaued at around 135 deaths per 1000 live births until around 1991. It then declined to about 76 deaths per 1000 live births in the five years leading to the 2004 DHS.

The U5MR declined from 359 deaths per 1000 live births in 1972 to around 251 per 1000 live births in 1983. It then slowed the pace of decline for the 10-year period from 1980 to around 1990 declining by about 27 deaths per 1000 live births over the 10 years. Finally it declined at a faster pace from the early 1990s to around 133 deaths per 1000 live births at the time of the 2004 DHS.

The 1992 and the 2000 DHS estimates are in close agreement in the period where they overlap (late 1970s to around 1991) for both IMR and U5MR. However the 2004 DHS gave lower estimates in this overlapping period (early 1980s to late 1990s). The data problems highlighted in Chapter 3 of this project are associated with the latest ten-year period before the survey. Surprisingly, the last two estimates expected to be problematic are actually in agreement with those from the earlier surveys (1992 and 2000 DHS) assuming that the latest 2000 U5MR is correct and that the downward trend continued beyond 2000.

The lower estimates in the periods earlier than ten years before the 2004 DHS could be due to omission of children who did not survive to the time of the 2004 DHS.

Mortality levels are higher in Malawi than in Kenya. U5MR experienced in Kenya over the period from the early 1970s to the time of the 2003 DHS are at roughly similar levels with the IMR in Malawi over the same period.

In Kenya the average difference between U5MR and the IMR has remained generally constant over the period under review while in Malawi this difference has been narrowing over time.

4.2.4. Indirect childhood mortality

For each of the datasets used, numbers of children ever born and children surviving (at the time of the survey or census) were tabulated by five-year age groups of mothers. The numbers of women in each of the five year age groups in the reproductive age range (15-49) were also tabulated.

The Trussell version of the Brass children ever born, children surviving method described in section 2.4.2.1 was applied to the tabulated numbers of children ever born and children surviving.

The North family in the Princeton model life table system was used for both Kenya and Malawi. It was decided, on the basis of previous studies, that the North family was the most suitable model life table for Kenya (Population Division United Nations Secretariat, 1990) and Malawi (Malawi National Statistical Office, 2002). The West family, which is recommended when there is no other information on the appropriate model life table family to use, was tried (results not shown). It gave no clear advantage over the North family in both countries, if anything, it gave more volatile trends.

The results obtained from the application of the Trussell variant of the Brass children ever born children surviving technique are given below in
Table 4.3 and Table 4.4.

4.2.5. Kenya

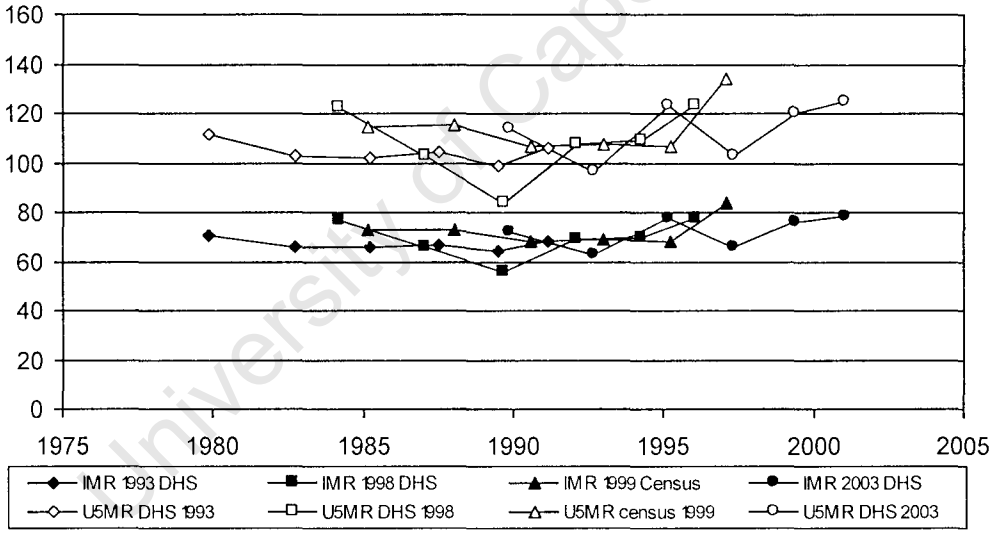
The Kenya childhood mortality trends from indirect estimates are for the period from 1979 to 2001. The trends constructed from these indirect estimates are shown in Figure 4.3 below.

Table 4.3 Indirect childhood mortality estimates for Kenya

1993 DHS			1998 DHS			1999 Census			2003 DHS		
Time	IMR	U5MR	Time	IMR	U5MR	Time	IMR	U5MR	Time	IMR	U5MR
1979.9	70.9	111.1	1984.2	77.0	122.0	1985.1	72.9	114.6	1989.8	72.5	113.9
1982.7	66.2	102.7	1987.1	66.1	102.5	1988.0	73.1	115.0	1992.7	62.5	96.2
1985.2	65.8	102.1	1989.7	55.5	84.0	1990.6	68.3	106.5	1995.1	77.7	123.2
1987.5	66.9	104.0	1992.1	68.7	107.2	1993.0	68.9	107.5	1997.4	66.1	102.6
1989.5	64.0	98.9	1994.3	69.5	108.6	1995.2	68.4	106.7	1999.4	75.7	119.6
1991.2	68.0	106.0	1996.0	77.7	123.3	1997.1	83.7	134.0	2001.1	78.3	124.3

The indirect estimates from the three surveys are erratic towards being constant. The estimates from the 1993 DHS are lower than those from the 1998 DHS and those from the 1999 census in all but the last three estimates. The 1998 DHS and the 2003 DHS indirect IMR estimates are more volatile than those from the 1993 DHS and the 1999 census.

Figure 4.3 IMR and U5MR trends in Kenya from the indirect method



The 1998 DHS and the 1999 census U5MR estimates are higher than those from the 1993 DHS for most of the overlapping period.

Generally, the indirect estimates from the various data sources used are showing a level trend with a lot of noise around the estimates in the period under review.

4.2.6 Malawi

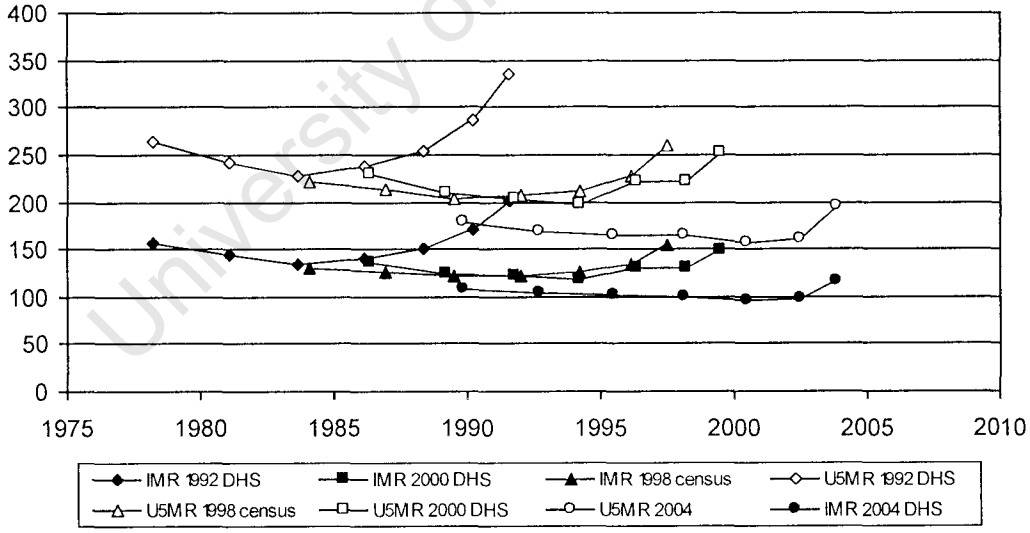
Table 4.4 provides the indirect childhood mortality estimates for Malawi estimated from DHS census data while Figure 4.4 shows the trends of childhood mortality constructed from these estimates.

Table 4.4 Indirect childhood mortality estimates for Malawi

1992 DHS			1998 census			2000 DHS			2004 DHS		
Time	IMR	U5MR	Time	IMR	U5MR	Time	IMR	U5MR	Time	IMR	U5MR
1978.2	155.9	263.2	1984.1	130.8	220.9	1986.4	136.1	230.0	1989.8	107.6	178.3
1981.0	143.6	242.6	1986.9	126.2	213.0	1989.2	123.9	208.7	1992.7	102.6	168.7
1983.7	135.0	228.2	1989.5	121.3	204.0	1991.8	121.3	203.9	1995.5	100.7	165.3
1986.1	140.0	236.7	1992.0	122.5	206.2	1994.2	117.0	196.0	1998.1	100.1	164.2
1988.3	150.1	253.5	1994.2	125.5	211.8	1996.4	130.8	221.0	2000.5	95.7	156.0
1990.2	169.6	285.8	1996.1	134.5	227.3	1998.2	130.9	221.1	2002.5	98.0	160.2

Generally there is a downward trend in the estimates of childhood mortality over time. However, there are some notable discrepancies in some of the estimates. The estimates from the 1992 DHS data increased from around 1984 until the early 1990s. This upturn is not in agreement with the trend shown by the 1998 census data and the 2000 DHS in the same period of time. These latter two datasets give a declining trend in this period of overlap and are in remarkable agreement. On the other hand, the 2004 estimates are lower than those from the 1998 census and the 2000 DHS in the period where the estimates overlap. This same problem was noted in the direct estimates. This suggests problems with the 2004 DHS dataset.

Figure 4.4 IMR and U5MR trends in Malawi from the indirect method



The indirect estimates for Malawi have inconsistencies that leave one without a clear picture of their trend over time. The 2004 DHS does not agree with the earlier surveys and the census. It gave lower estimates than those from the earlier surveys in the overlapping period.

4.3. Comparison of trends from the direct and the indirect methods

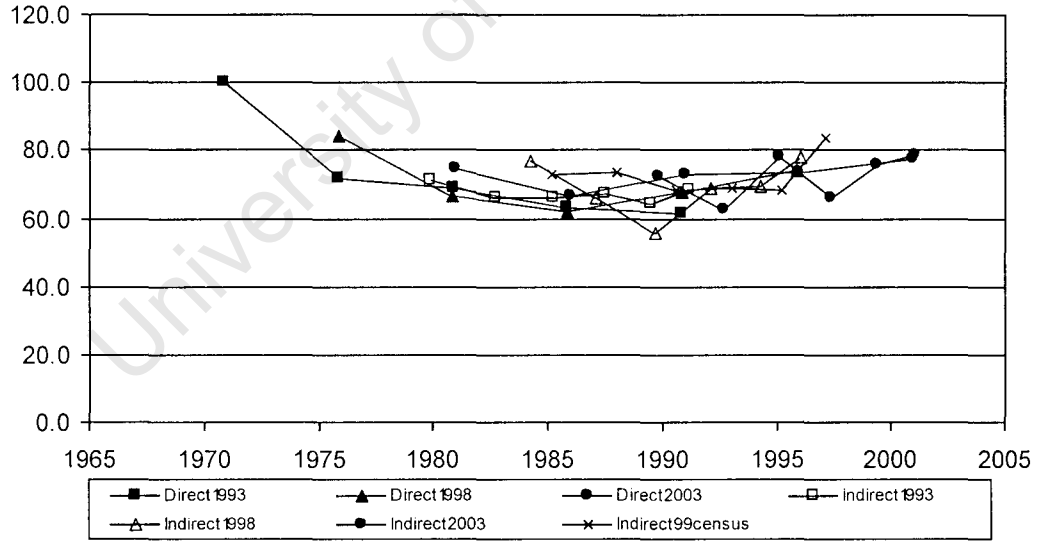
X-Y plots of the IMR and U5MR for each of the four childhood mortality rate-country combinations (IMR Kenya, IMR Malawi, U5MR Kenya and U5MR Malawi) were done. In each of these four combinations, the same pair of axes was used to plot the trends of childhood mortality from direct and indirect estimates. Comparison was then done to check whether the trends from the two methods were consistent.

4.3.1. Consistency of IMR trends

4.3.1.1. Kenya

The estimates from the direct and the indirect methods do not generally agree in both levels and trends. Figure 4.5 shows the Kenya IMRs from the direct and the indirect methods. The indirect estimates are more volatile than the direct ones.

Figure 4.5 Direct and indirect estimates of infant mortality for Kenya

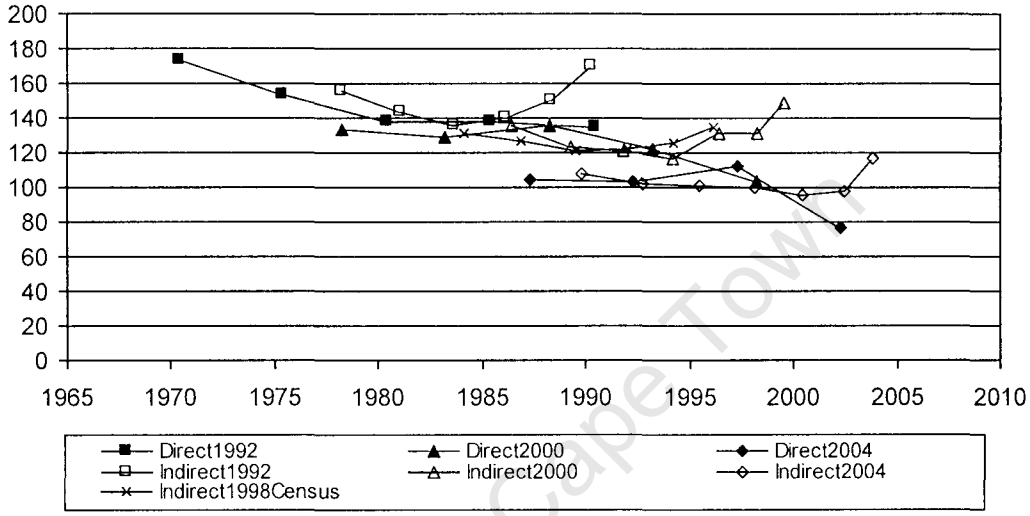


4.3.1.2. Malawi

Malawian data gave estimates which generally showed different trends from the direct and the indirect methods. As was observed for Kenya, there is also higher stability and a better defined pattern in the trends from the direct estimates of IMR as compared to the trend from the indirect estimates. The indirect method gave abnormally high estimates in later period of estimation (periods of around 10 – 15 years before the dates

of the surveys). Though the estimates from the youngest age group of women (15 – 19) are usually abnormally high due to artefacts in the data (Brass and Coale, 1968), it is questionable to have abnormally high estimates from as early as around 15 years before the survey date.

Figure 4.6 Direct and indirect estimates of infant mortality for Malawi

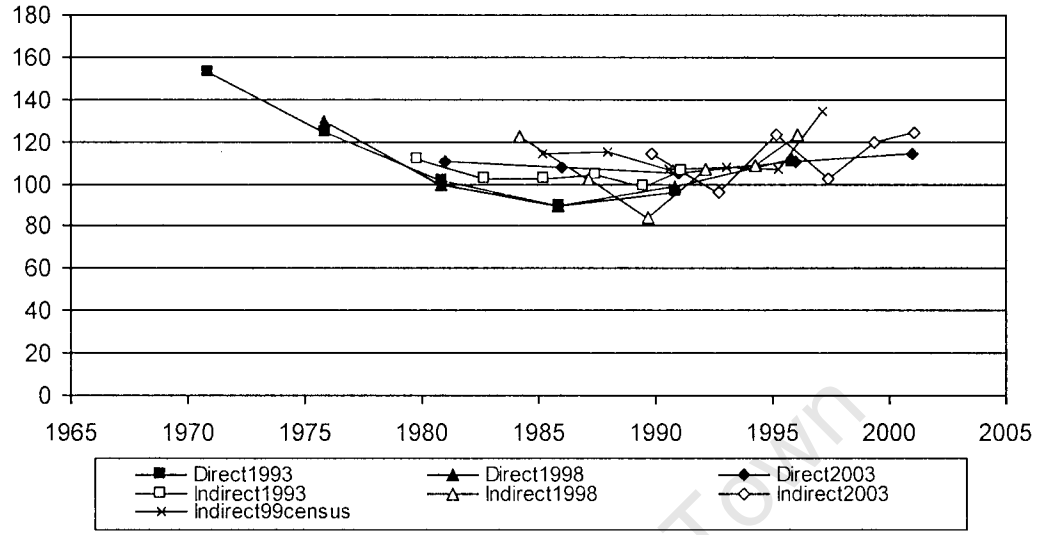


4.3.2. Consistency of U5MR trends

4.3.2.1. Kenya

As was observed for the IMR, the trend of U5MR from the direct method is better defined than that from the indirect method (Figure 4.7). There is again more volatility in the indirect than the direct estimates. Levels of U5MR from the direct method were also different from those from the indirect method. The noise around the indirect estimates makes it impossible to infer much about consistency of the trends.

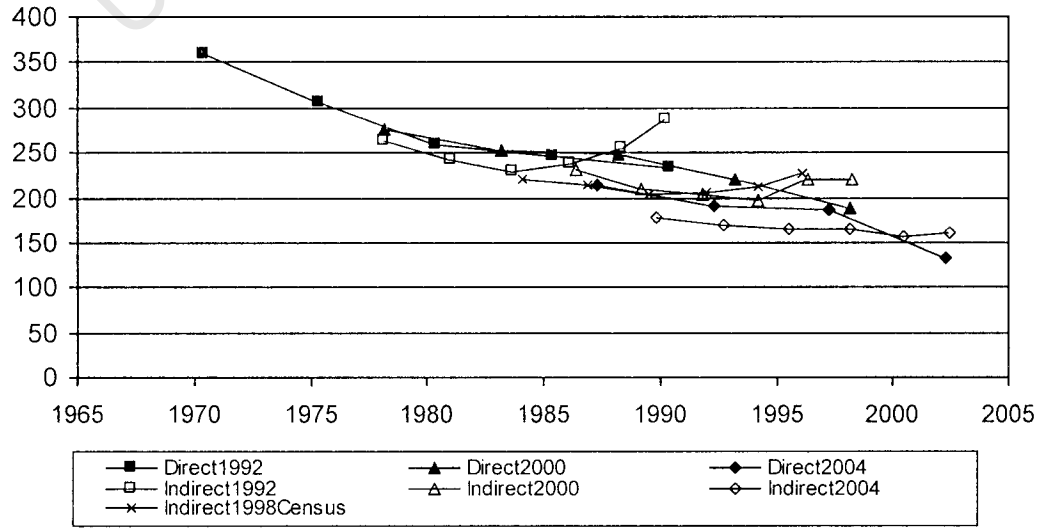
Figure 4.7 Direct and indirect U5MR estimates for Kenya



4.3.2.2. Malawi

The U5MR results for Malawi in Figure 4.8 also show that the trends constructed from the direct and the indirect estimates are not in agreement. It is interesting however to note that the indirect estimates in the period overlapping with the direct 2004 DHS agree with the estimates derived from the direct method for the period ten years or more earlier than the DHS. For the period from the late 1970s till the late 1990s, the indirect estimates were lower than the direct estimates.

Figure 4.8 Direct and indirect U5MR estimates for Malawi



4.4. Conclusion

The trend analysis done in this chapter has revealed various interesting features of childhood mortality and its measurement in Kenya and Malawi. The main findings are on how the two countries' mortality situations compare, on the levels from the direct and the indirect estimates and on the trends from the two methods.

Both the direct and the indirect estimates have shown that childhood mortality is much higher in Malawi than it is in Kenya. Despite the fact that (according to the direct estimates) childhood mortality in Kenya was worsening since the mid-1980s while it has been continuously declining in Malawi, Malawian childhood mortality remained above Kenyan childhood mortality throughout the period of investigation.

The results have also shown that the direct and the indirect estimates are generally at different levels during overlapping periods. The differences in the levels are however not consistent for the two countries. While Kenyan indirect estimates are generally above the direct estimates in the period before 1990 and then they fluctuate above and below the direct estimates after 1990, the Malawian indirect estimates are generally below the direct ones.

Finally, the trend analysis has shown that the direct and the indirect childhood mortality estimates for the period from the 1970s to the early 2000s in Malawi and Kenya generally give inconsistent trends. In the case of Kenya, while the direct estimates declined and then increased over time, the indirect estimates generally gave a roughly level trend with a lot of fluctuations. The trend constructed from the direct Malawian childhood mortality estimates is generally declining, while the indirect estimates gave an initially declining then increasing trend over time ignoring the estimates from the 2004 Malawian DHS, which gave lower estimates than those from the earlier surveys in the overlapping period.

Though in both Kenya and Malawi the estimates from the direct method have not given entirely consistent trends from the various data sources - the latest surveys in both countries gave trends inconsistent with the earlier surveys - the trends from the direct method are generally better defined than those from the indirect method.

5. HIV population attributable fraction (PAF)

5.1. Introduction

This chapter describes the method used to quantify the impact of HIV/AIDS on childhood mortality (HIV PAF). It also presents the results obtained from the application of the method to Kenyan and Malawian data. The formula used for the HIV PAF estimation in the current study is the same as the one that was used in the Zaba method (Equation 2-1). The difference between the two methods (the current methodology and the method used by Zaba and colleagues) is in the overall mortality and the mortality of uninfected children used in the formula. Zaba measured both the direct and the indirect effects of HIV/ AIDS on childhood mortality while this study only measures the direct effect. Section 5.2 considers the overall childhood mortality estimates used in the current study. Section 5.3 presents the estimates of mortality of the uninfected children. Section 5.4 presents the estimates of HIV PAF. Finally, section 5.5 gives the conclusion.

5.2. Overall childhood mortality

The overall childhood mortality estimates used in this study were obtained as follows: First, direct childhood mortality estimates from the Kenya 2003 and the Malawi 2004 DHS were confirmed as described before in sub-section 4.2.1. Second, the confirmed estimates were adjusted for bias due to HIV/ AIDS (1 per cent and 5 per cent respectively for IMR and U5MR) as suggested by Zaba, Marston and Floyd (2003). Third, an alternative set of overall childhood mortality estimates was derived by adding expected direct childhood AIDS deaths to non-AIDS deaths (mortality of the children of HIV negative mothers). Fourth, an average of the two estimates was obtained and was used as the overall childhood mortality. The overall childhood mortality estimates are tabulated in Table 5.1 below.

IMR from all causes (overall IMR) for Kenya in 2003 was slightly higher (81 per 1000) than the IMR from all causes in Malawi in 2004 (80 per 1000). The overall U5MR for Kenya (126 per 1000) was however lower than that for Malawi (140 per 1000) with the result that the contribution of child mortality to U5MR in Malawi was higher than in Kenya.

5.3. Mortality of uninfected children

5.3.1. Mortality of the children of the HIV uninfected mothers

DHS HIV testing results are stored separately from the normal DHS data on other variables. Therefore, the traditional DHS data had to be merged with the HIV results. The resulting file was spit on the basis of the HIV statuses of the women aged 15 - 49 involved. Birth histories of the HIV negative women were then analysed using the synthetic cohort approach illustrated in section 3A of the Appendix. The resulting childhood mortality of the children of HIV negative mothers 15 - 49 are presented in Table 5.1 below.

Table 5.1 overall childhood mortality and the mortality of the children of uninfected mothers

	Kenya (1999 – 2003)		**Malawi (2000 – 2004)**	
	Infant mortality rate	Under-five mortality rate	Infant mortality rate	Under-five mortality rate
Overall mortality	81.0	126.1	80.0	140.1
Children of HIV-negative mothers	76.1	105.5	73.7	111.5

The mortality of the children of uninfected mothers is lower than the childhood mortality from all causes.

5.3.2. Mortality of the HIV free children of HIV-positive mothers (HIV - exposed children)

Unlike the mortality of the children of the uninfected mothers, the mortality of the HIV uninfected children born to HIV positive mothers (HIV-exposed children) is not readily derivable from the DHS based birth histories of infected mothers. This is the case because the HIV infected mothers' times of infection are unknown, which in turn makes it difficult to know which children were born before their mothers got infected and which ones were born after.

On the other hand, use of the mortality of the children of the uninfected mothers only is also inadequate to represent the mortality of all uninfected children when measuring direct impacts of HIV/ AIDS for reasons mentioned before (section 2.7.2). Thus, the mortality of the HIV-exposed children has to be accounted for in the estimation of the mortality of all the uninfected children. This was done using the ratios of the mortality of the HIV-exposed children to the mortality of the children of the

uninfected mothers from other studies. The next sub-section describes how these mortality ratios were obtained and used

5.3.2.1. Mortality ratios comparing mortality of HIV-exposed children to mortality of children of uninfected mothers

The mortality of the HIV-exposed children was estimated using a method devised by Marston, Zaba, Salomon *et al* (2005). Marston and colleagues did a literature search for the ratios of the mortality of HIV-exposed children compared to the mortality of the children of the uninfected mothers. They then used the obtained mortality ratios to estimate the mortality of the children of uninfected mothers from the mortality of HIV-exposed children in situations when they only had mortality of HIV-exposed children.

A literature review of African studies which involved maternal and child HIV testing and child survival was done to identify studies other than those used by Marston and colleagues to derive the mortality ratios. Mortality ratios that were not included in the study by Marston, Zaba, Salomon *et al* (2005) were compared with those included in that study and the comparison led to the decision to use the same mortality ratios as those used by Marston and colleagues.

Five studies were identified in peer reviewed journals which estimated the mortality of the children of uninfected mothers and the mortality of the HIV-exposed children separately. The childhood mortality rates from these five studies are given in Table 5.2 below.

Table 5.2 Mortality of HIV-exposed children and children of HIV negative mothers from African longitudinal studies

Reference	Study type	Country	Sample (Children)	Age at mortality estimation	HIV – children Born to HIV+ mothers (per 1000)	HIV- born to HIV- mothers (Per 1000)	Mortality ratio
1	Intervention	Zimbabwe	13792	12 months	74.0	19.0	3.9
				24 months	92.0	29.0	3.2
2	observational	Uganda	4604	12 months	98.7	91.0	1.1
				18 months	130.5	112.8	1.2
				24 months	165.5	128.0	1.3
3	cohort	Rwanda	401	60 months	40.0	40.0	1.0
4	observational	Malawi	702	12- 36months	46.0	36.0	1.3
5	observational	Uganda	520	12-18months	28.0	16.0	1.8

1 - (Marinda, Humphrey, Iliff *et al.*, 2007), 2 - (Brahmbhatt, Kigozi, Wabwire-Mangen *et al.*, 2006),

3 - (Spira, Lepage, Msellati *et al.*, 1999), 4 - (Taha, Kumwenda, Broadhead *et al.*, 1999), 5 - (Berhane, Begenda, Marum *et al.*, 1997)

As mentioned by Marston, Zaba, Salomon *et al* (2005), the two Ugandan studies in Table 5.2 above show similar patterns in the mortality ratios comparing childhood mortality of the two groups of uninfected children.

The Rwandan and Malawian studies found no significant difference in the survival chances of the two groups of uninfected children. A Zimbabwean study (Table 5.1) gave a mortality ratio of the order 3.2 for ages $x < 1$; this ratio produces very high mortality of uninfected children thus leading to implausible values of HIV PAF. However the mortality ratio for the ages x between 1 and 2 years in the Zimbabwean study is 1.8, which is similar to the one obtained in the Ugandan studies which were used to estimate the mortality ratios by Marston, Zaba, Salomon *et al* (2005)

The final set of Mortality ratios chosen for use in this project are those used by Marston and colleagues provided in Table 5.3 below.

Table 5.3 Mortality ratios comparing mortality of the two groups of uninfected children

Age x *(in years)*	$x \leq 1$	$1<x<2$	$x>2$
Mortality ratio $C(x)$	1.1	1.8	1.8

U5MR for HIV-exposed children

The U5MR of HIV-exposed children was derived from the corresponding IMR and child mortality rate. First the IMR and the CMR[4] for the HIV-exposed children were obtained by multiplying the IMR and the CMR of the children of uninfected mothers by the appropriate ratios from Table 5.3. The U5MR for the HIV-exposed children was then obtained directly from their IMR and CMR. The resulting mortality rates are given in Table 5.4.

The results in Table 5.4 show that the IMR of the HIV-exposed children is 1.1 times higher than that of the children of the uninfected mothers and the U5MR of the HIV-exposed children is 1.2 times higher than that of the children of the uninfected mothers.

[4] See section 1.A in the Appendix for the definition of child mortality.

Table 5.4 Mortality ratios and childhood mortality of HIV-exposed children

Kenya	IMR (per 1000)	CMR (per 1000)	U5MR (per 1000)
Children of uninfected mothers	76.0	32.0	105.0
Mortality ratios (C(x))	1.1	1.8	
HIV-exposed children	83.6	57.6	136.4
Malawi	**IMR (per 1000)**	**CMR (per 1000)**	**U5MR (per 1000)**
Children of uninfected mothers	73.7	40.8	111.5
Mortality ratios (C(x))	1.1	1.8	
HIV-exposed children	81.1	73.4	148.5

5.3.3. Proportional contributions of the two groups of uninfected children to the mortality of all the uninfected children

To calculate the mortality of all uninfected children, contributions made by each of the two groups of uninfected children had to be determined. These contributions were estimated using an assumed vertical transmission rate and estimates of HIV prevalence among women giving birth in the five-year periods under consideration (1999-2003 for Kenya and 2000-2004 for Malawi).

The vertical transmission rate (v) assumed is 35 per cent. This same rate was also used by Zaba, Marston and Floyd (2003). 35 per cent is the mid-point of the range of vertical transmission rates (25-45 per cent) prevailing in populations where there is no intervention to reduce mother to child transmission of HIV and breastfeeding is universal. These were the conditions in Kenya and Malawi in the periods 1999 to 2003 and 2000 to 2004 respectively. Prevention of mother to child transmission (PMTCT) of HIV interventions were just beginning to be rolled out so their impact on vertical transmission had not yet been felt in that period (Kabudula, 2007; National AIDS Control Council and Office of the President Kenya, 2008).

The HIV prevalence of women aged 15-49 giving birth in the five-year periods leading to the Kenya 2003 and Malawi 2004 DHS surveys (p) was estimated using DHS-based HIV prevalence of women giving birth in the year leading to the DHS of interest and annual ANC-based HIV prevalence rates for the five year periods of interest.

Since the prevalence rates required in this study are for women aged 15-49 giving birth, national DHS-based age-specific HIV prevalence rates for women aged 15-49 were adjusted to represent women giving birth. This was done by weighting the

national age-specific prevalence rates by the numbers of women of corresponding ages giving birth in the year leading to the DHS involving HIV testing. The numbers of women giving birth in the respective one-year periods leading to the Kenya 2003 and Malawi 2004 DHS and the national age-specific HIV prevalence among women aged 15-49 from the two DHS surveys are presented in Table 5.5 below. Generally, the age-specific-prevalence rates from the Malawi 2004 DHS are higher than those from the Kenya 2003 DHS.

The HIV prevalence rates among women aged 15-49 giving birth estimated using the weighted age specific national HIV prevalence rates are 9.8 per cent and 13.7 per cent for Kenya (2003) and Malawi (2004) respectively.

The DHS-based prevalence rates have reliable levels (Grarcia-Calleja, Marum, Carcamo *et al.*, 2005) but they are inadequate for the estimation of prevalence in the five years leading to the DHS involving HIV testing. This is true for both Kenya and Malawi since there have been only one DHS that involved HIV testing in each of the two countries.

Table 5.5 Numbers of women giving birth and the DHS age-specific prevalence rates

Age group	Number of women giving birth in the year preceding the DHS		Age specific HIV prevalence of women (15-49) from the DHS	
	Kenya (2003)	Malawi (2004)	Kenya (2003)	Malawi (2004)
15-19	196	333	3.0	3.7
20-24	453	954	9.0	13.2
25-29	344	626	12.9	15.5
30-34	237	349	11.7	18.1
35-39	128	215	11.8	17.0
40-44	46	85	9.5	17.9
45-49	4	24	3.9	13.3
Total	1407	2589	8.7	13.3

It was considered implausible to assume that HIV prevalence among women aged 15-49 giving birth in the year leading to the DHS of interest were also applicable to the five years leading to the same DHS. This is especially true for Kenya since the HIV prevalence in the female population of reproductive age has been declining in Kenya (Cheluget, Baltazar, Orege *et al.*, 2006; The National AIDS Control Council and The National AIDS and STD Control Programme, 2007).

The available HIV prevalence rates from sentinel surveillance sites are not nationally representative in terms of their levels (The Joint United Nations Programme on HIV/AIDS (UNAIDS) and WHO Working Group on Global HIV/AIDS and STI Surveillance, 2000; Grarcia-Calleja, Marum, Carcamo *et al.*, 2005). However, these sentinel surveillance estimates give reliable trends over time (Central Bureau of Statistics (CBS) [Kenya], Ministry of Health (MOH) [Kenya] and ORC Macro, 2004).

Annual HIV prevalence rates from sentinel surveillance sites for the five-year periods leading to the 2003 Kenyan and 2004 Malawian DHS surveys are given in Table 5.6 below.

Ratios of the DHS-based prevalence rates for mothers aged 15-49 giving birth in the year leading to the DHS of interest to the sentinel surveillance prevalence rates were estimated for the years of the DHS surveys involving HIV testing (2003 and 2004 for Kenya and Malawi respectively).

Table 5.6 Sentinel surveillance based prevalence rates for Kenyan and Malawian women (15-49)

Year	1999	2000	2001	2002	2003	2004
HIV Prevalence (%)						
Kenyan women 15-49	13	13.4	12.8	10.6	9.4	-
Malawian women 15 - 49	-	16.1	15.9	15.7	15.5	15.4

The ratios of DHS-based prevalence to the sentinel surveillance prevalence are 1.05 for Kenya in 2003 and 0.89 for Malawi in 2004. These ratios were then used to adjust the levels of sentinel surveillance prevalence rates in the five years leading to the DHS which provided HIV prevalence rates. Averages of the adjusted prevalence rates were calculated. These average prevalence rates were then used as the estimates of the HIV prevalence rates among women aged 15-49 giving birth in the five- year periods leading to the Kenya 2003 and Malawi 2004 DHSs. The adjusted prevalence rates and their five year averages are shown in Table 5.7 below.

Table 5.7 Adjusted HIV prevalence rates for Kenyan and Malawian women 15-49

Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**Average**
Adjusted HIV Prevalence (%)							
Kenyan women 15-49	13.6	14.0	13.4	11.1	9.8	-	12.4
Malawian women 15-49	-	14.3	14.1	13.9	13.8	13.7	13.9

The adjusted prevalence rates show declining prevalence in Kenya and a stable prevalence in Malawi among women giving birth in the five year periods leading to the 2003 and 2004 DHS surveys. The levels of HIV prevalence reveal higher prevalence in Malawi compared to Kenya.

5.3.4. Mortality of all uninfected children

Having obtained the HIV prevalence among women aged 15-49 giving birth in the five-year period leading to the DHS survey involving HIV testing (p) and the vertical transmission rate (v), the required contributions were estimated.

The proportion of children born to HIV negative mothers in the population of all children born is $1-p$ and the proportion of HIV-exposed children is $p*(1-v)$.

The proportion of all births that is uninfected is therefore $(1-p) + p*(1-v)$ which can be simplified to $(1-p*v)$.

The contribution of the mortality of the children of the uninfected mothers to the mortality of all the uninfected children is $\frac{1-p}{1-p*v}$ while the contribution of the HIV-exposed children is $\frac{p*(1-v)}{1-p*v}$. The proportions contributed by the mortality of the HIV exposed children and the mortality of the children of the uninfected mothers to the mortality of all the uninfected children are presented in Table 5.8. The proportions show that the mortality of the HIV-exposed children contributed 8.4 per cent and 9.5 per cent to the mortality of all the uninfected children in Kenya and Malawi.

Table 5.8 Contributions to mortality of uninfected children Kenya (1999-2003), Malawi (2000-2004)

Country	*v*	*p*	*Contribution of the children of the uninfected mothers to the mortality of all uninfected children*	*Contribution of the HIV-exposed children to the mortality of all uninfected children*
Kenya	0.350	0.124	0.916	0.084
Malawi	0.350	0.139	0.905	0.095

To get the mortality of all uninfected children ($q_{U}(x)$) from the mortality of the HIV-exposed children ($q_{C\_M+}(x)$) and the mortality of the children of the uninfected mothers ($q_{C\_M\_}(x)$), Equation 5-1 below was used.

$$q_U(x) = \frac{1-p}{1-p*v} * q_{C\_M\_} + \frac{p*(1-v)}{1-p*v} * q_{C\_M+}(x) \qquad \textbf{Equation 5-1}$$

The estimates of the mortality of the uninfected children in Kenya and Malawi for the periods 1999-2003 and 2000-2004 respectively, obtained from application of Equation 5-1, the proportions presented in Table 5.8 and the mortality of the two groups of uninfected children are given in Table 5.9 below.

5.4. Estimation of the proportions of childhood mortality attributable to HIV/AIDS (HIV PAF)

After obtaining the mortality of the uninfected children and overall childhood mortality, the HIV PAF was estimated using the formula in Equation 2-1 above. The results obtained are shown in the last row of Table 5.9

Table 5.9 Mortality of all uninfected children and HIV PAF for Kenya (1999-2003) and Malawi (2000-2004)

	Kenya (1999 – 2003)		Malawi (2000 – 2004)	
	Infant mortality rate	Under-five mortality rate	Infant mortality rate	Under-five mortality rate
HIV-negative children	76.6	108.1	74.4	115.0
HIV PAF	5.3%	14.3%	6.8%	18.0%

The results show slightly higher IMR among HIV-negative children in Kenya compared to the HIV-negative infants in Malawi for the five year periods under review. The U5MR among the uninfected children is however higher in Malawi than in Kenya. This shows that, among the uninfected children, mortality after age one is higher in Malawi than in Kenya. The same observation was made concerning the overall mortality.

The HIV PAF results in Table 5.9 show that 5.3 per cent of IMR in the period 1999-2003 was attributable to HIV/AIDS in Kenya. The percentage of U5MR attributable to HIV/AIDS in the same period and country is 14.3 per cent. The corresponding percentages for Malawi in the period 2000-2004 are 6.8 per cent and 18.0 per cent respectively.

The HIV PAF values show heavier impact of HIV on Malawi than on Kenya for both the IMR and the U5MR in the period of time under review. The times to which the estimated HIV PAFs pertain for Kenya and Malawi are roughly similar.

5.5. Conclusion

In this chapter, childhood mortality HIV PAF has been estimated for Kenya in the period 1999-2003 and 2000-2004 for Malawi. The data used for the estimation are largely from DHSes involving HIV testing among women aged 15 - 49. In addition to the DHS data, sentinel surveillance HIV prevalence rates and results from African longitudinal studies were used.

The method used has accounted for HIV prevalence trends in the five-year periods of interest and the mortality difference between HIV-exposed children and children of uninfected mothers. The results obtained show that generally childhood mortality was higher in Malawi than in Kenya in the period 1999 to 2004. The results also show that the impact of HIV is higher on U5MR than on IMR. In both Kenya and Malawi, the percentage of mortality attributable to HIV/AIDS was lower among infants compared to the percentages among all children less than five. This means that more AIDS attributable deaths are happening in the period from age one to age five than those happening in the first year of life.

6. Discussion and conclusions

6.1. Introduction

The aims of this study were to check the consistency of the childhood mortality trends constructed from direct and indirect methods in high HIV prevalence settings, and to calculate HIV PAF using DHS data and results from African longitudinal studies. This chapter discusses the extent to which the results obtained from the data analysis meet the goals of the study. It also provides the main conclusions drawn from the study. The organization of the chapter is as follows: Section 6.2 considers the results of the comparison of the trends from the direct and the indirect methods. Section 6.3 looks at the estimates of the HIV PAF obtained. Section 6.4 gives the limitations of the study. Finally, section 6.5 gives the conclusions made from the study and recommendations for further studies.

6.2. Childhood mortality trends from the direct and the indirect methods

The comparison of the trends of direct and indirect estimates of childhood mortality suggests that the two methods give different trends. The trends from the direct method are more clearly defined compared to those from the indirect method which have a lot of noise around them.

The levels of childhood mortality from the two methods are different. This observation is in accord with the results from the analysis of levels of infant mortality done by Adetunji (1996). Adetunji mainly used statistical analysis of the levels of infant mortality, while this study uses graphical analysis. The differences in the levels require careful attention when constructing trends of childhood mortality using a mixture of direct and indirect estimates.

The differences in levels of the direct and the indirect estimates are not consistent between the two countries reviewed. While the direct estimates are generally lower than the indirect estimates in the case of Kenya, the direct estimates for Malawi are generally at higher levels than indirect ones. Kenya indirect estimates are also more volatile than the Malawian indirect estimates. It appears that the fluctuations are not due to the inherent properties of the indirect method (since they are absent in the Malawi estimates). The causes of these fluctuations require further investigation.

Though Malawi is showing higher childhood mortality than Kenya, childhood mortality is improving over time in Malawi while it has been increasing in Kenya since the mid 1980s. It is more useful to analyse not only levels of childhood mortality at a point in time but to also consider trends to identify countries which are improving over time and vice versa. The continual decline in the childhood mortality for Malawi most likely has to do with the fact that Malawi is coming off a high base, may have kept declining due to improvement in background mortality not necessarily effecting control of the effect of HIV/AIDS on childhood mortality.

The difference in the levels of infant mortality and under-five mortality is known to narrow as under-five mortality declines (UNICEF, WHO, World Bank *et al.*, 2007). This happens because infant mortality declines at a slower pace then mortality between ages 1 and 5. Malawian direct estimates show this narrowing as childhood mortality is declining. However, the Malawian indirect estimates do not clearly show a narrowing of the gap. Kenya experienced a decline then an increase so the gap between the trend line of under-five mortality and infant mortality is roughly constant over the period under review.

The choices of the model life tables to use with Malawian and Kenyan data were made on the basis of other studies. The North family of the Princeton model life table system was used in the past for Kenya (Population Division United Nations Secretariat, 1990; United Nations, 1992) and Malawi (Malawi National Statistical Office, 2002).

The use of the Princeton model life tables in African high HIV prevalence settings is problematic. This is the case because the construction of the Princeton model life tables was informed by mortality data from HIV/AIDS free and largely European populations (United Nations, 1983). The childhood mortality age patterns embodied by model life tables are therefore unlikely to be the same as those describing an HIV/AIDS affected African country. The model life tables give lower childhood mortality estimates than those obtained from empirical data, especially for ages 1 to 4 years (Mahy, 2003).

The problems highlighted above affect indirect childhood mortality measurement because this method relies heavily on the use of model life tables. The model life tables are the basis for the coefficients used to convert the proportions of children dead to life table mortality probabilities. They are also the basis for the coefficients used to determine the times to which the estimates pertain. Converting childhood mortality probabilities to common indexes again involves use of model life

tables. The Princeton model life tables are not ideal for the Kenyan and Malawian populations being investigated. These inadequacies of the model life tables lead to erroneous estimates.

Both the direct and the indirect childhood mortality estimates are biased downwards (Mahy, 2003). The downwards bias is due to the dependence of childhood mortality on maternal mortality. The children of the infected mothers have higher mortality than the children in the general population. If the infected mothers die, then the mortality of their children is not reported, this leads to the downwards bias in the estimates.

The indirect estimates could be improved by using model life tables which take into account the impact of HIV on childhood mortality. These model life tables have to be representative of African mortality experiences. Development of such tables will improve the indirect mortality estimates by providing reasonable age patterns and levels of childhood mortality.

A notable attempt was made by the INDEPTH network to construct model life tables applicable to sub-Saharan Africa (Indepth Network, 2004). These tables however have shortfalls which include being localised to the Demographic and Surveillance Sites which provided data used for the construction of the model life tables.

6.3. HIV/AIDS attributable childhood mortality (HIV PAF)

National HIV PAF has been estimated before in Kenya and Malawi (Walker, Schwartlander and Bryce, 2002; Zaba, Marston and Floyd, 2003; Kabudula, 2007). However, none of the methods prior to this project used birth histories of uninfected mothers as a basis for estimation of the mortality of uninfected children. This project uses the empirical and relatively reliable DHS data and results from longitudinal African studies to estimate HIV PAF for Kenya and Malawi.

The results from this study attribute 14.3 per cent and 18.0 per cent of under-five mortality to HIV/AIDS in Kenya and Malawi respectively. These estimates pertain to the periods 1999 – 2003 (Kenya) and 2000 – 2004 (Malawi).

Kabudula (2007) estimated HIV attributable under-five childhood mortality as 12.6 per cent for Malawi in the period 2000 – 2004. His estimate is for the same period as the current study. However, he used a methodology similar to the Walker method. His estimate is lower than the estimate from the current study.

Instead of modelling childhood birth, infection and survival after infection -as was done in the Walker method and by Kabudula - this project uses empirical DHS

birth histories data and empirical results from African longitudinal data to estimate mortality of uninfected children.

The estimates obtained in the Walker method corresponding to the year 1999 are 20.8 per cent for Kenya and 8.9 per cent for Malawi. Walker and colleagues considered the HIV impact on under-five mortality only. Though the Walker method estimated annual HIV PAFs for the period from 1990 to 1999 the estimates that were provided in the paper by Walker, Shwartlander and Bryce (2002) are for 1999 only. The 1999 estimates are not directly comparable to the estimates in the current study since the periods to which the estimates pertain are different. However, the HIV PAFs from this study seem too low.

In the Zaba method, HIV PAF estimates were estimated for the period 1990 to 2001. The HIV PAFs for Malawi from in 2001 is lower than that obtained in this study for under-five mortality (11.4 per cent) but higher for infant mortality (10.3).

The estimates of HIV PAF for Kenya derived from the Zaba method are much higher than those obtained in this study for both IMR and U5MR. The under-five HIV PAF was 29.7 per cent in 2001 and infant HIV PAF was 24.8 per cent. In the case of Kenya, the estimates from Zaba and colleagues are more plausible than those obtained from the current study, especially for under-5 mortality. However, they were derived using linearly extrapolated childhood mortality estimates from the pre-epidemic period as mortality estimates for uninfected children. This extrapolation completely ignored the reversal of childhood mortality trends in Kenya.

The DHS-based childhood mortality estimates were adjusted for the downwards bias due to the dependence of childhood mortality on maternal mortality (Ward and Zaba, 1999; Mahy, 2003). Alternative estimates were calculated by adding the expected direct AIDS deaths and non-AIDS deaths. An average of the adjusted estimates and alternative estimates was calculated. This average was then used as the estimate of the overall mortality. The decision to use the DHS-based childhood mortality estimates was made despite the fact that the surveys providing the data for these estimates were questionable – they gave trends out of line with earlier surveys. This was done because these surveys were the only ones in these two countries which involved HIV testing among women aged 15 - 19..

Instead of using DHS or ANC based prevalence rates only, a combination of DHS and ANC prevalence rates provided better estimates of prevalence of HIV among women aged 15 - 49 taking into account the trends and the levels which are more

plausible than those from either source considered separately. However, there are problems which are introduced by using a combination of DHS-based HIV prevalence rates and sentinel surveillance HIV prevalence rates. These problems include the samples involved. The DHS surveys test for HIV among women aged 15 - 49 in the general population while sentinel surveillance tests pregnant women visiting antenatal care. The groups of women involved in the two sources of prevalence data may be different thus leading to inaccurate prevalence rates. In order to improve consistency between the DHS prevalence estimates and the sentinel surveillance estimates, the DHS age-specific prevalence for all women 15 - 49 tested were weighted by the numbers of pregnant women in the same age range tested in the DHSes of interest.

The effect of prevention of mother to child transmission (PMTCT) of HIV has not been allowed for in the vertical transmission rate used. The reason is that PMTCT was not common in both Kenya and Malawi during the time considered in this study. The effect of PMTCT can be allowed for by adjusting the vertical transmission rate to the new value applicable when PMTCT is being used.

6.4. Limitations of the study

The study shows that, for Kenya and Malawi, there is inconsistency between the trends of childhood mortality from direct estimates and those from the indirect estimates. However, it does not provide a method of reconciling the trends from these methods. It also does not specify the role of HIV/ AIDS in causing the trends to be inconsistent.

Graphical analysis does not indicate whether the changes in childhood mortality over time are statistically significant or not. It is crucial to know whether the changes are statistically important, to facilitate identification of worsening of childhood mortality or improvements due to interventions.

Only two countries were considered in this study. It would be useful to analyse trends from a greater number of countries to see if there are any systematic ways in which the trends are related.

DHS samples are sometimes small. For example, the 1992 Malawi DHS used a sample size of 4849. Small sample sizes give national estimates of questionable representativeness and may cause fluctuations in the trends of childhood mortality.

The overall mortality estimates used in this study come from data which have given trends that are inconsistent with data from earlier surveys. This makes the estimates of overall mortality used for estimation of HIV PAF questionable.

The factors used to scale up the mortality of the children of uninfected mothers to obtain the mortality of the HIV exposed children are limited in that these are only from three African countries. Besides, they mainly involve country sub-populations followed up for two years. These factors may differ from the ones applicable for Kenya and Malawi.

The HIV PAF estimates are lower than what would be expected. Assuming that 60 per cent of the HIV infected children die before reaching the age 5 (The UNAIDS Reference Group, 2002), with the HIV prevalence of 12 – 14 per cent and mother-to child transmission of HIV of 35 per cent, the HIV PAF is supposed to be between 25 to 30 per cent. Therefore the estimates obtained using the current method are inconsistent with the expected results.

6.4.1. Uncertainty of the input to HIV PAF estimates

There are several sources of uncertainty in the inputs used to estimate the PAF. The inputs used include: the HIV prevalence among pregnant women aged 15 - 49, the mother-to-child HIV transmission rate, the adjustment factors used to get mortality of the HIV - negative children of HIV - positive mothers from the mortality of children of HIV – negative mothers and the overall childhood mortality estimates used.

The overall mortality estimates in DHS reports have a confidence interval of ±13 per cent, the vertical transmission rate is said to vary in the range 25 – 45 per cent in breastfeeding African communities (Zaba, Marston and Floyd, 2003). Not much is known about the differences in mortality between the children of uninfected mothers and HIV-negative children of HIV-positive mothers, this also increases the uncertainty surrounding the PAF estimates presented in this study. The prevalence used was obtained by combining DHS based and sentinel surveillance based estimates. These estimates came from different samples and different sampling methods thus compounding on the uncertainty of the PAF estimates. In addition to these known sources of uncertainty, there are other sources that are not known. The above sources of uncertainty inspire little confidence in the PAF estimates derived in this study.

6.5. Conclusions and recommendations

This study has mainly done two tasks. The first being the comparison of trends of direct and indirect estimates of childhood mortality and the second task was the estimation of the direct impact of HIV/AIDS on childhood mortality in Kenya and

Malawi. The trends were constructed using data collected from 1993 to 2003 in Kenya and 1992 to 2004 in Malawi. The HIV/AIDS impact assessment was done for the periods 1999-2003 in Kenya and 2000-2004 in Malawi. The key findings from the foregoing study are considered in this section.

Chapter 4 compared trends of childhood mortality from the direct and the indirect methods. The results of the comparison reveal that the two methods give trends that are inconsistent for both Kenya and Malawi. The direct estimates provide clearer trends in comparison to those from the indirect methods which are largely erratic. This is in line with the idea that has been held in the past that the indirect estimates give inaccurate trends (Ahmad, Lopez and Inoue, 2000; Garenne and Gakusi, 2006). There is therefore need to find ways of improving indirect estimates to make them more useful for determining general trends over time in high HIV prevalence settings.

According to the direct estimates, Malawian childhood mortality has been consistently declining throughout the period of analysis while Kenyan mortality declined then started to increase again. This is true if the estimates from the latest DHSes from the two countries are ignored. However, Malawian childhood mortality was consistently higher than Kenyan childhood mortality throughout the period considered in this study (1970s to 2003).

HIV impact assessment has given the following HIV PAF for childhood mortality. The PAF for infant mortality is 5.3 per cent and 6.8 per cent for Kenya and Malawi respectively, while the PAF for under-five mortality is 14.3 per cent and 18.0 per cent respectively for the two countries. These estimates pertain to the period 1999 – 2004.

These results indicate that HIV is affecting childhood mortality more in Malawi than it is in Kenya in the period under review. These results are in contrast to the findings from the previous studies that have assessed the HIV impact in the two countries. Both the studies by Walker, Shwartlander and Bryce (2002) and Zaba, Marston and Floyd (2003) showed higher impact in Kenya than in Malawi. These previous studies attributed the higher impact in Kenya to the lower overall mortality estimates in the same country compared to Malawi. The inconsistencies in the results obtained in this study, discussed earlier, and the uncertainty surrounding the estimates makes it impossible to judge whether the differences between the PAFs for Kenya and Malawi are material.

The HIV PAF obtained in this study are lower than expected and have large confidence intervals surrounding them. They therefore have to be improved further before they can be used for decision making.

It is recommended that the sensitivity of the HIV PAF estimates be assessed by varying the inputs used to obtain them, especially the HIV prevalence and the vertical transmission rates.

It still remains unknown at the end of the foregoing work whether the estimates of HIV PAF, having been improved, can be used to improve estimation of childhood mortality using the direct and the indirect methods. Further studies could be done to establish a way of using the HIV PAF to improve childhood mortality measurement in Africa.

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Appendix

1A. Important definitions

Live birth. According to the World Health Organization (2008), a live birth is defined as:

> The complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of the pregnancy, which, after separation, breathes or shows any other evidence of life – such as beating of heart, pulsation of the umbilical cord, or definite movement of voluntary muscles – whether or not the umbilical cord has been cut or the placenta is attached.

Neonatal mortality is the probability of dying before the age of 28 days for a live borne child expressed per thousand live births. (UNICEF, WHO, World Bank *et al.*, 2007)

Postneonatal mortality is the probability of dying after 28 days but before 1 year, expressed per thousand live births reaching 28 days. (UNICEF, WHO, World Bank *et al.*, 2007)

Infant mortality rate (IMR) is the number of deaths below age 1 divided by the number of births in a give period expressed per 1000. (National Statistical Office (NSO) [Malawi] and ORC Macro, 2005)

Child mortality rate is the probability of dying before age five for children who survive to age 1. (National Statistical Office (NSO) [Malawi] and ORC Macro, 2005)

Under-five mortality rate (U5MR) is the number of deaths under the age of 5 per 1000 births. (National Statistical Office (NSO) [Malawi] and ORC Macro, 2005)

Crude Death rate is a measure of mortality in a population obtained by dividing the number of deaths per year by the average population (United Nations, 1992)

A civil registration system is a system that establishes and provides legal documentation of vital events (live births, deaths, foetal deaths, marriages and divorces) while universally and continuously recording the occurrence and characteristics of these events. (Setel, Macfarlane, Szreter *et al.*, 2007)

A vital registration system comprises civil registration and other complementary systems which register individuals and record vital events without giving legal birth and death certificates. (Setel, Macfarlane, Szreter *et al.*, 2007)

Vital statistics are summary measures of vital events drawn from vital registration. (Setel, Macfarlane, Szreter *et al.*, 2007)

A cohort is a group of people who are linked together by means of experiencing the same event over a period of time. e.g., people born in the same year constitute a birth cohort. (Population Division United Nations Secretariat, 1990)

A synthetic cohort is a theoretical construct of a true cohort used to investigate the likely effects of conditions prevailing in a specified period of time. (Population Division United Nations Secretariat, 1990)

A life table is a tabular description of the way mortality impacts a cohort as it progresses through life. (Population Division United Nations Secretariat, 1990)

A model life table is a life table on the mortality experience of some real or hypothetical population selected on the basis of the best available evidence to describe mortality in a population of interest where data for construction of a life table are not available (Shryock and Siegel, 1976).

The widely used model life tables are the Princeton (Coale-Demeny) model life tables (Coale and Demeny, 1983) and the United Nations model life tables for developing countries (United Nations, 1982)

2A. DHS surveys reference dates

For each DHS used in this project, the mid-point of the data collection period was identified. The date of the month corresponding to the mid-point was recorded; it was then expressed in years. For example, the data collection for the Kenya 1993 DHS was done from 17 February to 15 August 1993. The mid-point of this data collection period was 17 May 1993. Expressing this date in years gives 1993+(137/365) = 1993.4 since there are 137 days from 1 January to 17 May and 1993 was not a leap year so, it had 365 days.

3A. STATA code for direct childhood mortality estimation using DHS data

The STATA 9.2 code used to verify DHS direct childhood mortality estimates and to derive mortality rates of the children of the uninfected mothers..

The given code is for direct childhood mortality rates from the Malawi 2004 DHS. This same code can be applied to other DHS datasets with appropriate changes.

Associated excel spreadsheets are provided; these spreadsheets were created from stata output. The STATA do files need to be executed separately.

do "C:\Direct Estimates\mdhs2004\child.do"

```
use "C:\m04individuals.dta"
keep caseid bidx_* bord_* v005 v008 b3_* b5_* b7_*
rename bidx_01 bdx1
rename bidx_02 bdx2
rename bidx_03 bdx3
rename bidx_04 bdx4
rename bidx_05 bdx5
rename bidx_06 bdx6
rename bidx_07 bdx7
rename bidx_08 bdx8
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rename b7_10 b710
rename b7_11 b711
rename b7_12 b712
rename b7_13 b713
rename b7_14 b714
rename b7_15 b715
rename b7_16 b716
rename b7_17 b717
```

```
rename b7_18 b718
rename b7_19 b719
rename b7_20 b720

reshape long bdx  bod  b0  b1  b2  b3  b4  b5  b6  b7  b8  b9  b10
b011  b012  b013 b014  b015  b016,  i(caseid) j(bord)
keep v005 v008 b3 b5 b7
keep if b3!=.

save "C:\child.dta"
```

do "C:\death1.do"

```
use "C:\child.dta"
gen agegr_1 = 0
gen agegr_2 = 1
gen agegr_3 = 3
gen agegr_4 = 6
gen agegr_5 = 12
gen agegr_6 = 24
gen agegr_7 = 36
gen agegr_8 = 48
gen agegr_9 = 60
gen period = 60
gen maxper = 6
gen upplim = v008 - 1
gen lowlim = v008 - (maxper*period)- 1
gen xproc = 0
replace xproc = 1 if lowlim <=b3 & b3 <= upplim & b5 == 0
keep if xproc ==1
gen j = 0
replace j = 1 if agegr_1 <=b7 & b7 < agegr_2
replace j = 2 if agegr_2 <=b7 & b7 < agegr_3
replace j = 3 if agegr_3 <=b7 & b7 < agegr_4
replace j = 4 if agegr_4 <=b7 & b7 < agegr_5
replace j = 5 if agegr_5 <=b7 & b7 < agegr_6
replace j = 6 if agegr_6 <=b7 & b7 < agegr_7
replace j = 7 if agegr_7 <=b7 & b7 < agegr_8
replace j = 8 if agegr_8 <=b7 & b7 < agegr_9
gen agedth = j - 1
keep if j != 0
gen perborn = int((v008-1-b3)/period)
gen limlow = v008 - (perborn+1)*period
gen agei = 0
replace agei = b3+agegr_1 if j==1
replace agei = b3+agegr_2 if j==2
replace agei = b3+agegr_3 if j==3
replace agei = b3+agegr_4 if j==4
replace agei = b3+agegr_5 if j==5
replace agei = b3+agegr_6 if j==6
replace agei = b3+agegr_7 if j==7
replace agei = b3+agegr_8 if j==8
gen nxtage = 0
replace nxtage = b3+agegr_2 if j==1
replace nxtage = b3+agegr_3 if j==2
replace nxtage = b3+agegr_4 if j==3
replace nxtage = b3+agegr_5 if j==4
replace nxtage = b3+agegr_6 if j==5
replace nxtage = b3+agegr_7 if j==6
replace nxtage = b3+agegr_8 if j==7
```

```
replace nxtage = b3+agegr_9 if j==8
gen limupp = limlow+period
gen n = 1
gen iter = 0
replace iter = 1 if limlow<= b3 &nxtage <= limupp
replace iter = 2 if agei < limupp & limupp <= nxtage
replace iter = 1 if b3< limupp & limupp <= agei
replace perborn = perborn - 1 if b3< limupp & limupp <= agei
replace iter = 1 if perborn == 0
replace n = n/iter if iter !=0
gen colper = perborn
gen rweight = n*v005/10
gen xtabs = 0
replace xtabs = 1 if iter != 0 & 0 <= colper & colper < 5
save "C:\death.dta", replace
keep if xtabs ==1
tabulate agedth colper [iweight=rweight]
clear
use "C:\death.dta"
replace colper = colper-1 if iter == 2
gen xtabs1 = 0
replace xtabs1 = 1 if iter == 2 & 0 <=colper & colper < 5
keep if xtabs1 == 1
tabulate agedth colper [iweight=rweight]
clear

do "C:\death2.do"
```

Table A 1 combine.csv

Dths	dthage	clper
20294290	0	0
5336918	1	0
9321301	2	0
10584727	3	0
8158534	4	0
5245233	5	0
3964895	6	0
1656646	7	0
16483346	0	1
4325564	1	1
5225522	2	1
10951891	3	1
7537633	4	1
4922188	5	1
1586014	6	1
1572188	7	1
14051216	0	2
4159472	1	2
4637349	2	2
9028712	3	2
5977753	4	2
2662060	5	2
2211377	6	2
1155456	7	2
11247693	0	3
1746915	1	3
3499535	2	3
5199018	3	3
4983383	4	3
2860252	5	3
1974917	6	3
639860	7	3
8611501	0	4
1831833	1	4
1817329	2	4
3069924	3	4
2467245	4	4
1408863	5	4
731740	6	4
431697	7	4
35526	0	0
86798	1	0
839236	3	0
1072100	4	0
649255	5	0
226847	6	0
112832	7	0
14121	0	1
34940	2	1
419320	3	1
1011631	4	1
597277	5	1
326091	6	1
172211	7	1
42547	1	2
95451	2	2
516031	3	2
646203	4	2
241488	5	2
220598	6	2
62461	7	2
444023	3	3
347851	4	3
283817	5	3
120937	6	3
78404	7	3
146521	0	4
36906	3	4
122157	4	4
120504	5	4
60564	6	4
63595	7	4

```
insheet using "C:\combine.csv", comma
tabulate  dthage clper [fweight = dths]
clear

/* create an excel csv file similar to the one in Table A 2
```

Table A 2 death.csv

Dths	dthage	clper
20329816	0	0
5423716	1	0
9321301	2	0
11423963	3	0
9230634	4	0
5894488	5	0
4191742	6	0
1769478	7	0
16497467	0	1
4325564	1	1
5260462	2	1
11371211	3	1
8549264	4	1
5519465	5	1
1912105	6	1
1744399	7	1
14051216	0	2
4202019	1	2
4732800	2	2
9544743	3	2
6623956	4	2
2903548	5	2
2431975	6	2
1217917	7	2
11247693	0	3
1746915	1	3
3499535	2	3
5643041	3	3
5331234	4	3
3144069	5	3
2095854	6	3
718264	7	3
8758022	0	4
1831833	1	4
1817329	2	4
3106830	3	4
2589402	4	4
1529367	5	4
792304	6	4
495292	7	4

do "C:\death3.do"

```
insheet using "C:\death.csv", comma
sort dthage clper
 save "C:\deaths.dta",replace
clear
```

do "C:\expos1.do"

```
use "C:\child.dta"
gen period=60
 gen maxper = 6
gen agegr_1= 0
gen agegr_2= 1
gen agegr_3= 3
gen agegr_4= 6
gen agegr_5= 12
gen agegr_6= 24
gen agegr_7=36
gen agegr_8=48
gen agegr_9=60
gen limupp= v008-1
gen limlow = v008-(maxper*period)-1
gen xproc = 0
replace xproc=1 if limlow<=b3 & b3<=limupp
keep if xproc==1
gen months=0
replace months=b7 if b5==0
replace months=v008-b3 if b5==1
gen perborn=int((v008-1-b3)/period)
save "C:\chld.dta", replace
gen ageexp=0
gen agei=b3
gen nxtage=b3+agegr_2
```

do "C:\mort2.do"

```
keep if agei <= b3+months
gen lowlim = v008-((perborn+1)*period)
gen upplim = lowlim+period
gen iter = 0
replace perborn = perborn-1 if upplim <= agei
replace iter = 1 if upplim <= agei
gen n = 0
replace n = 1 if upplim<= agei
replace lowlim = lowlim+ period if upplim <= agei
replace upplim = lowlim+ period if upplim <= agei
replace iter = 1 if nxtage < upplim
replace n = 1 if nxtage < upplim
replace iter = 2 if agei < upplim & upplim <= nxtage
replace n = 0.5 if agei < upplim & upplim <= nxtage
replace perborn = perborn-1 if upplim <= agei
replace iter = 1 if upplim <= agei
replace iter = 1 if agei < upplim & upplim <= nxtage & perborn == 0
gen colper = perborn
gen rweight = n*v005/100
gen xproc1 = 0
replace xproc1 = 1 if 0 <= colper & colper < 5
```

do "C:\mort3.do"

```
save "C:\mort2.dta", replace
keep if xproc1 == 1
tabulate ageexp  colper [iweight=rweight]
clear
use "C:\mort2.dta"
gen colper1 = colper - 1
gen xproc2 = 0
replace xproc2 = 1 if 0 <= colper1 & colper1 <= 4 & iter == 2
keep if xproc2 == 1
tabulate ageexp colper1 [iweight=rweight]
clear
use "C:\chld.dta"
gen ageexp=1
gen agei=b3+agegr_2
gen nxtage=b3+agegr_3
```

do "C:\mort2.do"

do "C:\mort3.do"

```
clear
use "C:\chld.dta"
gen ageexp=2
gen agei=b3+agegr_3
gen nxtage=b3+agegr_4
```

do "C:\mort2.do"

do "C:\mort3.do"

```
clear
use "C:\chld.dta"
gen ageexp=3
gen agei=b3+agegr_4
gen nxtage=b3+agegr_5
do "C:\mort2.do"
do "C:\mort3.do"
clear
use "C:\chld.dta"
gen ageexp=4
gen agei=b3+agegr_5
gen nxtage=b3+agegr_6
```

do "C:\mort2.do"

do "C:\mort3.do"

```
clear
use "C:\chld.dta"
gen ageexp=5
gen agei=b3+agegr_6
gen nxtage = b3+agegr_7
```

do "C:\mort2.do"

do "C:\mort3.do"

```
clear
use "C:\chld.dta"
gen ageexp=6
gen agei=b3+agegr_7
gen nxtage=b3+agegr_8

do "C:\mort2.do"

do "C:\mort3.do"

clear
use "C:\chld.dta"
gen ageexp=7
gen agei=b3+agegr_8
gen nxtage=b3+agegr_9

do "C:\mort2.do"

do "C:\mort3.do"

clear
```

```
do "C:\expos2.do"
```

Table A 3 explos1.csv

exp	expage	col
60572812	0	0
50759926	0	1
45070015	0	2
33435615	0	3
21294479	0	4
57826951	1	0
48591962	1	1
43282900	1	2
31752746	1	3
20079221	1	4
56309631	2	0
47748481	2	1
42029994	2	2
31158026	2	3
19179870	2	4
53017596	3	0
45773137	3	1
39561670	3	2
29386916	3	3
17391834	3	4
47843254	4	0
41773054	4	1
36058668	4	2
26148461	4	3
14947132	4	4
46629169	5	0
38750751	5	1
34622096	5	2
23102260	5	3
12832038	5	4
44908931	6	0
37133189	6	1
31647446	6	2
20761667	6	3
10742874	6	4
42847542	7	0
37288509	7	1
29084138	7	2
18611340	7	3
8675453	7	4
475182	0	0
414278	0	1
430424	0	2
211857	0	3
168373	0	4
873732	1	0
829976	1	1
551388	1	2
449694	1	3
184709	1	4
1205823	2	0

1101251	2	1	772284	2	2
			635891	2	3
			230863	2	4
			2442483	3	0
			2432310	3	1
			1930200	3	2
			1432137	3	3
			616126	3	4
			5327091	4	0
			3966947	4	1
			3615426	4	2
			1974846	4	3
			988136	4	4
			4780228	5	0
			4074625	5	1
			2877178	5	2
			1880148	5	3
			846324	5	4
			4439835	6	0
			4399605	6	1
			2905072	6	2
			1765058	6	3
			647797	6	4
			4002921	7	0
			3741198	7	1
			2575753	7	2
			1524765	7	3
			442855	7	4

```
 insheet using "C:\expo1.csv", comma
tabulate  expage col [fweight = exp]
clear
```

do "C:\expos3.do"

Table A 4 exposure.csv

exposure	ageexpos	colper
61047994	0	0
51174204	0	1
45500439	0	2
33647472	0	3
21462852	0	4
58700683	1	0
49421938	1	1
43834288	1	2
32202440	1	3
20263930	1	4
57515454	2	0
48849732	2	1
42802278	2	2
31793917	2	3
19410733	2	4

55460079	3	0
48205447	3	1
41491870	3	2
30819053	3	3
18007960	3	4
53170345	4	0
45740001	4	1
39674094	4	2
28123307	4	3
15935268	4	4
51409397	5	0
42825376	5	1
37499274	5	2
24982408	5	3
13678362	5	4
49348766	6	0
41532794	6	1
34552518	6	2
22526725	6	3
11390671	6	4
46850463	7	0
41029707	7	1
31659891	7	2
20136105	7	3
9118308	7	4

```
insheet using "C:\exposure.csv", comma
save "C:\exposure.dta", replace
clear
```
do "C:\combine_dth_expo1.do"

```
use "C:\deaths.dta", clear
gen id = _n
order id
sort id
save "C:\sdeaths.dta", replace
clear
use "C:\exposure.dta", clear
gen id = _n
drop  ageexpos colper
order id
sort id
save "C:\sexposure.dta", replace
clear
use  "C:\sdeaths.dta", clear
merge id using "C:\sexposure.dta"
rename dthage agemnth
rename clper colper
save "C:\dthsexp.dta", replace
label data "This file contains exposure and deaths for Malawi 2004"
label variable agemnth " Age in months - Deaths"
label variable colper " Periods of analysis of 5 years"
label variable exposure " exposure to the risk of dying"
label define agemnth1 0 " 0 " 1 "1 - 2" 2 "3 - 5" 3 "6 - 11" 4 "12 -
23" 5 "24 - 35" 6 "36 - 47" 7 "48 - 59"
label values agemnth agemnth1
```

```
label define  colper1 0 " 0 - 4 " 1 "5 - 9" 2 "10 - 14" 3 "15 - 19"
4 "20 - 24"
label values colper colper1
gen rweight= deaths/1000
tab  agemnth colper [iweight=rweight]
label variable agemnth " Age in months - exposure"
gen rweight1 = exposure/1000
tab  agemnth colper [iweight=rweight1]
gen agepro=agemnth
label variable agepro " Age in months - probabilities(times
1000000)"
label define agepro1 0 " 0 " 1 "1 - 2" 2 "3 - 5" 3 "6 - 11" 4 "12 -
23" 5 "24 - 35" 6 "36 - 47" 7 "48 - 59"
label values agepro agepro1
gen rweight2 = deaths*1000000/exposure
tab agepro colper [iweight=rweight2]
clear
```

do "C:\combine_dth_expo2.do"

Table A 5 Probs.csv

Probs	Ageprbs	colper
271499	0	0
105224	1	0
142644	2	0
263775	3	0
256819	4	0
200500	5	0
121333	6	0
53109	7	0
488295	0	1
140641	1	1
205937	2	1
337212	3	1
333524	4	1
275113	5	1
172391	6	1
82518	7	1
421531	0	2
124497	1	2
184897	2	2
347716	3	2
390023	4	2
262865	5	2
213779	6	2
125546	7	2
388841	0	3
157719	1	3
159965	2	3
378162	3	3
535474	4	3
378591	5	3
259886	6	3
112900	7	3
604728	0	4
141087	1	4

140262	2	4
335202	3	4
468047	4	4
338079	5	4
211679	6	4
138766	7	4

```
insheet using "C:\Probs.csv"
gen probdc = 0
gen mn = 0
gen infant =0
gen mortrate = 99
replace mortrate = 0 if ageprb ==0
replace mortrate = 2 if ageprb ==3
replace mortrate = 3 if ageprb ==7
replace probdc = 10000000-probs if mortrate==0
gen id =_n
sort id
tsset id
replace probdc = ((L.probdc)*(10000000-probs))/10000000 if
mortrate!=0
replace probdc = 10000000-probs if ageprbs ==4
replace probdc = ((L.probdc)*(10000000-probs))/10000000 if
mortrate!=0 & ageprbs!=4
replace mn = probdc if mortrate==0
replace mn = L.mn if mortrate !=0
replace infant = probdc if mortrate ==2
replace infant = L.infant  if mortrate!=2
gen rate = 10000000-probdc
save "C:\neonat.dta", replace
keep if mortrate!=99
tabulate colper mortrate [iweight=rate]
clear
use "C:\neonat.dta"
gen mortrate1=99
replace mortrate1 = 1 if ageprbs ==3
replace mortrate1 = 4 if ageprbs==7
replace rate = (10000000-probdc)-(10000000-mn) if mortrate1==1
replace rate = 10000000-((probdc*infant)/10000000) if mortrate1==4
keep if mortrate1!=99
tabulate colper mortrate1 [iweight=rate]
clear
```

do "C:\combine_dth_expo3.do"

Table A 6 rates.csv

colper	mortrate	rates
0	0	271499
0	2	761468
0	3	618109
1	0	488295
1	2	1124918
1	3	837752
2	0	421531
2	2	1038509
2	3	957644
3	0	388841
3	2	1043750
3	3	1230587

```
4       0   604728
4       2  1173337
4       3  1110346
0       1   489969
0       4  1332510
1       1   636623
1       4  1868430
2       1   616978
2       4  1896701
3       1   654909
3       4  2145895
4       1   568609
4       4  2153402
```

```
insheet using "C:\rates.csv"
order rates
label variable mortrate " Mortality Rates"
label define mortrate1 0 " Neonatal (NM) " 1 "Post-neo (PNM)" 2
"Infant (1q0)" 3 "Child (4q1)" 4 "Under-five (5q0)"
label values mortrate mortrate1
label variable colper " Periods of analysis of 5 years"
label define colper1 0 " 0 - 4 " 1 "5 - 9" 2 "10 - 14" 3 "15 - 19" 4
"20 - 24"
label values colper colper1
gen rweight6 = rate/10000
/*Infant and Child Mortality DHS Estimates for Malawi 2004 */
tabulate colper mortrate [iweight=rweight6]

/* ***************************** */
```