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Comparison of household survey estimates with projections of mortality and orphan numbers in sub-Saharan Africa in the era of HIV/AIDS

Short title: Adult mortality in Africa: surveys vs. models

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Abstract

The United Nations publish estimates of HIV prevalence, AIDS mortality and orphan numbers for all countries of the world. It is important to assess the validity of these model-based estimates since they underpin much care and prevention policy. Household surveys that ask questions about the survival of children's parents (orphanhood) offer an independent source of data with which these estimates can be compared. Survey estimates of maternal and paternal orphans are significantly lower than model estimates for 40 surveys in 36 countries of sub-Saharan Africa ($p<0.001$, $p=0.002$). This is probably because adult mortality due to causes other than AIDS is lower than assumed in the models, although under-reporting of orphanhood in surveys may also play a role. Reducing adult mortality due to causes other than AIDS brings the model estimates into close agreement with the surveys. This suggests that the fraction of orphans due to AIDS is greater than estimated previously.

Keywords: AIDS, orphans, mortality, surveys, population projection

Introduction

The Joint United Nations Programme on HIV/AIDS (UNAIDS) together with the World Health Organization (WHO) publish estimates of mortality due to AIDS for all countries of the world (UNAIDS/WHO 2002). In sub-Saharan Africa (SSA), where the bulk of AIDS deaths have occurred, estimates of adult deaths are based on fitting a simple model of the HIV epidemic to prevalence data from antenatal clinics (ANC) (UNAIDS Reference Group on Estimates Modelling and Projections 2002). The model estimates the numbers of new infections that must have occurred over time to produce the epidemic curve that best fits the ANC data. Survival of HIV positive individuals after infection is based on a Weibull distribution, with a median survival time of 9 years estimated from cohort data from less developed countries. Women are assumed to have a median survival time of 9.4 years, compared to 8.6 years for men. This difference does not reflect differences in survival by gender, but rather the younger ages at which women become infected in SSA. Younger age at seroconversion is one of few factors that significantly increases survival with HIV, other than treatment with antiretrovirals (UNAIDS Reference Group on Estimates Modelling and Projections 2002).

It is important to assess the validity of these projections of AIDS mortality and their underlying HIV prevalence estimates since they form the cornerstone of much prevention and care policy. For example, estimates of each country's need for antiretroviral drugs used to guide resource allocation by the Global Fund for HIV, Tuberculosis and Malaria, are based on these projections. Inevitably these estimates have significant uncertainty. National HIV prevalence estimates are quoted with a range of ±20 per cent for countries with good surveillance data, and up to ±35 per cent for countries with poorer data (Walker *et al.* 2003). Estimates of adult AIDS mortality will have a wider range, reflecting uncertainty in estimates of survival times after infection with HIV. In this paper we assess whether UNAIDS/WHO projections of adult AIDS and other-cause mortality are compatible with independent mortality data in SSA countries. We aim to identify any discrepancies at the country level and, more importantly, any systematic differences across SSA that may reflect problems with the projection methods and/or surveillance data.

Vital registration in SSA is rare, making direct estimation of adult mortality impossible in all but a handful of countries (e.g. South Africa and Zimbabwe). Instead, indirect methods based on household surveys that ask questions about survival of parents or siblings, or about recent deaths in the household, can be used to estimate adult mortality rates (Timæus 1998). The increasing availability of Demographic and Health Surveys (DHS) supported by USAID, together with the recent completion of a large number of end-decade Multiple Indicator Cluster Surveys (MICS) supported by UNICEF, now allow adult mortality estimates to be produced for a large number of countries in SSA. Although these estimates are not without their limitations (Timæus 1998), they provide an opportunity to assess the validity of UNAIDS/WHO projections of AIDS mortality.

The number of inquiries that have asked a sufficient number of households about recent deaths to obtain reasonably precise estimates of adult mortality is limited. The main source of information on adult mortality therefore has to be questions about survival of siblings or of parents. The former approach relies on questioning women about the date of birth of each of their brothers and sisters, and their ages at death if any of them have died. These questions have been included in some phase 2, as well as phase 3 and 4, DHS but are unavailable for MICS. Furthermore, methods to correct for bias towards underestimation of mortality due to correlation of risks of death for siblings are not available (Timæus 1998). By contrast, the estimation of adult mortality from questions about parental survival is well established (Brass and Hill 1973), and methods exist to adjust for biases introduced by the transmission of HIV from mother to child (Timæus and Nunn 1997). In this paper, therefore, we focus on data from the latter question, using reports of the number of orphans as a source of information about adult mortality.

Methods to estimate adult mortality from orphan numbers rely on the same set of assumptions as estimates of orphan numbers from mortality data (Timæus 1992; Timæus and Nunn 1997; UNAIDS Reference Group on Estimates Modelling and Projections 2002). Thus, this paper uses a direct comparison between household survey estimates of the proportion of children who are orphans and the equivalent estimates of orphanhood based on UNAIDS/WHO projections of AIDS and other-cause mortality published in 2002 (UNAIDS 2002; UNAIDS *et al.* 2002) to assess the projections of mortality. Estimates of orphans due to causes other than AIDS are important in their own right, but also make clear the relative magnitude of the impact of the AIDS epidemic. For example, at the end of 2001 approximately one third of all orphans under the age of 15 years living in SSA had lost at least one parent due to AIDS (UNAIDS *et al.* 2002).

In Zimbabwe, estimates of adult mortality from vital registration adjusted for completion of registration are available for several years (Feeney 2001). Comparison with estimates from DHS orphan data and UNAIDS/WHO projections is used in this paper to provide further insight into the causes of the discrepancies between the projections and survey-based estimates of orphan numbers.

Methods

Data

Survey-based estimates of the fraction of children aged 0-14 whose mother, father or both parents have died (maternal, paternal or dual orphans respectively) were collated from 43 household surveys completed since 1998 in 39 countries in SSA. These surveys are either DHS (18 surveys) or a variant (1 Sexual Behaviour Survey in Zambia), or MICS (24 surveys). The surveys enumerate the members of sampled households and ask the questions “Is NAME’s mother still alive?” and “Is NAME’s father still alive?” about each child in them. DHS and MICS use very similar sampling design and data processing techniques. The training of interviewers differs between the two programmes of surveys, but this is unlikely to have a large effect on responses to these questions about household members.

In countries where more than one survey in the same programme has been completed since 1998, the most recent survey was chosen. In Mozambique the most recent survey is a DHS in 1997 – this was included for completeness. In four countries orphanhood data are available for both MICS and DHS. In these cases both surveys are included in the analysis and, additionally, estimates from the two programmes for the same country are compared.

Projections of the fraction of children orphaned by AIDS and by other causes are taken from the CD-ROM (US Census Bureau 2002) that accompanies the ‘Children on the Brink 2002’ report (2002) and the UNAIDS/WHO report on the global epidemic of HIV (UNAIDS 2002). These figures are based on UNAIDS/WHO estimates of AIDS mortality and model life-tables for non-AIDS mortality. Projections of AIDS and other-cause orphans are based on a simple model that estimates the number of children born to those who have died and whether these children are still alive to be counted as orphans (Grassly and Timæus submit.).

In the simplest case, the number of maternal AIDS orphans is estimated by multiplying together the number of women dying of AIDS over time, the average number of children born to these women, and the probability that the children are still alive and aged less than 15 at the time of interest. Estimates of the number of children born to women who died from AIDS must account for their HIV status at the time of birth and the impact of HIV on fertility, in addition to the age-specific fertility pattern for the country of interest. The probability that a woman is HIV positive a certain number of years before her death from AIDS can be calculated from the distribution of survival after infection. HIV infection is estimated to decrease fertility by 20 per cent for women aged 20 years and over (UNAIDS Reference Group on Estimates Modelling and Projections 2002). However for younger women the correlation with unprotected sex means HIV positive women have 50 per cent higher fertility than uninfected women. Child survival depends on the probability of mother-to-child transmission of the virus (35 per cent in breastfeeding populations), and the survival probabilities by single years of age for HIV positive and negative children. Cohort studies of the natural history of HIV in children in SSA in the absence of highly active antiretroviral therapy suggest a median survival time for HIV positive children of just 2 years (UNAIDS Reference Group on Estimates Modelling and Projections 2002). Despite the complexity introduced to these calculations by the HIV epidemic, the key determinant of the fraction of children who are orphans remains the level of adult mortality.

Estimates of maternal orphans due to causes other than AIDS and of paternal orphans due to AIDS and other causes are based on a similar approach. Further details of the methods and assumptions used to estimate orphan numbers from projections of AIDS and other-cause mortality are described elsewhere (Grassly and Timæus submit.).

Country-level projections of the number of children who are orphans due to AIDS and other causes are published for the end of the year. Linear interpolation between successive end-of-year estimates was used to produce estimates for the year and month that corresponded to the mid-point of fieldwork for each of the surveys.

No projections of AIDS mortality are available for 3 countries in SSA with survey data on orphanhood. Therefore, in total, 40 comparisons between projections and survey-based estimates were made for 36 countries (Table 1).

Statistical analysis

An initial comparison of the model projections and survey estimates of the fraction of children whose mother has died, irrespective of the survival status of the father, is made using a Wilcoxon signed-rank test for paired data. The same test is applied to estimates of the fraction of children whose father has died, irrespective of the survival status of the mother. These two comparisons allow inferences about the difference between projection model and survey estimates of women's and men's mortality respectively.

Subsequently, linear regression is used to examine the relationship between the absolute percentage difference separating the survey and model estimates of the fraction of children orphaned, and the projected level of orphanhood, HIV prevalence five years before the survey, survey programme (DHS vs. MICS), and the interactions of the projected level of orphanhood with HIV prevalence and with survey programme. We assume that the survey estimates are binomially distributed, and weight the regression analysis by their variance. As the precision of the mortality and fertility projections and assumptions about vertical transmission and child survival is unknown, it is not possible to calculate the variance of the model estimates of orphan numbers. We therefore assume the projection model estimate is known without error and hence can be included in the regression as an independent variable. Model estimates of deaths of men in Rwanda and Burundi are far too low since they do not account for the impact of war and genocide. We therefore exclude these countries from the regression of paternal orphan estimates.

Adult mortality in Zimbabwe

We compare UNAIDS/WHO projections of adult mortality with estimates for 1986 and 1995 from vital registration in Zimbabwe (Feeney 2001). If we assume that adult death rates due to causes other than AIDS remained constant from 1986 to 1995, and that the majority (96 per cent) of deaths in 1986 were not due to AIDS (in agreement with UNAIDS/WHO projections), it is possible to estimate the excess mortality in 1995 due to AIDS. The cause-specific death rates estimated in this way can then be compared with the AIDS and other-cause rates from the projections. The assumption that mortality due to causes other than AIDS remained unchanged over this period is supported by constant mortality estimates from household survey data on survival of parents for the years prior to the AIDS epidemic (late 1980s) and the absence of any major social upheaval. Vital registration estimates of mortality were adjusted to correct for incomplete reporting by assuming constant mortality among 10-14 year olds over the period 1986-1995 (Feeney 2001).

Results

Model-based projections of the fraction of children aged 0-14 whose mother has died are consistently higher than household survey estimates (Wilcoxon signed-rank test, $p < 0.001$; Figure 1a). The only exceptions are Mozambique and Rwanda, where civil war and genocide respectively have resulted in a large number of adult deaths that have not been accounted for sufficiently in UNAIDS/WHO projections. The projections of the fraction of children aged 0-14 whose father has died are also significantly higher than survey estimates (Wilcoxon signed-rank test, $p = 0.002$), although this appears to be the case mainly for countries with low HIV prevalence ($p = 0.002$ for countries with < 5 per cent HIV prevalence five years before survey compared to $p = 0.23$ for countries $\geq$ 5 per cent HIV prevalence; Figure 1b). The projections fail to capture the impact of war and genocide on paternal orphan numbers in Rwanda and Burundi, and consequently these countries fall far below the line of equivalence between survey and model estimates.

Regression analysis of the difference between survey and model estimates of maternal orphans suggests that the model estimates are consistently higher (negative intercept, p-value = 0.02; Table 2). This difference does not depend on HIV prevalence ($p = 0.91$) or on which survey programme measured orphanhood (DHS vs. MICS, $p = 0.33$). There is some suggestion that the difference between the estimates may widen as the fraction of children orphaned increases (borderline significance, $p = 0.06$) (Table 2). Consideration of the interaction terms provides no evidence that this relationship varies between the two sets of surveys or with HIV prevalence ($p = 0.61$, 0.38). For the comparisons included in this paper, on average 5.4% of children are estimated to be maternal orphans based on UNAIDS/WHO projections of mortality, compared to 3.5% in the household surveys (an absolute difference of 1.9%). .

Regression analysis of the difference between the survey and model estimates of the fraction of children whose father has died reveals no overall difference but suggests that the relationship depends on HIV prevalence ($p = 0.03$; Table 3). Moreover, the interaction between HIV prevalence and absolute levels of orphanhood predicted by the model is of borderline significance (negative coefficient, $p = 0.05$). This is in agreement with the visual impression that the model estimates tend to be higher in low prevalence, low orphanhood countries (Figure 1b). The difference between model and survey estimates is independent of the survey programme (p = 0.48).

The regression analysis suggests that the discrepancy between the survey and model estimates of maternal orphans is found at low as well as high levels of HIV prevalence. For paternal orphans this discrepancy is confined to low prevalence countries. In countries where HIV prevalence five years before the survey was less than 5 per cent, survey estimates of the fraction of children who are maternal orphans are on average 45 per cent lower than model estimates, compared to 41 per cent lower in all countries, including those with high HIV prevalence. For paternal orphans the survey estimates are on average 27 per cent lower for countries with an HIV prevalence five years before the survey of less than 5 per cent, compared to 17 per cent lower for all countries. This evidence suggests that the cause of the discrepancy is unlikely to be errors in the model estimates of AIDS deaths. Instead, the estimates of adult mortality due to causes other than AIDS, on which projections of orphan numbers are based, may be too high. If these estimates are reduced by 45 per cent and 20 per cent across all ages for women and men respectively, in agreement with the observed discrepancy for countries with low HIV prevalence, the model and survey estimates of the fraction of children orphaned due to all causes are no longer significantly different (Wilcoxon p = 0.09 and 0.67 respectively; Figure 2).

Neither regression analysis suggests that MICS and DHS give significantly different results when compared with the model estimates. In the four countries – Cameroon, Niger, Togo and Kenya – where both MICS and DHS have been carried since 1998, the two survey programmes give broadly consistent estimates. MICS estimates of the fraction of children whose mother have died are the same as DHS estimates (average MICS:DHS ratio 0.98 [range 0.89 – 1.13]). However, the MICS were carried out on average 2.3 years later than the DHS (range 2.1 – 2.4 years) and in all these countries the number of orphans is thought to be rising due to AIDS. In the case of children whose father has died the difference is greater (average MICS:DHS ratio 0.91 [range 0.73 – 1.03]), suggesting that MICS may be less likely to identify paternal orphans. However, this inference is based on just four countries and may not apply to MICS and DHS surveys carried out in other countries by different implementing agencies.

Despite the lower estimates of maternal and paternal orphans in the MICS, the fraction of children whose parents had both died (dual orphans) is higher than in the DHS for all four countries except Niger (average MICS:DHS ratio 1.19 [range 0.54 – 1.64]). An increase in the fraction of children who are dual orphans is to be expected in countries with a growing HIV epidemic (UNAIDS *et al.* 2002). However, it is unclear why a similar rise in the fraction of children whose mother or father only have died is not captured by the MICS.

In Zimbabwe, comparison of the imputed cause-specific death rates from vital registration with the UNAIDS/WHO model estimates for 1995 suggests that both AIDS and other-cause mortality have been overestimated in the model (Figure 3). This comparison entails assumptions about underlying trends in adult mortality due to causes other than AIDS. However, the model estimates of mortality rates due to other causes in 1995 can only be reconciled with the registration-based estimates by assuming that other-cause mortality has risen steeply in Zimbabwe (The crude adult death rate (15-69 yrs) due to causes other than AIDS would have had to have risen by 34 per cent from 1986 to 1995). This seems unlikely. Estimates of AIDS deaths from the two sources cannot be reconciled even if death due to causes other than AIDS are assumed to decline to zero.

Discussion

Projections of maternal orphans are consistently higher than household survey estimates, irrespective of the prevalence of HIV before the survey or the fraction of children orphaned. Projections of paternal orphans also tend to be higher than survey estimates, although the discrepancy decreases as HIV prevalence increases. Projections of the prevalence of orphanhood largely depend on the estimates of adult mortality used to calculate them (absolute numbers of orphans also depend on the total fertility rate). Thus, either high mortality estimates, or a failure to enumerate all orphans by surveys, or a combination of these errors is likely to explain the discrepancy. Additional factors such as the age distribution mortality and fertility can affect projections of the prevalence of orphanhood. However, the sensitivity of projections to realistic changes in these distributions is limited (Grassly and Timæus submit.).

The level and pattern of adult mortality in most African countries is poorly understood. Except in South Africa, civil registration of deaths is incomplete or absent. While 2000-round population censuses have been carried out in a number of countries, few data from these censuses are available as yet. Population projections (United Nations 2002a) and estimates of orphan numbers (UNAIDS *et al.* 2002) therefore tend to rely on model life tables.

The estimates of orphans due to causes other than AIDS in SSA published by UNAIDS, USAID and UNICEF in 2002 are based on the Princeton 'West' model life tables (Coale and Demeny 1983), and estimates of life expectancy made by the United Nations Population Division (United Nations 2002a). In the majority of SSA countries, these estimates of life expectancy are themselves based on extrapolation of infant and child mortality estimates to adult mortality using a Princeton 'North' model life table (United Nations 2002b). The Princeton 'West' and 'North' model life tables are derived from vital registration data from western and northern Europe collected in the latter half of the nineteenth and early twentieth century. Both have high levels of adult mortality relative to child mortality.

A more appropriate set of model life tables for SSA may be the Princeton 'South' models based on data from southern Europe, or a Brass relational model with an

African standard and β parameter of 0.7 (Brass 1971), which embody higher levels of infant and child mortality and relatively low adult mortality. Projections made with these alternative life tables would forecast approximately 25 per cent fewer deaths of adults aged 20-54 years (the ages at which adult deaths are most likely to orphan children) for a life expectancy at birth of 50 years (Figure 4). Current projections estimate that of the 34 million orphans under the age of 15 years living in SSA, 32 per cent have lost at least one parent to AIDS (UNAIDS *et al.* 2002). Using a Princeton 'South' life table would reduce the estimated number of orphans to about 29 million, with 40 per cent having lost at least one parent to AIDS. This suggests that, in addition to the numbers of orphans being overestimated, the relative impact of the HIV pandemic on orphans in SSA has been underestimated.

Recent analyses by the INDEPTH network of data from demographic surveillance sites in developing countries also suggest lower adult mortality in the absence of HIV/AIDS than the Princeton 'North' or 'West' life tables (INDEPTH Network 2002). Based on sites mainly in West Africa, the INDEPTH life table in the absence of AIDS (Pattern 1) gives 13 per cent fewer deaths in the age range 20-54 years than the Princeton 'West' for a life expectancy at birth of 50 years.

Use of inappropriate life tables and the overestimation of adult mortality from causes other than AIDS is likely to explain much of the difference between survey and model estimates of orphan numbers. However, it cannot explain all of the difference, particularly for maternal orphans. Surveys may miss orphans for a number of reasons. It has long been recognized that children orphaned at a young age may be reported as the natural children of their foster-carers by interviewers (Timæus 1998). This may occur more frequently for children whose mother has died, since paternal orphans do not always acquire a foster father. This could contribute to the larger discrepancy between model and survey estimates seen for maternal orphans.

Surveys may also fail to accurately report the survival of parents who are not co-resident with the child. This would result in under-reporting of orphans if parents who have lost touch with their children are assumed to be still alive. Alternatively, social desirability bias may result in absent parents being reported as dead, in which case orphan numbers would be over-estimated. However, such problems are more likely to affect the reporting of paternal than maternal orphanhood. Moreover, the reported proportions of children in a survey with a dead mother or father are not associated with the proportions of children who live with the parent in question (data not shown). This suggests absence of parents is not associated with a systematic tendency to over or under report parental deaths.

Household surveys also fail to capture street children and children in institutions, many of whom may have been orphaned. In most of Africa, the number of such children is relatively small and they are restricted to urban centres. However, this may change as the unfolding orphan crisis caused by AIDS begins to stretch the extended family beyond its capacity.

In countries where independent estimates of adult mortality from vital registration data exist – Zimbabwe and South Africa – these estimates are in close agreement with indirect estimates from DHS data on orphanhood (Feeney 2001; Timæus *et al.* 2001). Furthermore, estimates of adult mortality from questions about sibling survival in DHS show good agreement with estimates based on questions about orphanhood (Timæus 1998). This indicates that DHS are enumerating all or nearly all orphans in these two countries and suggests that under-enumeration of orphans by DHS may not be a major problem. The broad agreement between MICS and DHS in the four countries where both surveys were implemented further suggests that MICS are enumerating most orphans.

After adjusting down estimates of adult mortality due to causes other than AIDS, projected number of maternal (but not paternal) orphans still exceed the number enumerated in surveys for a few countries with high HIV prevalence, notably Zimbabwe and Botswana (Figure 2a). The idea that the projections overestimate AIDS mortality in Zimbabwe is confirmed by the analysis of cause-specific mortality in 1995 (Figure 3). In the case of Zimbabwe, the most recent surveillance data suggest that the end-2001 estimate of prevalence and associated epidemic curve were indeed too high – a result of anomalous high prevalence surveillance data from 2000 and misrepresentation of the rural population by peri-urban surveillance sites (Ministry of Health and Child Welfare 2003). Inaccuracies in the estimated level of HIV epidemics from ANC surveillance data may contribute to model over-estimates of orphan numbers in Botswana and other countries. However, in all high prevalence countries, a number of additional factors may play a role. In particular, accurate estimates of the timing of epidemics are very important, since the fraction of children orphaned can rise dramatically in a year. In Zimbabwe, for instance, the annual increment between 1995 and 2000 was around 20 per cent.

The impact of HIV on fertility can also affect orphan numbers. If the fertility reduction in HIV positive women aged 20 years and over is 50 per cent not 20 per cent, the number of maternal AIDS orphans for SSA countries will be approximately 20 per cent lower. In countries where AIDS orphans constitute a large fraction of all maternal orphans, this would significantly reduce the model estimates. Furthermore, prevalence among women who die from causes other than AIDS is unknown and the relationship to prevalence in the female population complicated by correlations between risk of HIV infection, lifestyle and environmental factors and risk of death from other causes. Since most of these women are of older age, prevalence is assumed to be zero (Grassly and Timæus submit.). This assumption may result in an overestimate of the number of maternal orphans due to causes other than AIDS since, if in fact their mother is infected, some of these orphans will have died from AIDS. However, even if these women had the same prevalence as pregnant women aged 15-49 years old, in a country with 25 per cent adult HIV prevalence maternal orphans due to causes other than AIDS would only be overestimated by about 6 per cent.

It is also possible that a median time to death from AIDS of 9.4 years for women post-infection with HIV is too short. People infected with HIV between ages 25 and 39 years old in Uganda have a median survival time of 9.9 years (Morgan *et al.* 2002). However, in most SSA countries median age at infection among women is significantly younger than 25 years (Boerma *et al.* 1999; Gouws *et al.* 2002; Mbulaiteye *et al.* 2002). Since age at infection and survival are correlated, with infection one year earlier being associated with an increase in median survival of just under two months, most women may survive longer than 9.4 years (Collaborative Group on AIDS Incubation and Survival including the CASCADE EU Concerted Action 2000). On the other hand, studies of survival post-infection in non-African developing countries, although with shorter follow-up times, suggest quicker progression to AIDS and death (UNAIDS Reference Group on Estimates Modelling and Projections 2002).

Finally, if the assumed ratio of female-to-male HIV prevalence of 1.2 in a mature epidemic is too high, then levels of AIDS mortality among women would be over-estimated. However, this is not suggested by 14 population prevalence surveys carried out between 1990 and 2002 in SSA, where the average female-to-male ratio is 1.4 (Kigadye *et al.* 1993; Fylkesnes *et al.* 1998; Kilian *et al.* 1999; Kwesigabo *et al.* 2000; Fylkesnes *et al.* 2001; Glynn *et al.* 2001; Gregson *et al.* 2002; Central Statistical Office Zambia *et al.* 2003).

To conclude, current evidence suggests that an incorrect assumption about adult mortality due to causes other than AIDS is the major cause of the discrepancy between model-based projections and household survey estimates of orphan numbers in Africa. The typical relationship between mortality in childhood and mortality in adulthood in SSA may be more like that in the Princeton ‘South’ models than that in the ‘North’ or ‘West’ models. Under-reporting of orphans in surveys may also play a role, although surveys in South Africa and Zimbabwe appear to have enumerated the great majority of orphans.

Reducing adult mortality from causes other than AIDS produces remarkably close agreement between the model and survey estimates, considering the numerous assumptions made by the model and the inherent problems of sampling error and bias that affect both survey and HIV prevalence data. For both maternal and paternal orphans, 80 per cent of the revised model-based projections fall within ±40 per cent of the survey estimates. This is encouraging, both for the United Nations and for those implementing surveys that collect data on orphanhood. Nevertheless, while a more appropriate choice among existing models of mortality may improve projections for Africa, it cannot substitute for reliable and up-to-date statistics from the region. To develop a better understanding of the demographic impact of the HIV epidemic and models that can represent this, far more effort than in the past must be devoted to the collection and analysis of empirical data on both AIDS and non-AIDS adult mortality in Africa.

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Table 1 Projections and household survey estimates of the fraction of children aged 0-14 who are maternal, paternal, or double orphans

			Model-based projections (%)				Household surveys (%)				HIV
Country	Survey type	Mid-year of survey	M	P	D	Total	M	P	D	Total	prevalence 5-yrs before survey (%)
Angola	MICS	2002	4.8	7.7	1.5	11.0	3.2	9.0	1.3	10.9	3
Benin	DHS	2002	3.7	6.0	1.1	8.6	1.9	4.8	0.5	6.2	3
Botswana	MICS	2001	7.8	11.4	3.9	15.3	3.8	10.8	1.5	13.2	32
Burundi	MICS	2000	7.3	9.4	2.9	13.8	6.6	15.1	2.6	19.1	11
Cameroon	MICS	2001	4.4	7.1	1.3	10.2	2.7	6.6	0.8	8.5	6
Cameroon	DHS	1998	4.1	6.7	1.1	9.7	2.9	6.6	0.6	8.9	4
Central African Rep.	MICS	2001	6.9	10.7	3.0	14.6	4.1	7.8	1.5	10.3	13
Chad	MICS	2001	4.9	7.8	1.6	11.1	1.8	4.5	0.3	6.0	4
Cote d'Ivoire	MICS	2001	6.7	9.9	3.2	13.4	2.7	6.2	1.4	7.5	12
DR Congo	MICS	2001	5.0	7.1	1.4	10.7	3.2	7.2	1.0	9.4	6
Equatorial Guinea	MICS	2001	6.2	8.7	2.1	12.7	3.0	6.9	1.1	8.8	1
Ethiopia	DHS	2001	5.4	8.2	1.6	12.0	4.1	7.4	0.8	10.7	6
Gabon	DHS	2001	4.5	8.1	1.5	11.1	2.6	3.8	0.4	6.0	4
Gambia	MICS	2000	4.9	8.1	1.6	11.4	2.0	6.6	0.7	7.9	2
Ghana	DHS	1999	3.9	6.3	1.0	9.2	2.4	4.0	0.4	6.0	3
Guinea	DHS	1999	5.1	7.5	1.8	10.9	3.0	5.8	0.9	7.9	2
Guinea-Bissau	MICS	2000	5.1	8.0	1.7	11.4	2.4	6.3	1.4	7.3	2
Kenya	DHS	1998	4.6	6.9	1.2	10.3	2.8	7.4	0.9	9.4	10
Kenya	MICS	2001	5.7	7.7	1.7	11.7	2.5	7.1	1.2	8.4	12
Lesotho	MICS	2000	5.4	9.6	2.1	13.0	3.8	13.5	1.6	15.7	20
Liberia	DHS	2001	3.7	6.2	1.0	8.9	2.9	4.9	0.6	7.2	4
Madagascar	MICS	2001	3.5	5.4	0.5	8.4	2.4	4.5	0.4	6.5	0
Malawi	DHS	2001	8.2	10.5	3.2	15.5	4.9	8.3	1.9	11.4	18
Mozambique	DHS	1997	4.7	7.9	1.3	11.3	5.4	7.7	1.0	12.1	3
Namibia	DHS	2001	5.0	7.6	1.8	10.9	3.6	8.7	1.1	11.2	12
Niger	MICS	2001	4.6	6.4	1.0	10.0	2.1	2.6	0.2	4.5	1
Niger	DHS	1998	4.8	6.7	1.1	10.4	2.3	3.5	0.3	5.5	1
Nigeria	DHS	1999	4.3	6.4	1.2	9.5	2.9	3.9	0.9	5.9	3
Rwanda	MICS	2001	7.0	9.3	2.7	13.6	8.4	24.7	4.9	28.2	11
Senegal	MICS	2001	3.9	6.5	1.2	9.2	1.9	4.4	0.4	5.8	1
Sierra Leone	MICS	2000	5.7	9.2	2.3	12.6	4.6	10.2	2.4	12.3	4
South Africa	DHS	1998	2.9	6.2	0.6	8.4	2.2	8.5	0.8	9.9	4
Sudan	MICS	2001	3.6	5.9	0.7	8.7	1.1	3.3	0.2	4.2	1
Swaziland	MICS	2001	6.2	9.8	2.5	13.5	3.7	9.8	2.0	11.4	23
Tanzania	DHS	2000	5.2	7.7	1.8	11.2	3.4	6.3	1.1	8.7	9
Togo	MICS	2001	4.3	6.9	1.5	9.6	3.3	6.8	1.0	9.1	6
Togo	DHS	1998	4.0	6.5	1.3	9.2	2.9	6.6	0.6	8.9	4
Uganda	DHS	2001	7.6	9.7	3.0	14.3	5.2	9.6	2.3	12.5	9
Zambia	SBS	2001	8.7	9.6	3.3	14.9	9.5	13.7	2.9	20.3	25
Zimbabwe	DHS	2000	9.7	12.1	4.6	17.1	5.0	11.5	2.1	14.4	30
Average			5.4	8.0	1.8	11.5	3.5	7.7	1.2	9.9	8.1

M=Maternal, P=Paternal, D=Double, Total =M+P-D

Source: Demographic and Health Surveys, years shown; Multiple Indicator Cluster Surveys, years shown; Projections UNAIDS *et al.* 2002

Table 2 Weighted least-squares regression of the absolute difference in percent between survey estimates and model projections of the fraction of children aged 0-14 whose mother has died (maternal orphans)

Parameter	Coefficient	p-value	95% Confidence Limits	
			Lower	Upper
Intercept	-4.672	0.02	-8.461	-0.884
HIV prevalence (%)	-0.016	0.91	-0.309	0.277
Model maternal orphans (%)	0.675	0.06	-0.016	1.365
Survey: DHS vs. MICS	1.968	0.33	-2.102	6.037
Model maternal orphans (%)* HIV prevalence	-1.015	0.61	-5.031	3.000
Model maternal orphans (%)* Survey	-0.310	0.38	-1.018	0.399

* indicates an interaction
Source: Estimates in Table 1

Table 3 Weighted least-squares regression of the absolute difference in percent between the survey estimates and model projections of the fraction of children aged 0-14 whose father has died (paternal orphans)

Parameter	Coefficient	p-value	95% Confidence Limits	
			Lower	Upper
Intercept	-2.366	0.45	-8.693	3.962
HIV prevalence (%)	0.516	0.03	0.062	0.970
Model paternal orphans (%)	0.121	0.77	-0.694	0.936
Survey: DHS vs. MICS	-2.055	0.48	-7.840	3.729
Model paternal orphans (%)* HIV prevalence	-4.243	0.05	-8.509	0.024
Model paternal orphans (%) * Survey	0.249	0.46	-0.423	0.921

* indicates an interaction
Source: Estimates in Table 1

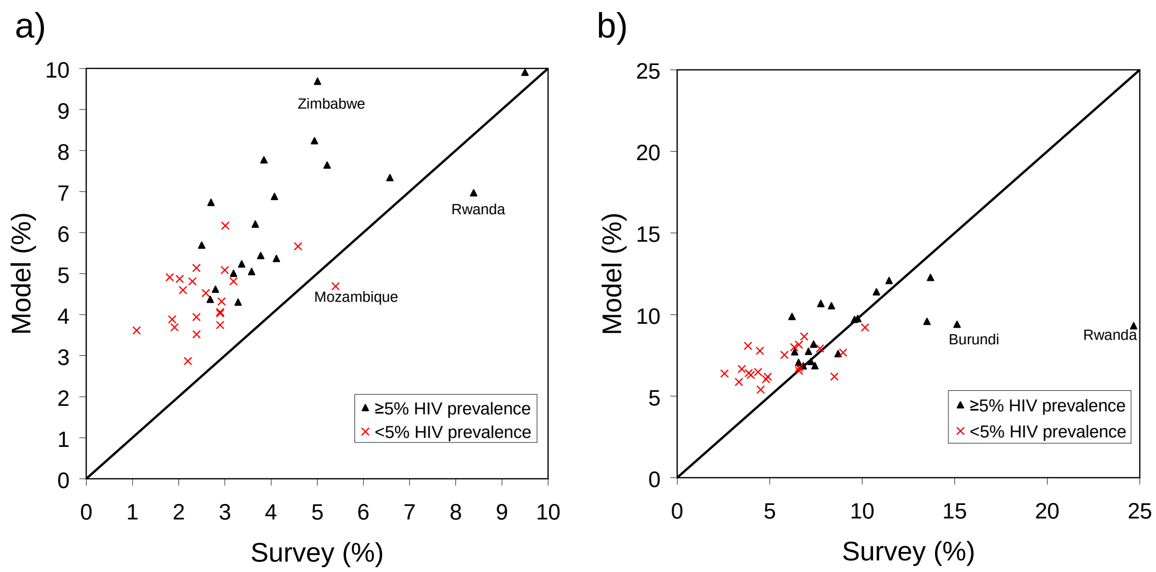
Figure Legends

Figure 1 Relationship between UNAIDS/WHO projections and survey estimates of the fraction of children aged 0-14 whose a) mother and b) father has died, irrespective of the survival status of the other parent, together with the straight line showing equivalence of the estimates. Points are distinguished according to HIV prevalence 5 years before the survey date.

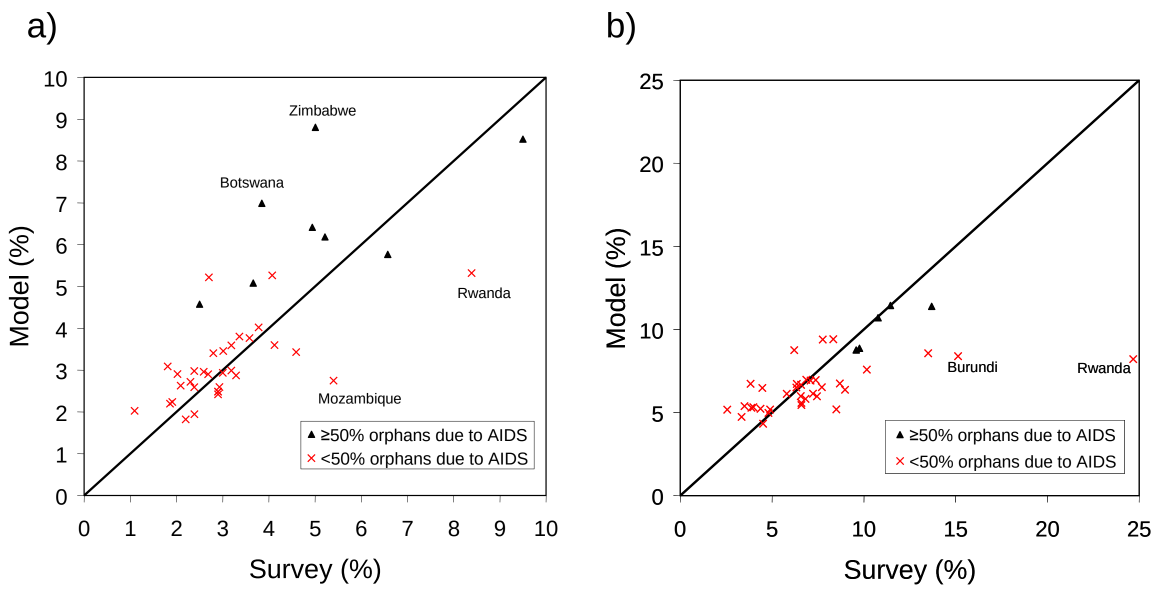
Figure 2 Relationship between projected and survey estimates of the fraction of children aged 0-14 whose a) mother and b) father has died, after adjusting projected deaths due to causes other than AIDS downwards by 45 per cent and 20 per cent respectively. Points are distinguished according to the fraction of orphans whose parent died from AIDS.

Figure 3 Ratio of vital registration to UNAIDS/WHO estimates of AIDS and other-cause death rates by age for **a)** women and **b)** men in Zimbabwe in 1995 assuming mortality from causes other than AIDS remains constant from 1986 to 1995.

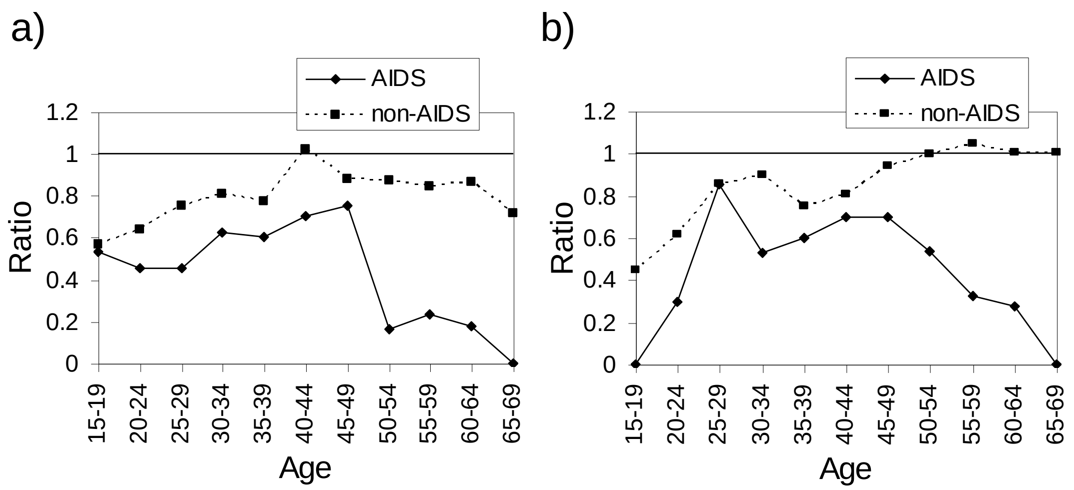
Figure 4 Deaths from causes other than AIDS predicted for a birth cohort of 100,000 by three different sets of model life tables with a life expectancy at birth of 50 years. Deaths for the Brass relational model are estimated using an African standard with high infant and child mortality (β = 0.7) (Brass 1971).



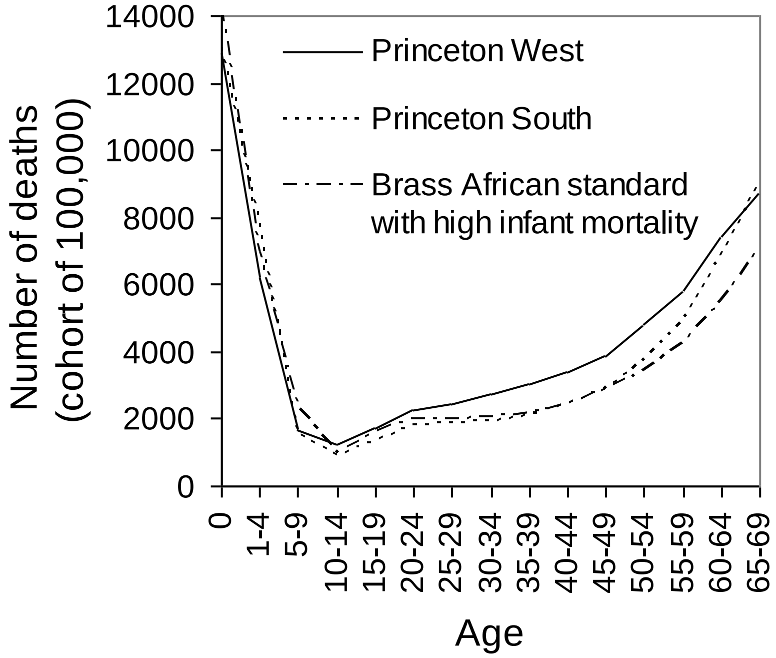
Source: Estimates in Table 1



Source: Estimates in Table 1



Source: UNAIDS/WHO projections UNAIDS 2002; Vital Registration estimates Feeney 2001



Source: Coale and Demeny 1983; Brass 1971