# What can data on household deaths tell us about adult mortality in Lesotho and Botswana?[1]

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## Introduction

Mortality estimation in African populations has been a major source of demographic concern. In the absence of well developed civil registration systems most mortality estimates in African countries are derived from indirect demographic methods. These techniques make maximum use of easily available information collected from sample surveys and censuses. More recently, increases in the spread of HIV/AIDS mortality, have generated an even greater need for reliable mortality estimates that are useful for monitoring purposes. Some of this need is currently being addressed using data from a variety of sources including diseases surveillance systems. However, the programmatic need for more period mortality estimates calls for the exploitation of all available data sources in order to develop a comprehensive understanding of mortality levels and trends. This study focuses on one such data source – data on household deaths collected in censuses - and evaluates the usefulness of these data for mortality estimation in countries in which HIV/AIDS prevalence is high. A number of African censuses now collect this information based on deaths that occurred in the previous year. However, until quite recently, this information has been largely underutilized.

In no other African region has the impact of HIV/AIDS on adult mortality been as severe as it has in Southern Africa. Adult HIV prevalence levels in the region in 2001 were estimated to range from about 20% in South Africa to about 39% in Botswana (Ngom and Clarke 2003). Not surprisingly, these levels are among the highest in the world. Interest in estimating the impacts of HIV/AIDS on adult mortality in Southern Africa has therefore increased, and a growing number of studies now use estimates from indirect sources to investigate of how mortality in African countries have been affected by the spread of the epidemic (e.g. Timaeus 1998, Blacker 2004).

## Objectives

The general objective of this study is to use data on household deaths collected during censuses in Lesotho and Botswana to estimate intercensal levels of adult mortality. Because of the potential biases associated with census data on household deaths (UN 1997), the analysis begins with an assessment of the completeness of these data, using three death distribution methods: the Generalized Growth Balance (GGB) method, the Synthetic Extinct Generations (SEG) method, and the adjusted Synthetic Extinct Generations method, that have been developed to evaluate death registration completeness. Specifically, the study focuses on three main objectives. First, it evaluates the completeness of census data on household deaths by sex and age. Second, it adjusts data on household deaths using estimates of average completeness and uses the adjusted data to generate estimates of age-specific adult mortality levels. Third, the study compares estimates derived from the adjusted data on household deaths with estimates of adult mortality from other sources. In other words, the study assesses the consistency of estimates from household deaths with estimates from other studies in an attempt to locate our estimates within the context of possible mortality trends in both countries.

**Census data on household deaths**

Indirect methods for mortality estimation in African countries were developed several decades ago to fill the void created by the absence of complete vital registration systems. Most previous census questions on deaths were limited to questions about deaths among children who were born in the past 12 months. The use of census questions on deaths within a household during a specified reference period, normally the past year, is however on the increase. Analytically, however, data on household deaths are most useful when they are collected on a very large scale and include information from several hundreds of households (Timaeus 1991).

In the case of the 1996 Lesotho census, respondents were asked the following question, "[Did a] death occur in the household in the past 12 months?" (Bureau of Statistics, Lesotho 1996), with an affirmative response leading to further questions on the age and sex of the deceased, and for female deaths whether or not the death was pregnancy related. For Botswana, the respect question asked during the 1991 census was "Since Independence Day in 1990, has any member of this household died? (CSO Republic of Botswana 1991). Subsequent question were then asked on the age and sex of the deceased if the answer to the preceding question was in the affirmative.

Census data on household deaths are however associated with a number of limitations that are likely to bias mortality estimates derived from them. First, the process of collecting data on deaths within households selectively captures only certain types of deaths that occurred in the year preceding the census. For example, deaths that lead to the disintegration of households, such as deaths in single person households, are more likely to be underreported (Timaeus 1991, Stanton et al 2001). Second, age reporting is sometimes inaccurate for both the population of the deceased and the enumerated population. In the case of the latter, accurate age reporting is important because the enumerated population is used to generate the denominators used in all three death distribution methods in their assessment of estimated completeness of deaths relative to population counts. Other potential sources of error include time-reference errors associated with the inability of respondents to locate household deaths within the specified reference period, and errors associated with the reluctance of respondents to talk about the dead (Timaeus 1991).

In spite of these limitations, a number of studies have demonstrated that it is possible to derive useful adjusted mortality estimates from data on household deaths (e.g. Bannister and Hill 2004). Thus, the utility of data on household deaths is based on the fact that they serve as a temporary source of mortality indicators useful for monitoring purposes, in the absence of the gold standard data source for mortality estimation i.e. data from civil registration systems.

**Methods**

1. The Generalized Growth Balance Method

The General Growth Balance (GGB) method is a generalization of the Brass Growth Balance method derived for stable populations (Brass 1975). The Demographic Balancing Equation expresses the identity that the growth rate of the population is equal to the difference between the entry rate and the exit rate. This identity holds for open-ended age segments *x*+, and in a closed population the only entries for such segments are through birthdays at age *x*. The birth (or birthday) rate *x*+ minus the growth rate *x*+ thus provides a residual estimate of the death rate *x*+. If the residual estimate can be calculated from population data from two population censuses and compared to a direct estimate using registered deaths, the completeness of death recording relative to population recording can be estimated. Hill (1987) shows that

$$\frac{\left({}_5N1_{x-5} * {}_5N2_x\right)^{0.5}}{5*\left(N1_{x+} * N2_{x+}\right)^{0.5}} - \frac{1}{t}\ln\left(\frac{N2_{x+}}{N1_{x+}}\right) \approx \frac{1}{t}\ln\left(\frac{k_1}{k_2}\right) + \frac{\left(k_1 * k_2\right)^{0.5}}{c} * \frac{D(x+)}{t*\left(N1_{x+} * N2_{x+}\right)^{0.5}} \quad (1)$$

where *N1* and *N2* are recorded population counts at two time points separated by *t* years, *D* are recorded intercensal deaths, and $k_1$ , $k_2$ , and *c* are the completeness, assumed invariant by age, of the first and second populations counts and the intercensal deaths, respectively.
The recorded death rate x+ is thus

$$\frac{D(x+)}{t*(N1_{x+} * N2_{x+})^{0.5}} \quad (2)$$

and the residual estimate of the death rate based on the age distributions is:

$$\frac{({}_5N1_{x-5} * {}_5N2_x)^{0.5}}{5*(N1_{x+} * N2_{x+})^{0.5}} - \frac{1}{t}\ln\left(\frac{N2_{x+}}{N1_{x+}}\right) \quad (3).$$

If the assumptions are met (key assumptions are that the population is closed to migration, that errors of omission from censuses or death registers are proportionately constant by age, and that the ages of the living or dead are accurately reported), the points for successive age segments x+ should lie on a straight line, the slope of which, $((k_1 * k_2)^{0.5}/c)$, represents the adjustment factor needed for the recorded death rates to bring them into consistency with the population data. Least squares or other line fitting methods can be used to estimate the slope.

2. The Synthetic Extinct Generations Method

The Synthetic Extinct Generations (SEG) method (Bennett and Horiuchi 1981, 1984) uses a distribution of deaths by age above age x together with age-specific growth rates to arrive at an estimate of the population of age *x*, a synthetic analog of Vincent's (1951) method of extinct generations. The completeness of death registration relative to population recording is then estimated by the ratio of the death-based estimate of population aged *x* to the observed population aged *x*. The synthetic estimate of the population aged *x* is given by:

$$\hat{N}(x) = \int_x^{\omega} D(y) e^{\int_x^y r(z)dz} dy \tag{4}$$

where $\hat{N}(x)$ is the estimated population aged *x*, *D(y)* is the observed number of deaths at age *y*, and *r(z)* is the age-specific growth rate of the population at age *z*. The deaths at each age above *x* are adjusted for the cumulative population growth rate between *x* and the age of the deaths to convert them into a stationary population equivalent. Bennett and Horiuchi's 1984 method gives similar results to the 1981 method, but without the diagnostic advantages of estimates of completeness for a range of ages *x*. Key assumptions of the method include all those of the GGB method plus the assumption that the age specific population growth rates are correct (implying in practice that any errors of omission in census counts are proportionately equal in each census).

3. Adjusted Synthetic Extinct Generations Method

Hill and Choi (2004) used simulations to evaluate how common patterns of data error affect the performance of the GGB and the SEG methods. Their results show that even quite a small change in coverage from one census to the next, if unadjusted for, can seriously bias the completeness estimates from SEG, while SEG estimates seemed to be more robust to a typical pattern of age misreporting than GGB. Taken together, the simulation results suggested that better estimates of death registration completeness can be derived by combining the GGB and SEG methods, first using GGB to estimate any change in census coverage (from the intercept of the fitted straight line), then using this estimate to adjust the census counts to be consistent, and finally applying SEG to arrive at an adjustment factor for deaths. We describe this hybrid as the Adjusted Synthetic Extinct Generations (GGB/SEG) method.

With all three methods, the analyst has a choice of age ranges from which an estimate of completeness can be derived, since there are points typically from age 5 to age 80 (for populations and deaths tabulated by five year groups up to an open interval of 85+). We test three ranges: age 5 to age 65, age 15 to age 65, and age 30 to age 70. The rationale for using the latter age range is based on the findings of Thomas and Hill (2007) that show that points in the older age groups are less likely to be affected by net migration

**Summary Results**

Diagnostics plots of adjusted SEG estimates of completeness demonstrate that the completeness of household deaths data varied by age and sex. In the Lesotho data, Figures 1a and b, estimated completeness is below 1.0 in all age groups suggesting that household deaths in the 1996 Lesotho census were generally underreported. Estimates of completeness, however, were much lower below age 20 regardless of sex, while the age disparities in completeness generally disappear in the older adult ages. In terms of sex differences, Figures 1a and b, show that across all age groups levels of completeness were higher among males compared to females. In the case of Botswana (Figures 2a and b) the results suggest that there was an over-reporting of household deaths in the 1991 census, i.e. completeness is greater than 1.0 across all age groups and among both males and female. However, levels of over-registration of deaths are slightly lower among the oldest females. The general observation of the over-recording of deaths is likely a consequence of the fact that the methods evaluate deaths in recorded in 1991 with the average deaths implied by population change between 1981 and 1991. Although HIV/AIDs may have had negligible effects on the average number of deaths between 1981 and 1991, its effect may have slightly inflated the number of deaths recorded in the 1991 census around the start of the epidemic. Hence, deaths recorded in the 1991 census are likely to represent a slight over-estimation of the average number of deaths occurring between 1981 and 1991.

- *Figures 1a and 1b about here –*

Age variations in estimated completeness were also observed in the diagnostic plots of both the GGB and the SEG methods (not shown). As a result of this, we test the sensitivity of the adjusted inter-censal estimates of the probability of dying between ages 15 and 60 (45q15) to levels of adjustment based on the use of three age-ranges used for fitting average completeness. Table 1, presents adjusted estimates of 45q15 in Lesotho, for all three methods, by age range used to fitting average completeness. Male adult mortality estimates were more consistent across method and fitting age range. Although mortality estimates based on adjustments for completeness from the SEG method were the highest, the corresponding mortality estimates associated with the adjusted SEG estimates of completeness were relatively more stable.

- *Figures 2a and 2b about here –*

In general, all estimates in Table 1 indicate that at least half of all 15 year old males in Lesotho would die before celebrating their 60$^{th}$ birthdays. Therefore, as with adult mortality estimates for around the same period derived from other sources, estimates from the 1996 census data on household deaths still place male adult mortality in Lesotho among the highest in the world. Male 45q15 estimates in Lesotho were also relatively higher than the respective estimates for women. Nevertheless, the female adult mortality estimates were much higher than comparative estimates for other African countries found in other studies. Mortality estimates based on 1991 Botswana census data are presented in Table 2. Regardless of estimation method, the results also indicate there was a female mortality advantage in Botswana, although the sex disparities are greater among estimates associated with the GGB.

- *Tables 1 & 2 about here –*

The preceding analyses therefore demonstrate three important points that are essential to the understanding of adult mortality estimation from censuses in both countries. In terms of method, the adjusted SEG method produced estimates that were less likely to vary by age-group used for fitting average completeness. This method has also been shown to be relatively less sensitive to age –reporting errors and net migration biases (Hill and Choi 2004, Thomas and Hill 2007). As a result of this and the robustness of completeness estimates produced by fitting to older age-groups (Thomas and Hill 2007), the study considers estimates based on the adjusted SEG method fitted to ages 30 to 70+ to be our best estimates. With regard to sex disparities, Table 2 also shows that the female adult mortality advantage is consistent in both Lesotho and Botswana. However, Table 2 also suggests that adult mortality levels in Lesotho were much higher than they were in Botswana during their respective intercensal intervals.

Age-specific estimates of the probability of dying above age 30 for males and females are presented in Figures 3a and b. Consistent with the findings reported in Figure 1a, the adjusted age-specific probabilities presented in Figure 3a are higher than the observed probabilities since deaths are adjusted upwards (Figure 2a) because of the incompleteness of household deaths information in Lesotho (Figure 1a). The reverse is true for Botswana (Figure 2b). More importantly, both figures show the expected increase in the probability of dying with increasing age. However, although there is a female mortality advantage in all ages in Lesotho and Botswana, the disparities slightly differ in both countries. The female mortality advantage in Lesotho begins to increase at a much younger age (around age 45), than they do in Botswana (around age 55), and become more accentuated in the oldest age groups.

- *Figures 3a and 3b about here –*

In Figures 4a and b, we present mortality estimates for broader adult age groups (i.e. 15 to 29, 30 to 44, and 45 to 59). In Figure 4a, the higher male mortality disadvantage in the older ages in Lesotho is confirmed. Although males in the 15 to 29 age group are almost as likely to die as females in similar ages, there is a clear interaction between sex disparities in mortality and age, with the male disadvantage becoming more pronounced in subsequent age groups. A similar pattern of increasing male mortality is observed in the Botswana data (Figure 4b), but the sex disparities are less distinct. Our analysis indicates that this may also be a consequence of a slower female adult mortality increase with age in Lesotho, i.e. by a factor of 2 between age-group 15-29 and 45-59, compared to similar increases among females in Botswana i.e. by a factor of 3 between similar age groups.

- *Figures 4a and 4b about here –*

Disparities in adult mortality estimates between Lesotho and Botswana are also likely to reflect differences in mortality conditions in both countries during different stages of the HIV/AIDS epidemic. Estimates based on household deaths data collected in Lesotho in the 1996 census may be higher relative to those in Botswana because these data were collected around the time when the initial effects of HIV/AIDS related causes on adult mortality were first being observed in Lesotho. We explore this explanation further in Figure 4a and b, by comparing census estimates of adult mortality (CEN96) for males and females with adult mortality estimates for Lesotho and Botswana from various sources, ( including Timaeus 1993, The World Bank 2006, WHO 2000, WHO 2007, UNPD 2005, and Lopez at al 2002) for years between 1975 and 2006.

- *Figures 5a & 5b about here –*

In the case of Lesotho, in Figure 5a, the trends suggest that adult mortality estimates based on the 1996 census data may be better understood within the context of the beginning of a reversal of the mortality declines experienced between the mid 1970s and 1980. Thus, although the 1996 census adult mortality estimates are higher than estimates for 1980, adult mortality in Lesotho has also increased consistently since 1996 with such increases usually explained in terms of the deleterious impacts of HIV/AIDS. With regard to Botswana (Figure 5b) two possibilities may explain the relatively lower levels of adult mortality captured in the 1991 census data. The first is that 1991 census data captured deaths in Botswana that were not likely to be related to HIV/AIDS related causes. Consequently, estimates in Figure 5b for the late 1990s to 2005 are much higher because they reflect the higher likelihood of mortality from HIV/AIDS related causes at a much later stage in the epidemic that are not captured in the 1991 data. Alternatively, estimates derived from the 1991 census may be lower simply because they may be affected by other types of biases that are not accounted for by the death distribution methods used in this study.

**Conclusions**

In countries with high levels of HIV/AIDS prevalence the need for estimates of mortality levels and trends is increasing. At the same time, few conventional data sources needed to derive such estimates are available in African countries. In this study, we have attempted to evaluate the usefulness of census information on household deaths for mortality estimation in Lesotho and Botswana. The results of this study provide reasonable evidence that estimates derived from censuses data can be useful for understanding the dynamics of mortality in both countries. The robustness of estimates derived from census information for each specific year however needs to be evaluated in context of other period mortality estimates that are generated from other sources. Parallel adult mortality estimates generated from orphanhood data collected during these censuses as well as data from sample registration systems could be important in this regard.

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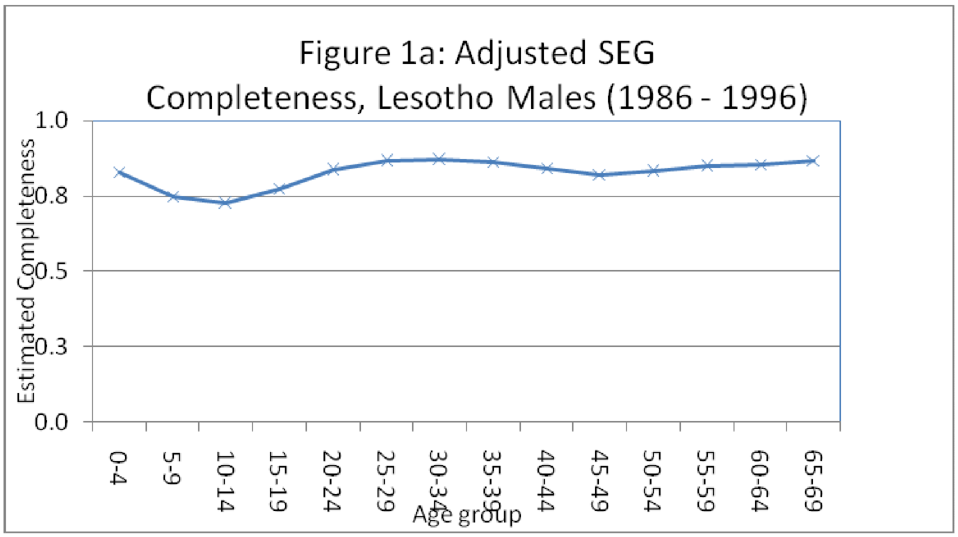
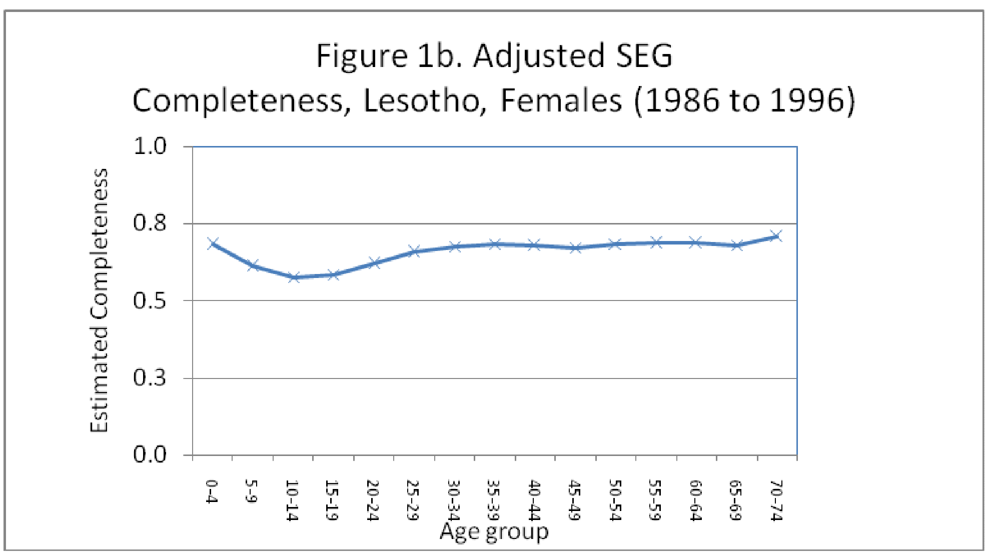
## Tables and Figures



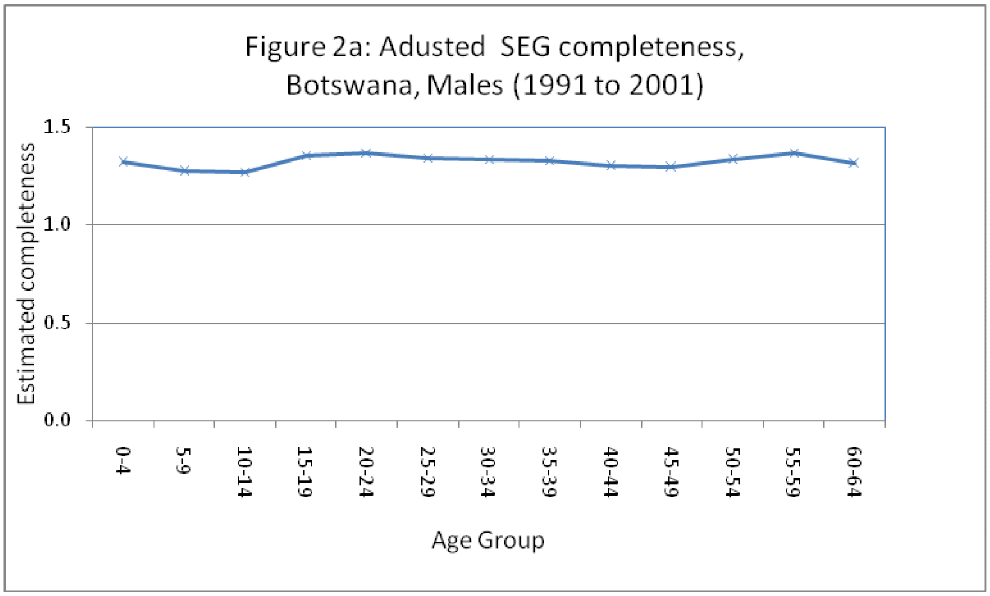


Figure 2a: Adusted SEG completeness,
Botswana, Males (1991 to 2001)
Estimated completeness
1.5
1.0
0.5
0.0
0-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
Age Group

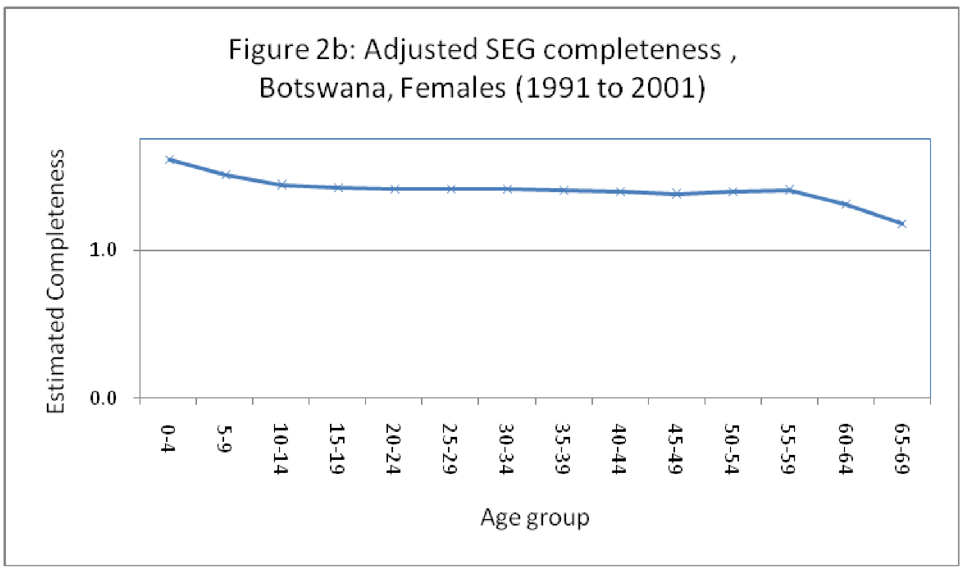


Figure 2b: Adjusted SEG completeness ,
Botswana, Females (1991 to 2001)
Estimated Completeness
1.0
0.0
0-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
Age group

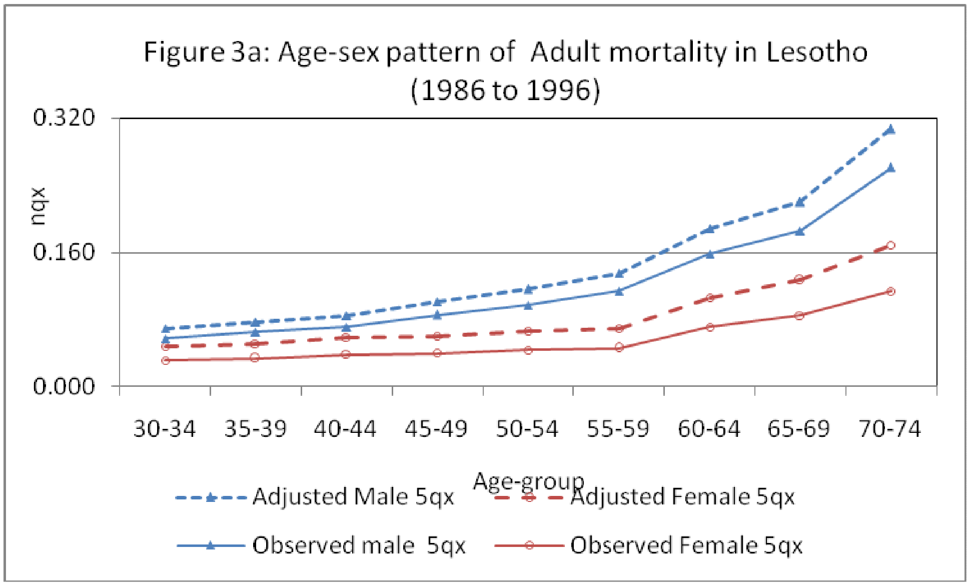


Figure 3a: Age-sex pattern of Adult mortality in Lesotho (1986 to 1996)
0.320
0.160
0.000
nqx
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
Age-group
Adjusted Male 5qx
Adjusted Female 5qx
Observed male 5qx
Observed Female 5qx

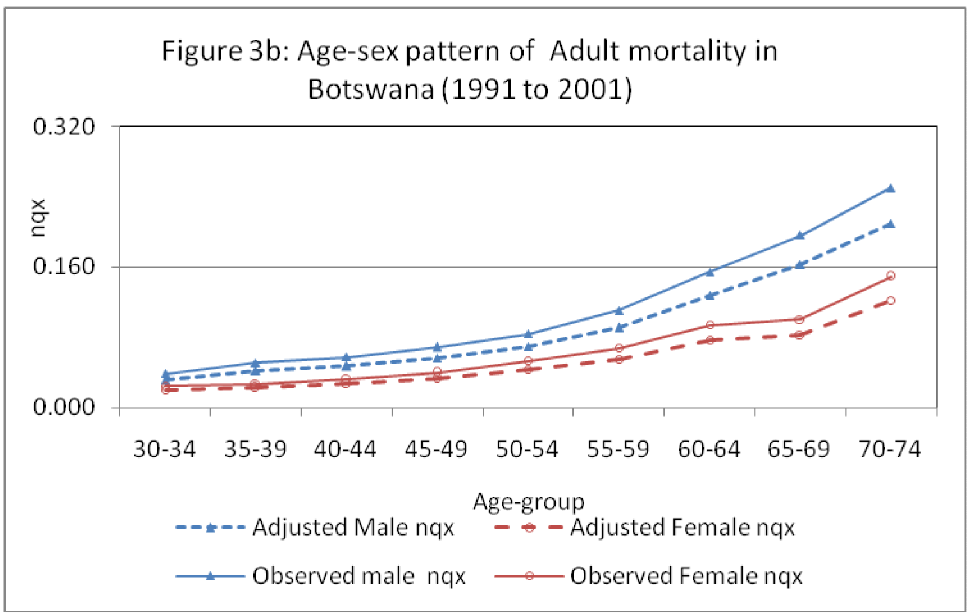


Figure 3b: Age-sex pattern of Adult mortality in Botswana (1991 to 2001)
0.320
0.160
0.000
nqx
30-34
35-39
40-44
45-49
50-54
55-59
60-64
65-69
70-74
Age-group
Adjusted Male nqx
Adjusted Female nqx
Observed male nqx
Observed Female nqx

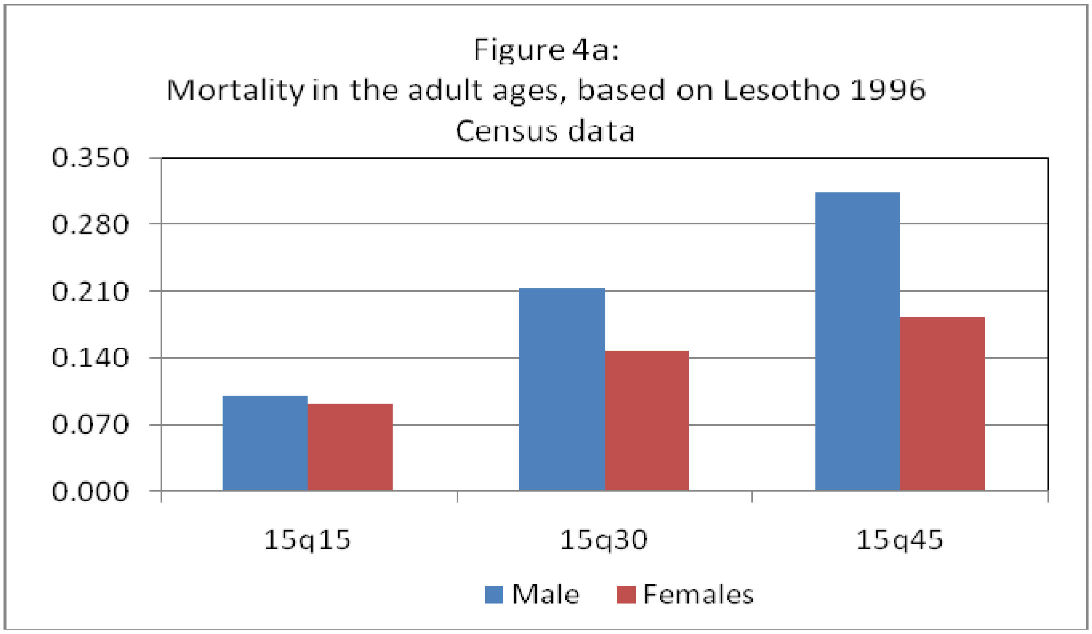


Figure 4a:
Mortality in the adult ages, based on Lesotho 1996 Census data
0.350
0.280
0.210
0.140
0.070
0.000
15q15
15q30
15q45
Male
Females

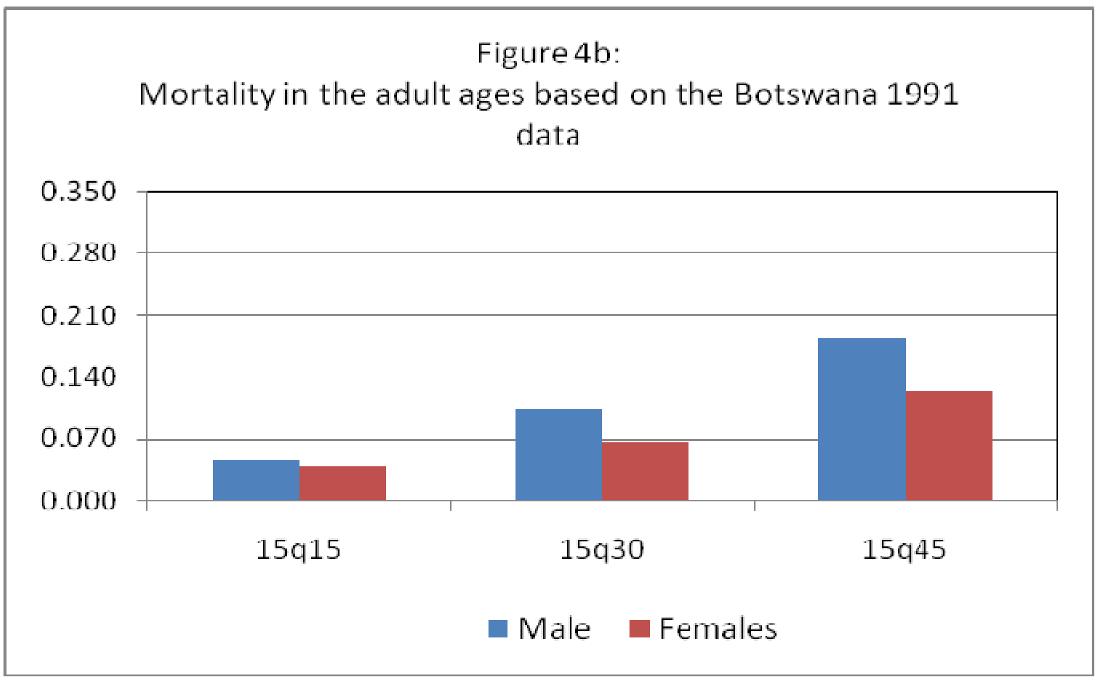


Figure 4b:
Mortality in the adult ages based on the Botswana 1991 data
0.350
0.280
0.210
0.140
0.070
0.000
15q15
15q30
15q45
Male
Females

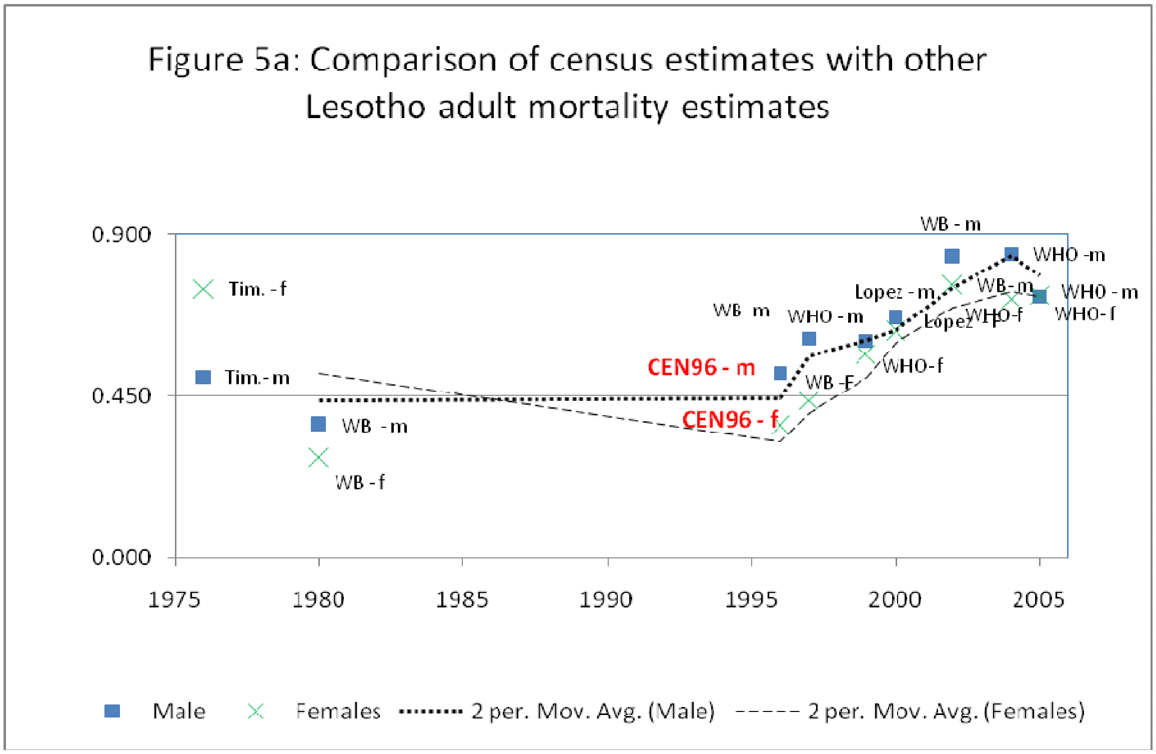


Figure 5a: Comparison of census estimates with other Lesotho adult mortality estimates
0.900
0.450
0.000
1975
1980
1985
1990
1995
2000
2005
Tim. - f
Tim.- m
WB - m
WB - f
CEN96 - m
CEN96 - f
WB - F
WHO - m
WHO-f
Lopez - m
Lopez
WB - m
WHO -m
WHO - m
WHO- f
Male
Females
2 per. Mov. Avg. (Male)
2 per. Mov. Avg. (Females)

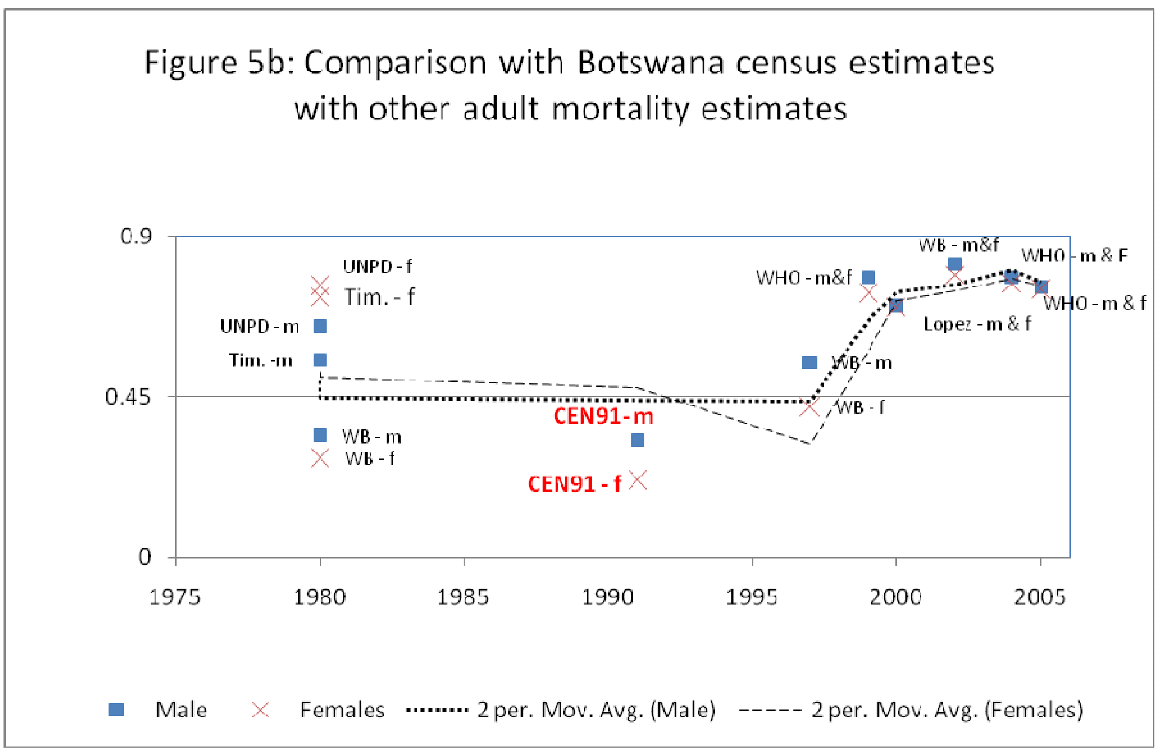


Figure 5b: Comparison with Botswana census estimates with other adult mortality estimates
0.9
0.45
0
1975
1980
1985
1990
1995
2000
2005
UNPD - f
Tim. - f
UNPD - m
Tim. - m
WB - m
WB - f
CEN91-m
CEN91 - f
WHO - m&f
WB - m
WB - f
WB - m&f
WHO - m & F
WHO - m & f
Lopez - m & f
Male
Females
2 per. Mov. Avg. (Male)
2 per. Mov. Avg. (Females)

Table 1: Estimates of 45q15 by method and age group used for fitting completeness, Lesotho, 1986 to 1996

| | Males | | |
|---|---|---|---|
| | GGB | SEG | SEG Adjusted |
| 5-65+ | 0.510 | 0.589 | 0.504 |
| 15-65+ | 0.508 | 0.572 | 0.504 |
| 30-70+ | 0.517 | 0.552 | 0.514 |
| | Females | | |
| | GGB | SEG | SEG Adjusted |
| 5-65+ | 0.357 | 0.448 | 0.354 |
| 15-65+ | 0.344 | 0.44 | 0.342 |
| 30-70+ | 0.373 | 0.415 | 0.367 |

Table 1: Estimates of 45q15 by method and age group used for fitting completeness, Botswana, 1991 to 2001

| | Males | | |
|---|---|---|---|
| | GGB | SEG | SEG Adjusted |
| 5-65+ | 0.304 | 0.279 | 0.367 |
| 15-65+ | 0.307 | 0.281 | 0.311 |
| 30-70+ | 0.332 | 0.290 | 0.330 |
| | Females | | |
| | GGB | SEG | SEG Adjusted |
| 5-65+ | 0.159 | 0.216 | 0.194 |
| 15-65+ | 0.152 | 0.216 | 0.193 |
| 30-70+ | 0.186 | 0.213 | 0.214 |