The impact of HIV/AIDS on adult mortality in South Africa

Technical Report

Burden of Disease Research Unit
Medical Research Council

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Disclaimer

The research presented in this report is based in part on data supplied by Departments and Agencies of the Government of South Africa. These data have been analysed and in some cases reworked by the Medical Research Council and its collaborators. The results and interpretations presented here are those of the Medical Research Council and its collaborators and are not necessarily endorsed by any Department or Agency of the Government of South Africa.

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Glossary

ANC	Antenatal care
ASSA	Actuarial Society of South Africa
DoH	Department of Health
DHA	Department of Home Affairs
MTC	Mother to child
RSA	South Africa excluding the TBVC homelands
Stats SA	Statistics South Africa
TBVC	Transkei, Bophuthatswana, Venda, and Ciskei - the former "independent" homelands

Preface

In 1982, in Oxford, Dr Harold Jaffe, a senior investigator from the Centers for Disease Control (CDC) in Atlanta presented a cluster of cases of homosexual men who were engaged in risky sexual behaviour, who had all the features of Acquired Immune Deficiency Syndrome (AIDS). At this stage the Human Immunodeficiency Virus (HIV) had not been isolated or identified yet but AIDS, as a syndrome, had been described a year earlier by the CDC. At this meeting I remarked that "This syndrome may be more common in Africa than it is appreciated". I made this premature, but predictive, remark for the following reasons: as a medical student at King Edward Hospital in the years 1973 to 1976 I had seen several young, male patients with Kaposi's Sarcoma and I knew homosexual behaviour was being practised within African communities but always denied or suppressed. In rural Sekhukhune, for example, we always heard of the practice of 'matanyola' (sexual practice between men) and we also heard of men who engaged in this practice, particularly in prisons. In KwaZulu-Natal I also came to know of 'isitabane', a Zulu word for homosexual practice.

However, when AIDS was first wrongly linked to homosexual practice many Africans promoted the notion that homosexual practices were 'unAfrican', thus sowing the seeds for denial to justify why AIDS would not be prevalent in their communities. This denial predictably became the first African public response to AIDS and swept across the continent as country after country became engulfed in the HIV/AIDS epidemic. Today, despite many documented cases of homosexual practice in Africa, this denial continues. The AIDS denial was later compounded by stigmatisation, chauvinism, the distortion of scientific information and ignorance.

In 1985, actor Rock Hudson died of AIDS. Much later Freddie Mercury of Queen and Rudolf Nureyev (the Russian ballet dancer) also died of AIDS. In the 1990s, tennis player, Arthur Ashe died of AIDS after a transfusion of HIV-infected blood. Noerine Kaleeba, Director of the AIDS Support Organisation in Uganda lost her husband Chris through AIDS; former Zambian President, Kenneth Kaunda lost his son through AIDS and Fela Kuti, world-renowned Nigerian musician and political activist died from AIDS. At the same time, many thousands of nameless people were dying from AIDS through heterosexual transmission. One name, Nkosi Johnson, became well known through his brave campaign after he became infected through mother-to-child transmission. I point out this history to illustrate that HIV/AIDS knows no boundaries of class, status, race or sexual preference. Both the powerful and powerless in every society are caught up in this vicious epidemic and it is now estimated that 36 million have been infected worldwide.

A virus named HIV has been identified and fully characterised by its unique sequence. HIV has fulfilled all of Koch's postulates as the sole cause of AIDS. It is vitally important to recognise that diagnosis and classification of a disease in medicine is based on the exponential summation of discriminating characteristics from four components: medical history, clinical signs, laboratory investigations and response to treatment. At each level there should be a discriminating feature that, when taken in context and in toto with the others, allows us to arrive at a probable diagnosis. This, too, is the case with AIDS. From this report, it has become clear that statistical modelling of epidemiological and mortality data adds a fifth component to the art of diagnosis.

Preface

The data presented in this report make the following salient points:

i) the pattern of mortality from natural causes in South Africa has shifted from the old to the young over the last decade particularly for young women - this is a unique phenomenon in biology;

ii) there is a differential mortality pattern between women and men;

iii) this shift in mortality pattern fits several AIDS models;

iv) the future burden and impact of the epidemic is broadly predictable from the models with reasonable confidence over the next decade;

v) the differential patterns of mortality and prevalence will allow for differential intervention strategies in the different parts of the country.

Malegepuru William Makgoba
President of the MRC South Africa

July 2001

This report is a chilling reminder of how powerful stereotypes across society have colluded in creating the most explosive epidemic in the history of our country. Comprehensive, powerful and rigorous as these data are, they can be seized upon positively by individuals, government and society to intervene at many levels such that no South African person, family or community has to live under the cloud of this vicious and unrelenting epidemic.

I sincerely hope that information in this report will be used to promote the culture of 'Breaking the Silence' around this silent killer of our nation. As Africa faces the challenges of its renewal or renaissance, there is no greater potential barrier to the attainment of this vision than the spectre of the HIV/AIDS epidemic.

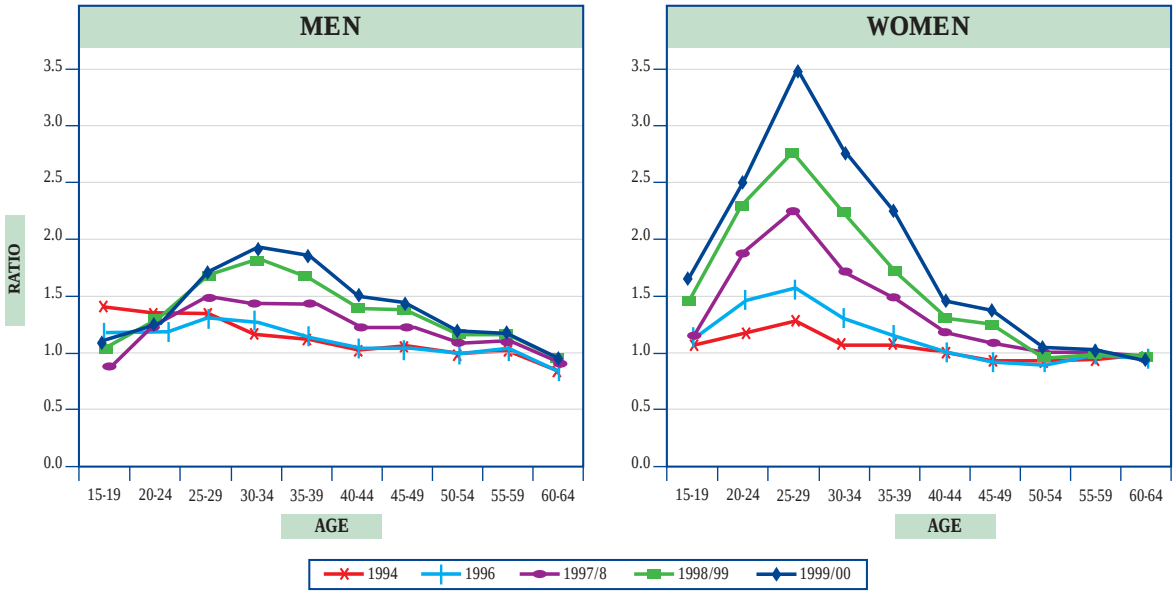
South Africa is experiencing an HIV/AIDS epidemic of shattering dimensions. The main source of information about the epidemic is the antenatal clinic HIV seroprevalence surveys conducted by the Department of Health. Reliable statistics on HIV/AIDS deaths in South Africa are not available despite Government's extensive, and largely successful, efforts to improve the national vital registration system. The most recent official death statistics available are those for 1996. By 1996 the proportion of deaths due to AIDS was too low to tell us much about the shape of things to come. Even if the numbers of AIDS deaths were substantial, vital registration statistics may well be an unreliable source of cause of death information because the true cause of death of someone who died of AIDS can be expected to be frequently misreported.

Demographic projections of the epidemic indicate that HIV/AIDS will cause a rapid change in the age and sex pattern of deaths. A system to rapidly monitor the age pattern has been developed by the Medical Research Council. Details of registered deaths are obtained directly from the Population Register maintained by the Department of Home Affairs.

Standard indirect techniques have been adapted for estimating the extent of under-reporting of deaths to allow for different levels of completeness at different ages which can be expected in South Africa, in order to estimate the extent of under-registration in both the routine vital statistics reported by Stats SA as well as the data obtained from Home Affairs. The coverage of adult death registration appears to have improved from 54% of deaths occurring in 1990 being reported to 89% of adult deaths (in those older than 15 years) occurring in the 12-month period to the end of June 2000 being reported. This is a clear sign of the success of the extensive efforts on the part of Government to improve vital registration. While this system provides good information on adults, deaths among children are under-represented as a relatively high proportion of children are not recorded on the Population Register.

The data show that there has been a steady increase in adult mortality during the 1990s. The mortality of young, adult women has increased rapidly in the last few years with the mortality rate in the 25-29 year age range in 1999/2000 being some 3.5 times higher than in 1985 (see graph). The mortality of young men has also increased,

Estimated increase in adult death rates relative to the 1985 death rates



however, the pattern suggested that this may be a combination of a rise during the early 1990s in injury-related deaths, that typically occur among men in their twenties, that began to fall in the late 1990s, and a more recent increase in deaths due to AIDS in a slightly older age group. Mortality in the 30-39 year age range in 1999/2000 was nearly 2 times higher than in 1985 (see graph), but obviously this is off a much higher base.

The pattern in the empirical data is largely consistent with that predicted by models of the AIDS epidemic, in particular the ASSA600 model developed by the Actuarial Society of South Africa, suggesting that it is reasonable to interpret an increase in young, adult mortality as being essentially a consequence of HIV/AIDS. We looked at alternative explanations for these patterns and found none of them plausible. In addition, we cite evidence from a number of sources in support of our interpretation.

While there is inevitably some degree of uncertainty because of the assumptions underlying both the model and the interpretation of the empirical data, we estimate that about 40% of the adult deaths aged 15-49 that occurred in the year 2000 were due to HIV/AIDS and that about 20% of all adult deaths in that year were due to AIDS. When this is combined with the excess deaths in childhood, it is estimated that AIDS accounted for about 25% of all deaths in the year 2000 and has become the single biggest cause of death. The projections show that, without treatment to prevent AIDS, the number of AIDS deaths can be expected to grow, within the next 10 years, to more than double the number of deaths due to all other causes, resulting in 5 to 7 million cumulative AIDS deaths in South Africa by 2010.

This study has demonstrated the value of supplementing the routine vital statistics with rapid mortality surveillance, making use of administrative data from the Population Register. The system needs to be formalized as rapidly as possible with the data being released routinely to inform research and policy. Further work to improve models and data is needed to develop the surveillance tool to meet the needs of provinces and local government and for assessment of the impact of interventions. Although there is an impressive consistency between the pattern of total deaths by age projected by the ASSA600 model and those captured on the Population Register, the discrepancies suggest that the model can be improved in a number of ways. Among these it is suggested that no allowance be made for a reduction in adult mortality since 1985 when estimating the non-AIDS mortality. In addition, the results suggest that the estimates of prevalence based on the early antenatal clinic survey data probably exaggerated the prevalence in those years. Various other recommendations are made including extending this work to the provincial level. It is also important to develop a mechanism to monitor the impact of the AIDS epidemic on the mortality of children.

The rapid change in the empirical death rates confirms predictions of the profound impact of AIDS on mortality. These shocking results need to galvanise efforts to minimize the devastation of the epidemic.

Introduction

The HIV/AIDS epidemic in South Africa continues to grow at a rapid rate. UNAIDS estimates that in 2000, 19.9 % of adults were infected, up from 12.9 % two years previously[1]. According to UN figures with an estimated total of 4.2 million infected (and some put the figure higher than this), South Africa is said to have more people living with HIV than any other country.

Reliable empirical data on the epidemic in South Africa are hard to come by. The main source of information is the series of annual antenatal seroprevalence surveys conducted by the Department of Health (DoH). These show that South Africa has experienced a very rapid spread of HIV during the last decade. In 1990, the first year of the survey, prevalence was less than 1% and by 2000 its level was nearly 25%[2]. This yearly survey, covering all the regions of the country, is conducted on a sample of the routine bloods taken from pregnant women who attend the public health sector for antenatal care. The majority of pregnant women (over 80%) make use of public antenatal care. This group of women makes an ideal sentinel group for monitoring the epidemic as they have recently had unprotected sex. In 1998 the protocol for this survey was revised to standardise procedures and sampling methodology across all the provinces. It was also changed to allow women to choose whether or not to be tested[3], however, it is thought that very few refuse. Not only does this change make it difficult to compare the figures of more recent years with earlier years, it also makes the recent data more difficult to interpret. Despite the observed anomalies in the provincial level results, this survey provides reasonably consistent data that form a foundation for surveillance of the epidemic.

Various projections of the demographic impact of HIV, based on the antenatal survey results, suggest that the disease will have a considerable impact on mortality in South Africa[4,5,6,7]. While the projections differ somewhat, they suggest that between 2000 and 2010, somewhere between four and seven million South Africans will die from AIDS[8]. This number of AIDS deaths will be considerably larger than that from any other single cause of death and will be almost double the number of deaths from all other causes combined over that period[8]. Model projections of the impact of HIV/AIDS have an important role to play in providing planning information. However, their accuracy depends on the many assumptions that are made in the model. Considering the magnitude of the epidemic, it is extremely important for South Africa to monitor AIDS mortality so as to provide reliable information for planning and to be able to assess the impact of interventions.

Routine mortality statistics are compiled by Statistics South Africa (Stats SA) from the vital registration system. The statistics are based on the medical certification of the cause of death, required by law, at the time of registration of the death with the Department of Home Affairs (DHA). However, the statistics are problematic, as death registration is known to have been incomplete and to suffer from misclassification of cause of death[9]. After 1994, the Government initiated extensive efforts to improve death registration and statistics[10]. These involved significant interdepartmental collaboration, the introduction of a new death certificate, dissemination of manuals on how to complete the death certificate and classify the cause of death, and the establishment of a task teams in each province to improve registration. Comparison with projections from the ASSA600 model (of the Actuarial Society of South Africa) suggest that the percentage of all deaths registered improved from a low of slightly more than 50% in 1990 to 78% in 1995 and over 80% in 1996.

Despite improved registration, delays continue to occur in the production of full cause of death statistics. The most recent detailed statistics are for 1996. Furthermore, cause of death statistics significantly underestimate the number of AIDS deaths. Due to the stigma associated with HIV and AIDS, details completed on the certificate tend to

focus on opportunistic infections or the mechanism of death rather than providing the underlying cause. Thus, the routine official death statistics fail to provide timely or accurate information on the extent of AIDS deaths and, at best, give under-estimated numbers some time later.

The Department of Home Affairs maintains the national population register on computer. It comprises administrative details of all persons who have been issued with a South African identity document. A unique identity (ID) number is allocated to each individual on the register. Death details are also included on the population register. This database provides information on the age and sex of dead individuals who were on the Population Register. Since many children are not registered, this data source does not provide adequate statistics on children.

This study investigates the trends in reported deaths up until 1996 based on the statistics from Stats SA and compares the results for adults with more recent data obtained from the population register. After adjusting for the under-reporting of deaths, the trend in the age pattern and the broad cause of death profiles are considered to assess the impact of HIV/AIDS on mortality in South Africa. The empirical data are compared with model estimates based on the ASSA600 AIDS and demographic model to assess the consistency of the empirical data with the model projections.

Data on Deaths

Data sources

Two reporting systems that provide data on deaths are considered here:

- **Firstly**, the routine cause of death data compiled and reported by Stats SA (formerly the Central Statistical Services) which have been published as official reports for many years[11] formed the main source of data. During the period covered in this technical report there have been two series of annual official mortality reports published: (03-09-01) which covered whites, coloureds and Asians from 1985 onwards, and a separate series (03-10-01) which covered deaths of Africans. Beginning with the report covering 1991, the series (03-10-01) was discontinued and series (03-09-01) continued under the new title of "Recorded Deaths". The new series no longer reported the population group of the deceased. These reports are published approximately 4 to 5 years after the year covered. The most recent year for which full cause of death statistics have been released is 1996[12]. In an endeavour to speed up the publication of mortality data Stats SA now releases a series (P0309.1), the advance release of recorded deaths. These advance reports do not contain cause of death data. The source of data for the official published statistics is based on the detailed cause of death information recorded on the medical certificate required for death registration. Once the forms are fully processed and archived by the Department of Home Affairs, Stats SA codes the underlying cause of death information according to international standards. The official published statistics for a given year contain data for that year which are received *up to a particular cut-off date*. (This date varied from year to year). Thus the official report for a given year not only omits some late registrations for that year,

but also contains late registrations for previous years. In this technical report we describe the tabulation of deaths processed in this manner as by "year reported". At the same time that the official printed reports were released, an anonymised micro data computer file of the individual records used to produce the report was released to researchers. Unfortunately this data was available in computerised form only for a limited time before the government agency destroyed the tape. (This practice ceased after 1994). Nonetheless the MRC has collected and preserved a complete set of these tapes dating from 1968 onwards. The most recent one is for 1996. By extracting the deaths for a particular year from the tape for that year, and for succeeding years, it is possible to obtain the numbers of deaths which actually occurred in that particular year (given, of course, that the death was registered). The final year in any such series will however still be subject to under-reporting. The mortality data are analysed in this technical report on the basis of **deaths by year in which they occurred.** This differs from the year in which the deaths were reported, which is the method of reporting used in the official published statistics. The details of the total number of deaths reported in each year in the official reports and number that actually occurred in each year are shown in Appendix A, Table A1. The deaths for the years 1985-1996 are also analysed and tabulated in Table A2 by age and sex; as well as in Table A3 by age, sex and broad category of cause of death (including, external, non-communicable, infectious/maternal and ill-defined natural causes). This is the first time that data for this period has been published by "year of occurrence".

- **Secondly**, permission has been obtained from the Department of Home Affairs to analyse the data on deaths that are included on the Population Register. These data were extracted electronically from the monthly log of the transactions on the register†. The register does not include all the deaths registered in a particular year but only those of people who are on the population register (i.e. those that have an ID number). Data from this source have been obtained for the period June 1999 through to the end of September 2000 and have been supplemented by data from the same source that were previously analysed by Stats SA for the Department of Health (covering the period mid-1997 to mid-1998) and data collected by the Department of Health on a monthly basis (from mid-1998 to mid-1999). The data had to be cleaned to remove duplicates that arose when administrative alterations were made to a death record on the Population Register and to remove a few cases which were missing information. The data set includes the cause of death information captured by the Department of Home Affairs. This is generally the cause specified in the top line of the medical section of the certificate, the immediate cause, or else simply "natural" and "unnatural". The cause of death information in this data set is not standardised but it is possible to categorise most of the data into natural causes and the external causes. These data for the period 1997/98 to 1999/2000 are tabulated in Appendix A, Table A4. Full details of the data cleaning exercise are reported in Appendix B. The consolidated data have been divided into three sets of annual data, by period of occurrence, for analysis by age, sex and natural/external classification. Stats SA is about to issue a report (in series P0309.1) on the advanced release of mortality covering the years 1997 - 2000 based upon data derived from the population register of home affairs. However, these figures will differ from those given in Table A4 not least because they will not be adjusted for undercount but also because of a slightly different method of extraction and a different calendar year of reporting.

†. The data include a personal identifier and are treated as confidential. They are stored under secure conditions, behind a firewall and with protected access keys.

Data limitations

All the death data suffer from under-reporting. In particular, there has been considerable under-registration in the rural areas of the Republic of South Africa and the former so-called independent homelands of Transkei, Boputhatswana, Venda and Ciskei (TBVC) were not included in the reporting system until 1994. However, registration has improved since 1994, particularly since the introduction of the new death certificate in 1998. It is not clear what effect the efforts to improve registration of deaths and the centralisation of the processing of death records since 1994 has had on the patterns of under-reporting by age.

Mortality patterns

The results for the period 1988-1996 (which are derived from Stats SA cause-specific data sets) are shown in Figures 1.1 to 1.3. The distribution of the number of registered deaths by age has a distinct pattern which is a function of both the age-specific death rates and the age structure of the population. Infants (age 0) account for the highest number of deaths and the number per age group then drops to a very low level for children aged 5-14. In the case of women, the number of deaths in each age group increases in a concave pattern to a peak in the 65-79 age groups. In the case of men, the number of deaths among young adults increases rapidly with age, giving the increase over the age range a convex shape. The relative number of deaths of young men varies from year to year. In all years, adult deaths reach a peak at ages 65-69 but from 1995 the peak in young adults is almost as high.

The cause of death profile for the women is fairly consistent over the years. In the case of men, fluctuations appear that are related to the number of deaths from external causes. The number of young adult male deaths in 1992 is low in comparison to 1991 and 1993. When the data were examined by place of death, the number of external deaths registered in Durban in 1992 was substantially lower than that registered in 1991 and 1993. However, data from the Gale Street Mortuary show that the number of external deaths in Durban was stable during this period, if not higher in 1992[13]. Thus it would appear that a batch of death certificates originating in the Gale Street Mortuary was omitted from the vital statistics for 1992.

The deaths reported for 1996 are shown in Figure 1.3. Compared with 1995, there were more deaths reported for both men and women, but they are distributed similarly by age although the proportion of infant deaths was slightly lower. The men's deaths have a broader, flatter peak in adulthood while for women a slight peak is emerging at ages 25-34 in addition to the peak in old age.

The age distributions of adult deaths from the population register of the Department of Home Affairs (DHA) are shown in Figures 2.1 to 2.3. For the 12 month period, mid-August 1997 to mid-July 1998, the number of deaths of adults over 15 years of age is almost equal to the total number of deaths in 1996. The adult deaths display a very similar age pattern to that in 1996. The numbers of adult deaths in 1998/99 and 1999/2000 show annual increases in the numbers and a shifting age pattern. By 1999/2000, the peak in the young adults is higher than that in old age for men while the female distribution has a distinct bi-modal pattern, with equally high peaks in early adulthood and old age.

Figure 1.1: Cause of death by age and sex by year of occurrence 1988 , 1989 and 1990 (Stats SA data)

Figure 1.2: Cause of death by age and sex by year of occurrence 1991, 1992 and 1993 (Stats SA data)

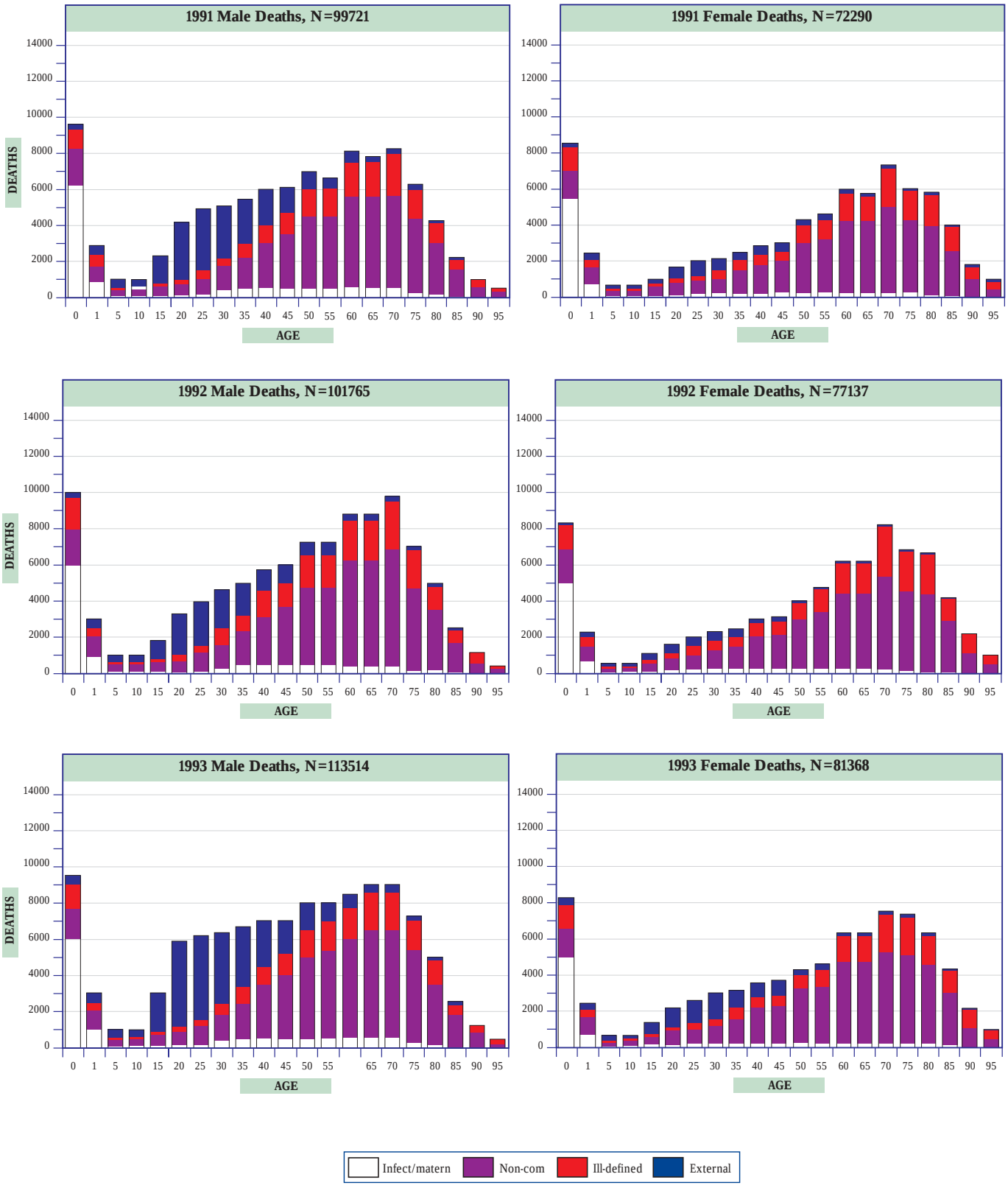


Figure 1.3: Cause of death by age and sex by year of occurrence 1994, 1995 and 1996 (Stats SA data)

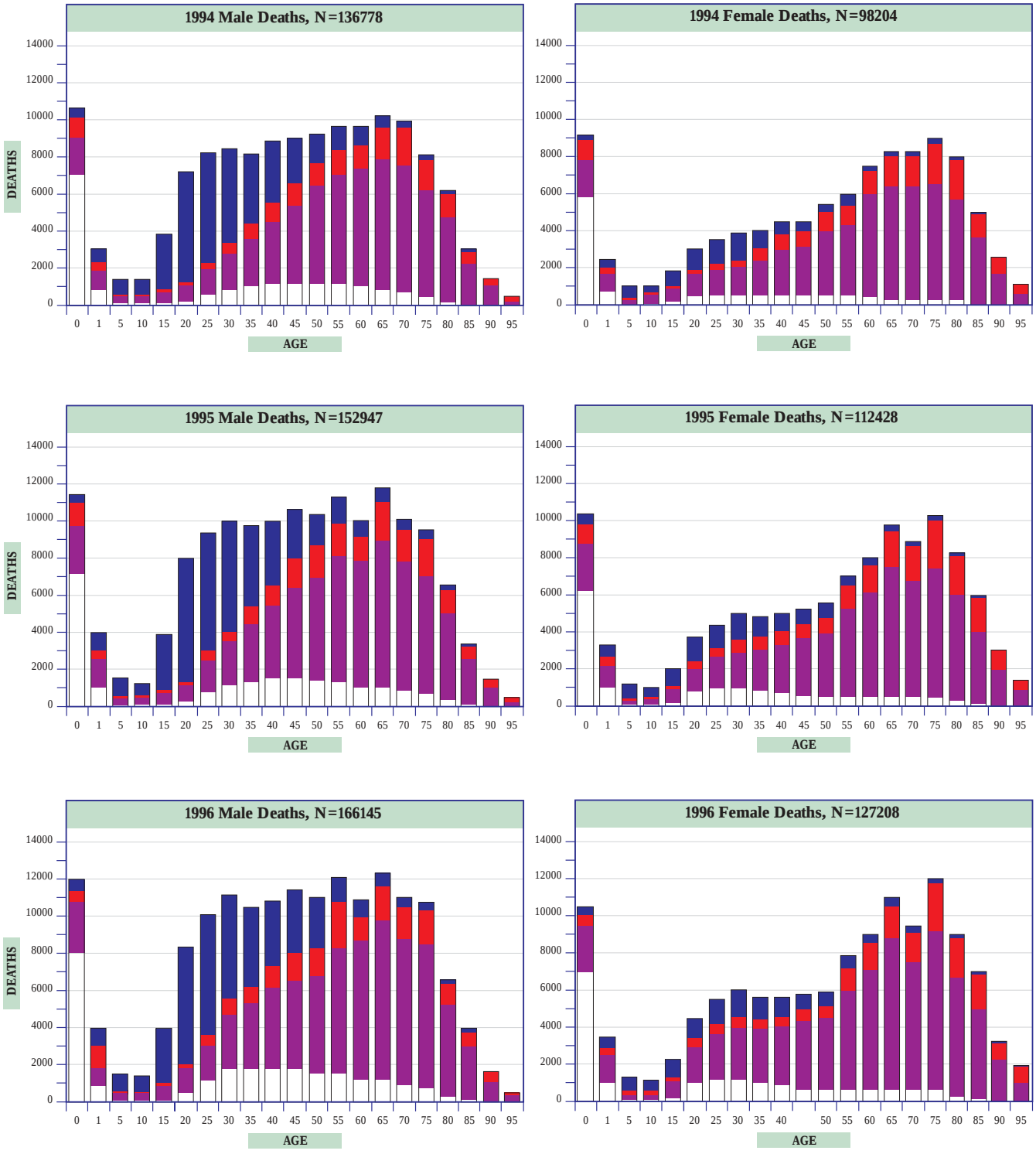


Figure 2.1: Adult deaths by age and sex by year of occurrence
August 1997 - July 1998 (DHA data)

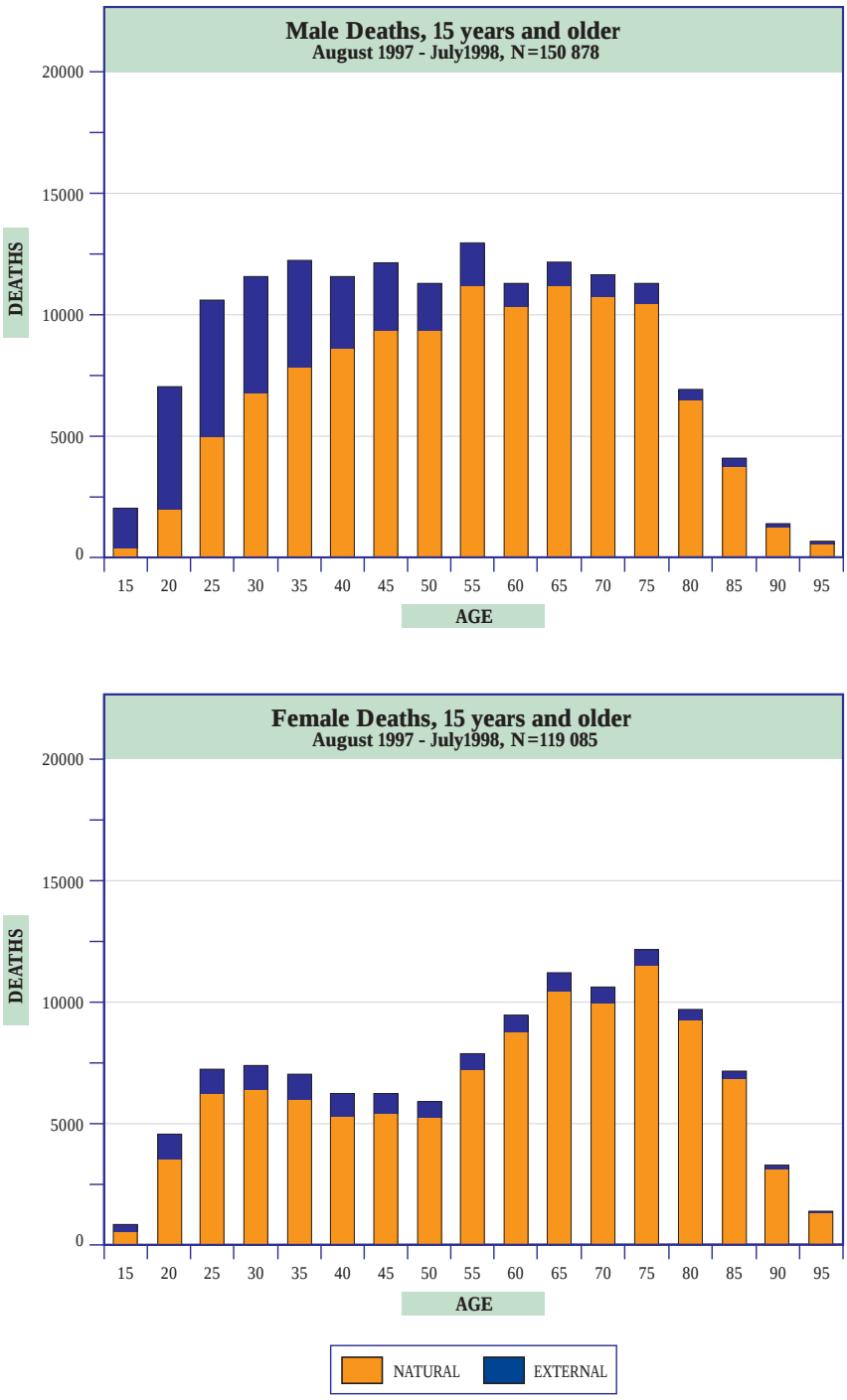


Figure 2.2: Adult deaths by age and sex by year of occurrence
July 1998 - June 1999 (DHA data)

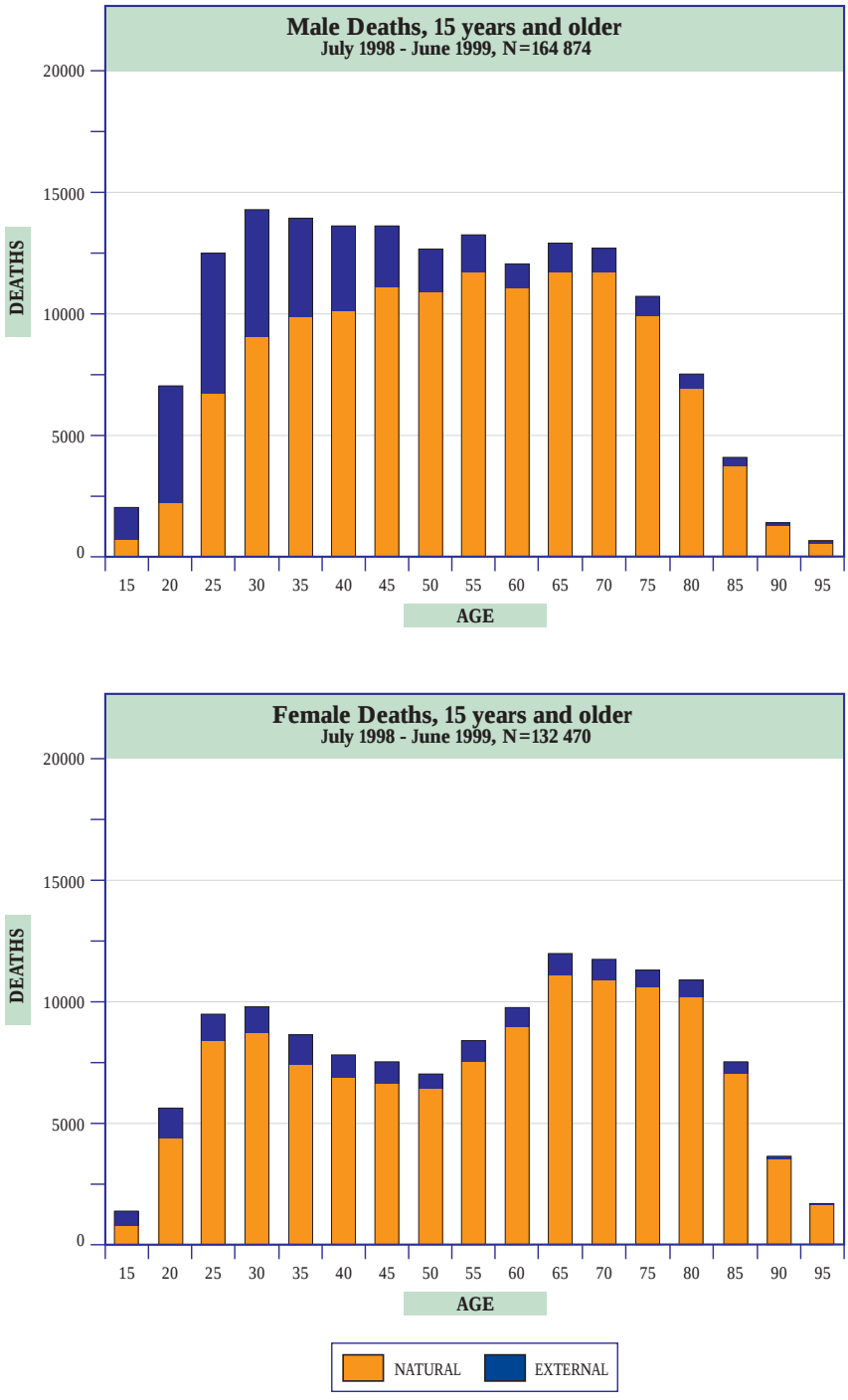
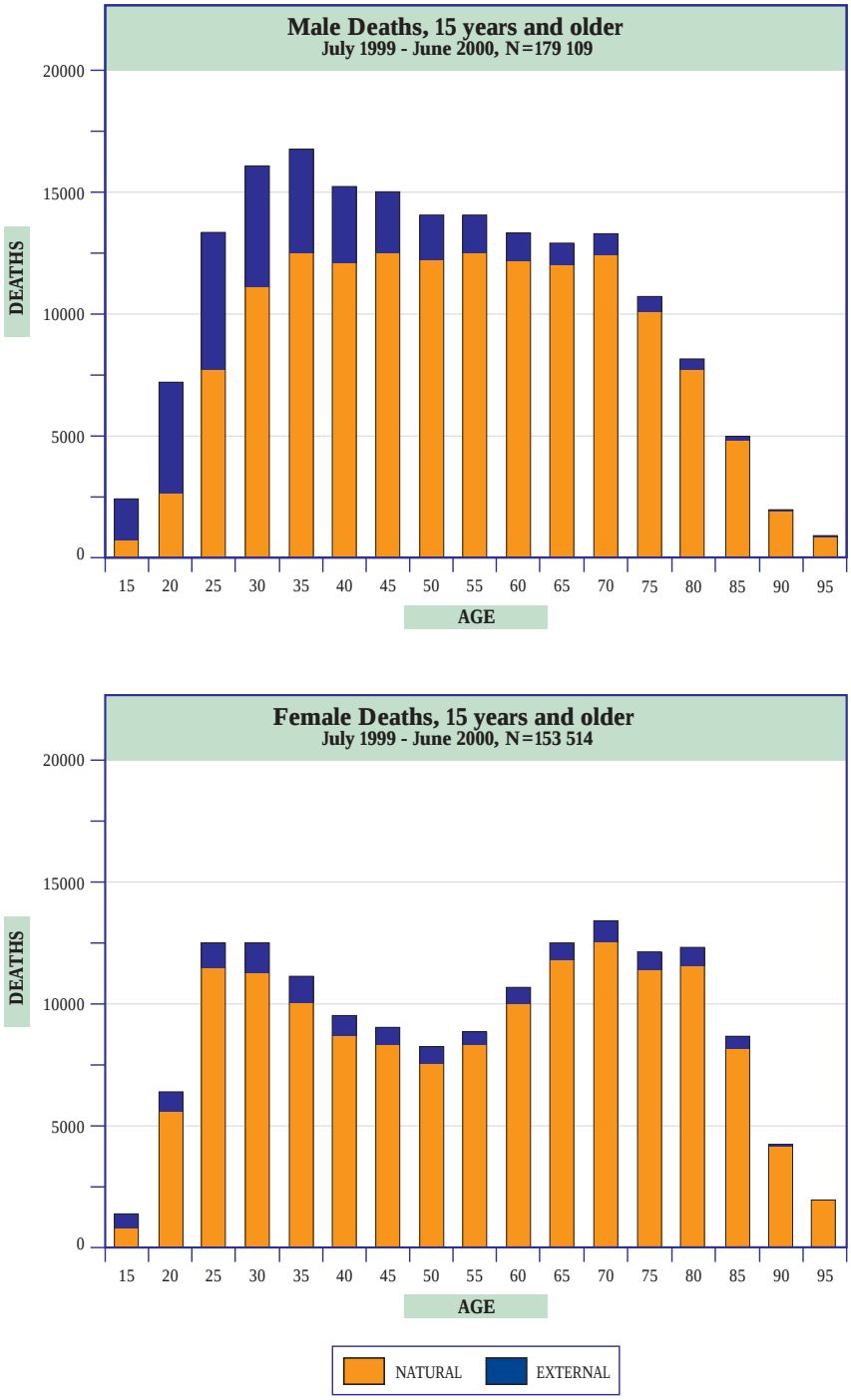


Figure 2.3: Adult deaths by age and sex by year of occurrence July 1999 - June 2000 (DHA data)



A simple summary index of the shift in mortality is the ratio of the sum of deaths aged 15-49 years to the sum of deaths aged 50 and over. The larger this ratio the more the deaths are skewed towards the young ages. This ratio was fairly level prior to 1990 but as can be seen from Table 1 it has been increasing since then and particularly rapidly in the most recent three years.

Table 1: Ratio of deaths aged 15 - 49 to deaths aged 50+ for reported deaths by year of occurrence and sex

Year	Ratio	
	Female	Male
1990	0.31	0.66
1993	0.37	0.73
1996	0.47	0.82
1997/98	0.57	0.88
1998/99	0.67	0.97
1999/00	0.78	1.00

Completeness of registration of deaths

Under-registration of deaths has long been known to be a problem in South Africa[9,16] and it is important to estimate the extent of under-reporting. Standard demographic techniques such as the Brass's Growth Balance method[14] or that developed by Bennett and Horiuchi[15] can be applied to the data for the years prior to 1990 because the deaths can be analysed separately for each population group. In particular, under-reporting can be assumed to be negligible in the non-black African groups and, importantly, to be constant over all adult ages for Africans. However, the fact that the age structures of the population groups differ and as a consequence the level of completeness of registration differs by age invalidates the assumption of constant under-reporting for all adult ages for the total population. An innovative approach[16] was developed for the analysis of the data for the period 1989-91 whereby the extent of distortion introduced by this heterogeneity could be estimated from the proportion of the total deaths that were in Africans in 1985. This was then used to estimate the extent of under-reporting by age for the black population group in this period. However, for the more recent years, the problem is complicated further by the fact that extrapolations from 1985 become less reliable and further distortions are introduced by AIDS deaths. For these years the completeness of death reporting and proportion of deaths that were in Africans in each age group were estimated iteratively for a range of assumptions about the completeness of reporting of deaths in adult Africans. We then determined which of these adjustments yielded complete reporting using the method proposed by Bennett and Horiuchi[17].

An additional complication is that the DHA do not computerise all deaths for which there is a death certificate. They only capture deaths of individuals on the Population Register, i.e., those for which an ID number or birth certificate exists. In order to allow for the deaths in persons with a certificate but no ID, the DHA data were scaled up by dividing by the proportion estimated to have IDs, estimated from an inspection of a sample of certificates. This correction has been incorporated in the data contained in Table A4 in Appendix A. Of course both of these adjustments assume that there is no bias in the under-registration.

In other words those not captured on the Population Register experience the same level of mortality as those registered. The impact of any selection bias on estimates of overall mortality is likely to be small as more than 90% of deaths registered at ages 15+ are of individuals on the register, suggesting that, even before their adjustment, the registration data cover more than 80% of all adult deaths

The estimated completeness of registration of adult deaths over the age of 15 for each year (relative to the population estimate from the ASSA model after first correcting the DHA data to allow for South Africans not on the Population Register) is shown in Table 2*. It can be seen that there has been a major improvement in coverage of death registration in the last few years, as a result of the national efforts of Government. It can also be seen that having adjusted for the improved registration, there has been a steady rise in the number of adult deaths during this last decade. Over this period while the population grew by about 37% the deaths have grown by some 73%!

Table 2: Number of deaths, completeness of registration and estimated number of deaths 15 years and older by year of occurrence

Year	Number of adult deaths registered	Estimated Completeness[17]	Estimated number of adult deaths
1989	141 876	60%	237 000
1990	129 256	54%	241 000
1991	145 587	59%	247 000
1992	152 485	61%	250 000
1993	168 489	57%	270 000
1994	205 266	73%	280 000
1995	231 932	79%	292 000
1996	258 220	85%	304 000
1997/98+	295 483	87%	339 000
1998/99+	326 761	87%	375 000
1999/2000+	366 790	89%	412 000

+ deaths from the Population Register, scaled up to allow for deaths reported but not on the Population Register

* These figures are approximations at this stage as the method is still being fine-tuned.

ASSA600

The ASSA600 AIDS and Demographic model[18] of the Actuarial Society of South Africa (ASSA) has been selected to model the impact of AIDS on mortality in this report. Described as a model of the "third kind", it is neither limited to a simple functional extrapolation of the past development of the epidemic (e.g. Epimodel) nor involves a complex micro-simulation of individual behaviour. It is rather a behavioural demographic component projection model, which models the heterosexual epidemic for the country as a whole, ignoring race and geographical heterogeneity. One advantage of this approach is that as well as modelling the impact of HIV on mortality it produces population estimates which can be assessed against those derived from elsewhere.

This particular model was chosen for two main reasons. Firstly, although ASSA is in the process of developing an improved model (ASSA2000), the latter model is not yet fully calibrated. When it is, it will be calibrated, inter alia, on the reported deaths, and hence comparison with the reported deaths will be of limited usefulness. Secondly, the main alternative, the Metropolitan-Doyle model, is proprietary, and is anyway similar in structure to the ASSA models. However, the ASSA600 projections are compared with those from other models as a check on their plausibility.

ASSA600 models the demographic impact of HIV/AIDS on the national population by assuming that the population (those aged 15 to 59 at the start of the epidemic and those subsequently turning 14 in each future year) can be split into four risk groups depending on the risk of transmitting/contracting the virus. These comprise the following:

1. a small, high risk group comprising sex workers and clients;
2. a much larger group, assumed to be at similar risk of transmitting/contracting the virus as people who regularly contract STDs;
3. an even larger group who are at risk because of their sexual behaviour, but don't have STDs; and
4. a similarly sized group who are assumed never to be at risk.

The model allows for the impact of HIV infection on fertility and further details are given in Appendix C.

As a default the projections assume no behavioural changes or interventions. The processes incorporated in the model are illustrated schematically in Appendix C, Figure C1. It has a very similar conceptual basis to the Metropolitan-Doyle model but it is non-proprietary and accessible on the internet[19]. It has been widely used in South Africa and also used to model the epidemic in some neighbouring countries.

Assumptions

The starting level of non-HIV mortality has been set to the level estimated for 1985 by Dorrington *et al*[16] with an annual decline ranging from 2,5 - 3% for young adults to about 0.5% at the oldest ages. Mortality in childhood is assumed to decrease at between 3% and 3,5% a year.

The probability of transmission of HIV infection from mother to child is assumed to be 25% at birth and 10% after birth. These infants are assumed to die at a rate of 30% per annum. A median survival time from HIV infection to death of 10 years is assumed for adults.

Calibration of ASSA600

The model has been calibrated to reproduce the antenatal data, as they are the most representative and reliable data available concerning the HIV epidemic in South Africa. In particular, the model was calibrated to reproduce the prevalence of HIV recorded by the national antenatal care (ANC) surveys up to 1997[20]. While there was a significant difference between the model and the 1998 survey results, the fact that model estimates pass between the point estimates for

1998 and 1999[21] (Figure 3) and are reasonably close to the age-specific 1999 survey results[21] (Figure 4), suggests that the inconsistency may originate in problems with the recent survey results[22,23,24] rather than inadequate calibration of the model.

Figure 3: Prevalence of HIV amongst antenatal attendees, ASSA600 estimates and annual antenatal survey

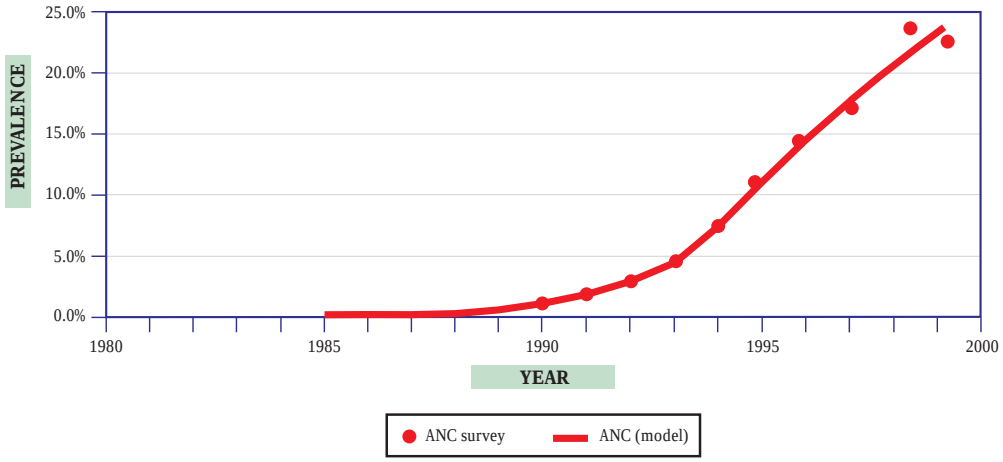
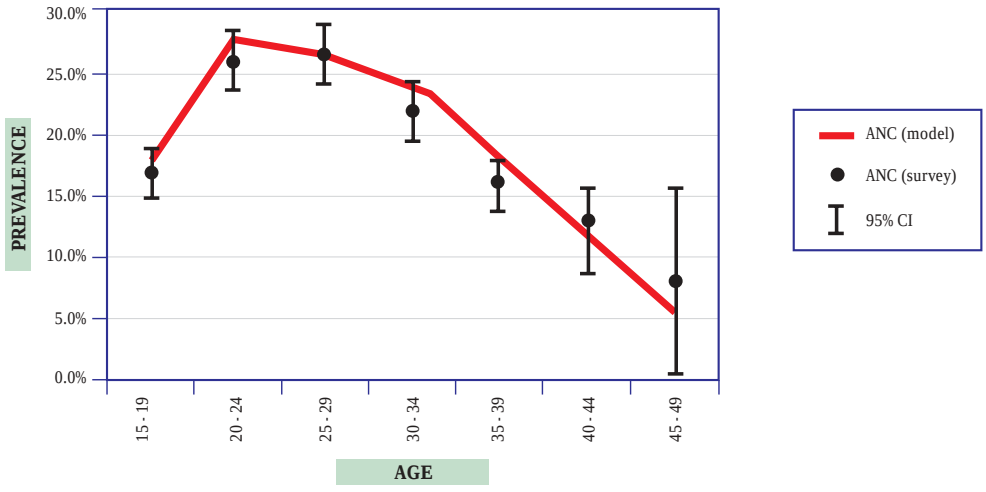


Figure 4: Age-specific prevalence of HIV amongst antenatal attendees, ASSA600 estimates and annual antenatal survey, 1999

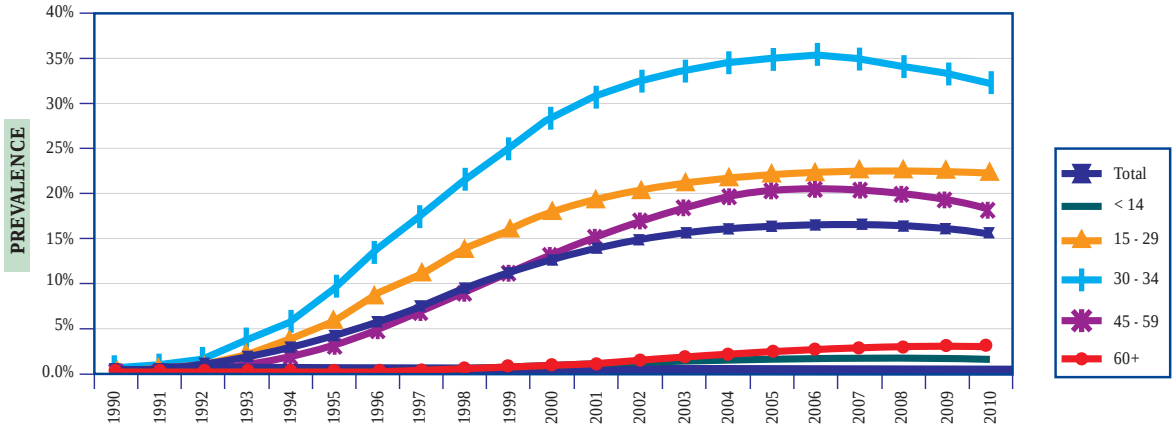


Further the model was parameterised to produce a population of 42.2 million as at the date of the 1996 census. It assumes net immigration, increasing rapidly from the early 1990s and levelling after 1996.

ASSA600 Projections

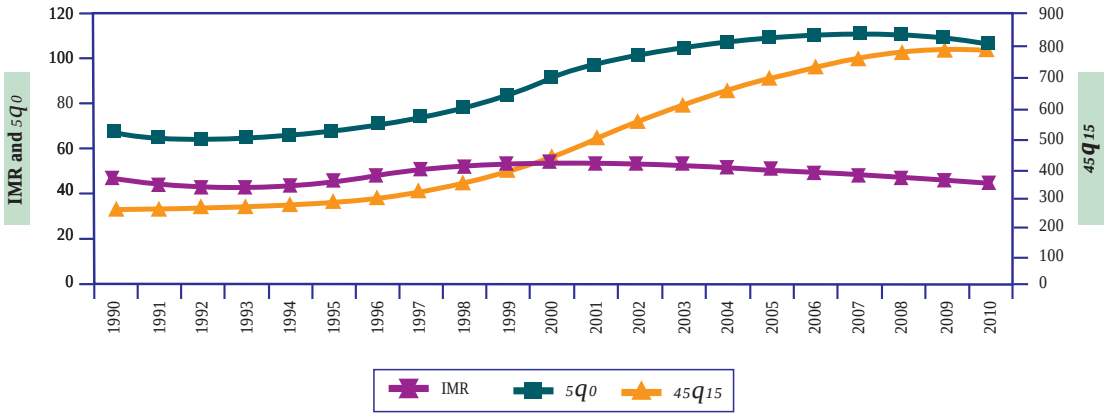
The ASSA600 model suggests that the population prevalence of HIV in 2000 is about 12% and that this proportion will stabilise by 2005/6 at about 15% (Figure 5). Infection will be most widespread in the 30-44 year old group, peaking at 35%.

Figure 5: Projected overall HIV prevalence by age group, ASSA600



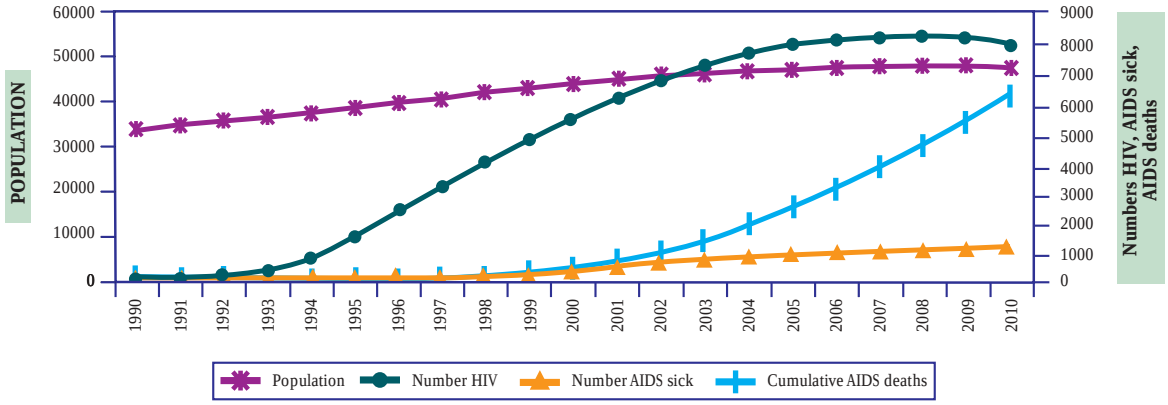
The epidemic will have an early impact on infant (IMR) and under-5 mortality ($_5q_0$). As a result of paediatric AIDS the death rate for infants under the age of 1 year will increase slightly rather than continuing to decline. Under-5 mortality will increase to double current levels (Figure 6). Premature adult mortality, indicated by the probability of a 15 year old dying before the age of 60, ($_{45}q_{15}$) will more than double, rising to as high as 800 out of 1000, i.e. 80%.

Figure 6: Projected mortality rates per 1000, ASSA600



From Figure 7 one can see that by the year 2010 the cumulative number of HIV/AIDS deaths is expected to exceed 6 million, while the number of AIDS sick people will be well over 1 million. The population growth rate will fall significantly such that while the population rises to 49 million in 2010, by that time it is barely growing.

Figure 7: Projected numbers of people living with HIV, AIDS sick and accumulated AIDS deaths (thousands), ASSA600



The changing pattern of ages at death and the proportion of deaths due to AIDS, as projected from 1990 to 2010, are shown in Figure 8. The increasing proportion of deaths due to AIDS, and the shift in the age structure can be clearly observed.

Figure 8: Projected age and sex pattern of number of deaths for 1990, 2000 and 2010, ASSA600
(note the axes differ for each graph)

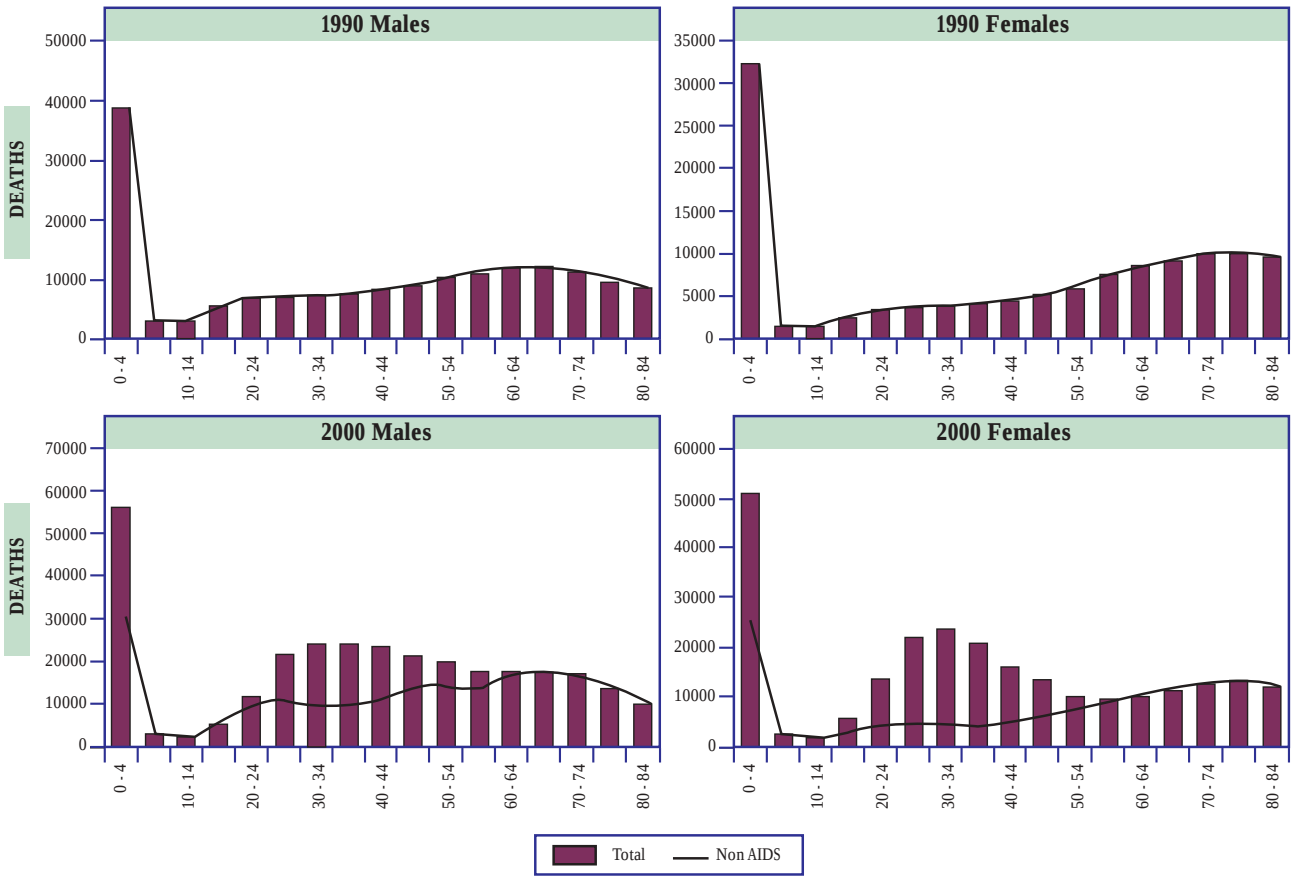
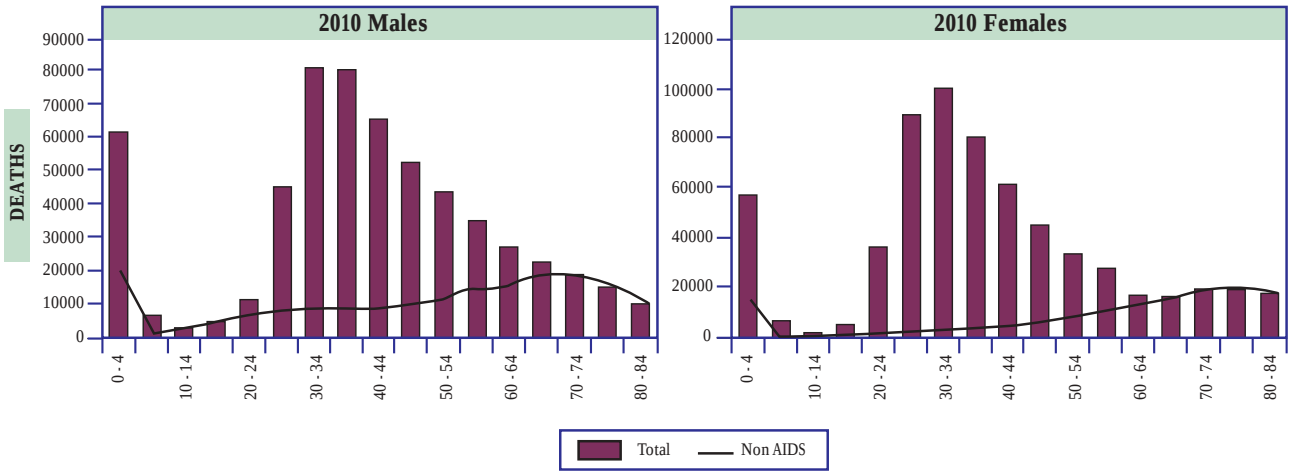


Figure 8 continues on following page

Figure 8 (continued): Projected age and sex pattern of number of deaths for 1990, 2000 and 2010, ASSA600



Comparison of ASSA600 projections with other models

In order to assess the plausibility of the projections made with the ASSA600 model, they were compared with those from three other models, one South African (the Metropolitan-Doyle model[5]) and two international world population projections (that used by the US Bureau of the Census[6], and that used by the UN[7]). None of the forecasts assumes any behavioural change or significant interventions over the period under consideration.

The balance equations of the four models between the years 2000 and 2010 are presented in Table 3. From this comparison we can see that the projections differ significantly in terms of the base population estimate. (In particular, the UN estimate for the year 2000 is below the 1996 Census estimate, which itself is thought by many demographers to be an underestimate.) The level of migration assumed also differs significantly (with, in particular, the US Bureau of the Census assuming net out migration). These differences in migration undoubtedly explain a large part of the difference in the midyear population estimates.

Table 3: Balance equations (figures in thousands)

	US Bureau of the Census	United Nations	Metropolitan-Doyle	ASSA600
Midyear population 2000	43 421	40 377	42 719	**46 079**
+ Births	8 327	10 125	9 573	**11 072**
- Deaths: non-AIDS	3 173	2 598	3 911	**3 399**
- Deaths: AIDS	6 999	5 402	3 755	**5 931**
+ Net immigration	-468	13	0	**1 515**
Midyear population 2010	41 108	42 515	44 626	**49 336**

Projections of mortality in South Africa

In order to better compare the forecasts, the figures were recast assuming the same base population and level of migration as for the ASSA600 projections (Table 4). The latter figures suggest:

- the impact of HIV/AIDS is projected to be significant (between 4 and 7 million deaths in the next 10 years)
- the number of non-AIDS deaths in the Metropolitan-Doyle model appears to be high
- the number of AIDS deaths forecast by both the UN and the US Bureau of the Census models appears high
- the number of births in the UN forecasts appears high (this might explain why their projections do not forecast a drop in population despite assuming high mortality), while the number of births in the US Bureau of the Census forecasts appears to be on the low side
- given the pattern of deaths exhibited by the ASSA600 model (Figure 10 on pages 26-27) the ASSA600 estimate of non-AIDS deaths is probably a little on the low side (as shown by the under-estimate of male deaths) and the AIDS deaths a little exaggerated (as shown by the exaggeration of the female deaths).

Table 4: Recast of balance equations to ASSA600 base population and migration
(figures in thousands)

	US Bureau of the Census	United Nations	Metropolitan-Doyle	ASSA600
Midyear population 2000	*46 079*	*46 079*	*46 079*	**46 079**
+ Births	*9 626*	*13 451*	*11 341*	**11 072**
- Deaths: non-AIDS	*3 668*	*3 451*	*4 633*	**3 399**
- Deaths:AIDS	*8 091*	*7 176*	*4 449*	**5 931**
+ Net immigration	*1 515*	*1 515*	*1 515*	**1 515**
Midyear population 2010	*45 461*	*50 417*	*49 853*	**49 336**

Figures in italic have been eatimated by the authors

Comparison of the estimates of the impact of HIV/AIDS

The HIV/AIDS related output of the models (where available) for the years 2000 and 2010 are shown in Table 5 and Figure 9. These results suggest that:

- the models all project a significant increase in mortality and a drop in life expectancy of between five and 16 years over the next 10 years;
- the forecasts of HIV prevalence from the Metropolitan model, particularly in the oldest age groups, appear low;
- according to the US Bureau of the Census forecast, over a million AIDS deaths have already occurred in South Africa. This seems unlikely;
- the US Bureau of the Census estimates for child mortality are much higher than the estimates from the other models;
- so is the US Bureau of the Census's estimate that nearly a quarter of the total population will be HIV positive by 2010, with over 50% of the 30-44 year olds being infected; and
- as a consequence, their estimate of life expectancy of 35 years seems low (while the UN's estimate of 46 years may be on the high side).

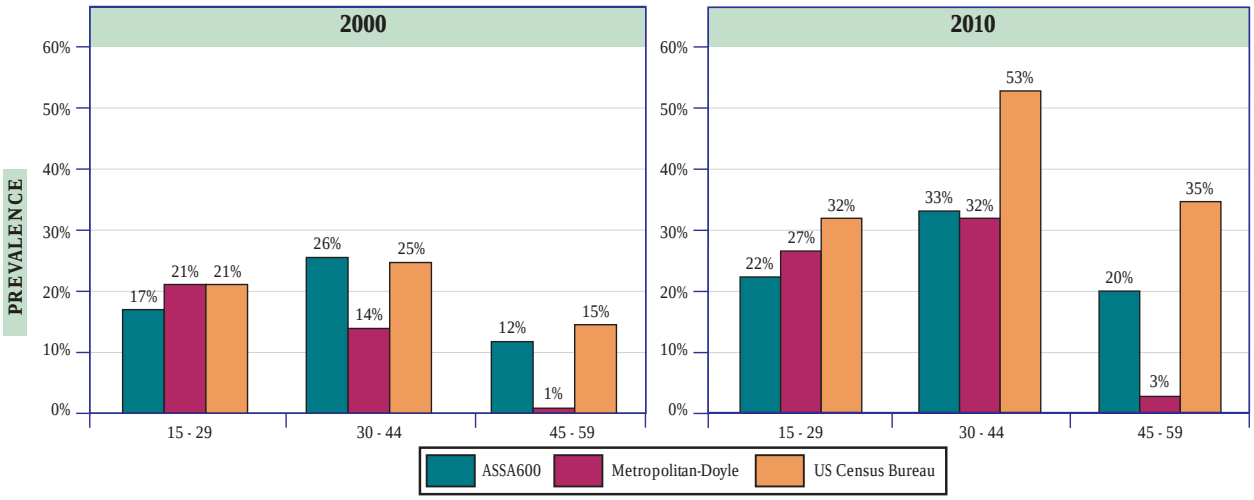
Table 5: Comparison of output of the models (figures in thousands)

2000	Total HIV	Total HIV (recast)	Total Mortality: AIDS deaths to date	IMR	Child $_5q_0$	Adult $_{45}q_{15}$	Life expectancy
ASSA600	**5 437**	**5 437**	**517**	**54**	**95**	**419**	**55**
Metropolitan	3 755	*4 050*	352	*60*	*97*	n/a	55
US Bureau of Census	*5 578*	*5 919*	1 043	59	120	498	51
United Nations	*4 335*	*4 947*	1 069	61	96	n/a	51

2010	Total HIV	Total HIV (recast)	Total Mortality: AIDS deaths to date	IMR	Child $_5q_0$	Adult $_{45}q_{15}$	Life expectancy
ASSA600	**7 992**	**7 992**	**6 449**	**48**	**106**	**790**	**40**
Metropolitan	6 484	*7 168*	4 107	*59*	*120*	n/a	39
US Bureau of Census	*10 135*	*12 164*	8 042	67	147	840	35
United Nations	*6 692*	*7 766*	6 471	58	103	n/a	46

Figures in italic have been estimated by the authors
n/a - Figures could not be supplied

Figure 9: Age-specific prevalence of HIV projected by ASSA600 and Metropolitan/Doyle Models in 2000 and 2010



It is interesting to contrast the above mortality estimates with those recently published by the WHO[28]. The WHO estimates for 1999 are:

- child mortality ($_5q_0$) of 76 per thousand (i.e. lower than any of the preceding estimates for 2000)
- adult mortality ($_{45}q_{15}$) of 567 per thousand (i.e. higher than any of the preceding estimates for 2000)
- life expectancy of 48 (i.e. lower than any of the preceding estimates for 2000).

Comparison of reported deaths and model projections

Numbers of deaths

Figure 10 compares the number of deaths projected by the ASSA600 model with the number of reported deaths and the number of reported deaths adjusted for under-reporting. From these figures it appears that the model has underestimated the number of deaths of men and exaggerated the number of deaths of women. In total the model appears to underestimate the adult deaths by 5-7% (see Table D1 in Appendix D).

The deficit of deaths of men is likely to be the result of two factors. The first is that the estimate of the national mortality derived by Dorrington *et al*[16] was based on deaths by year reported instead of by year occurred. The authors show that had year of occurrence data been used, the mortality rates for males would have been higher. The second is an underestimating of the non-AIDS deaths, particularly those due to violence and accidents, as the forecast assumes that non-HIV/AIDS mortality improves over time and this appears not to have happened during the late 1980s and early 1990s. Although the problem appears to correct itself by 1999/00, this could be because the reported deaths for this year have not been adequately adjusted for under-reporting, although some of it could be due to late registration of deaths not yet fully accounted for.

The excess in deaths of women appears to result from overestimation of AIDS deaths. Given that the median time to death of women with HIV is assumed to be 10 years, which is quite high (i.e. a low mortality rate), the excess suggests that the problem originates with either the ANC survey estimates or the extrapolations from these estimates to the total population. We believe that the early ANC results may have been biased upward, probably as a result of sampling predominantly urban clinics.

Nonetheless the model appears to track the total empirical deaths quite closely.

Age-specific death rates

Adjusting for the under-registration of deaths, age-specific rates in the age range 15-64 are shown in Figure 11. These rates show, with

Figure 10: Comparison of reported deaths (Stats SA) with model projections 1990 to 1999/00

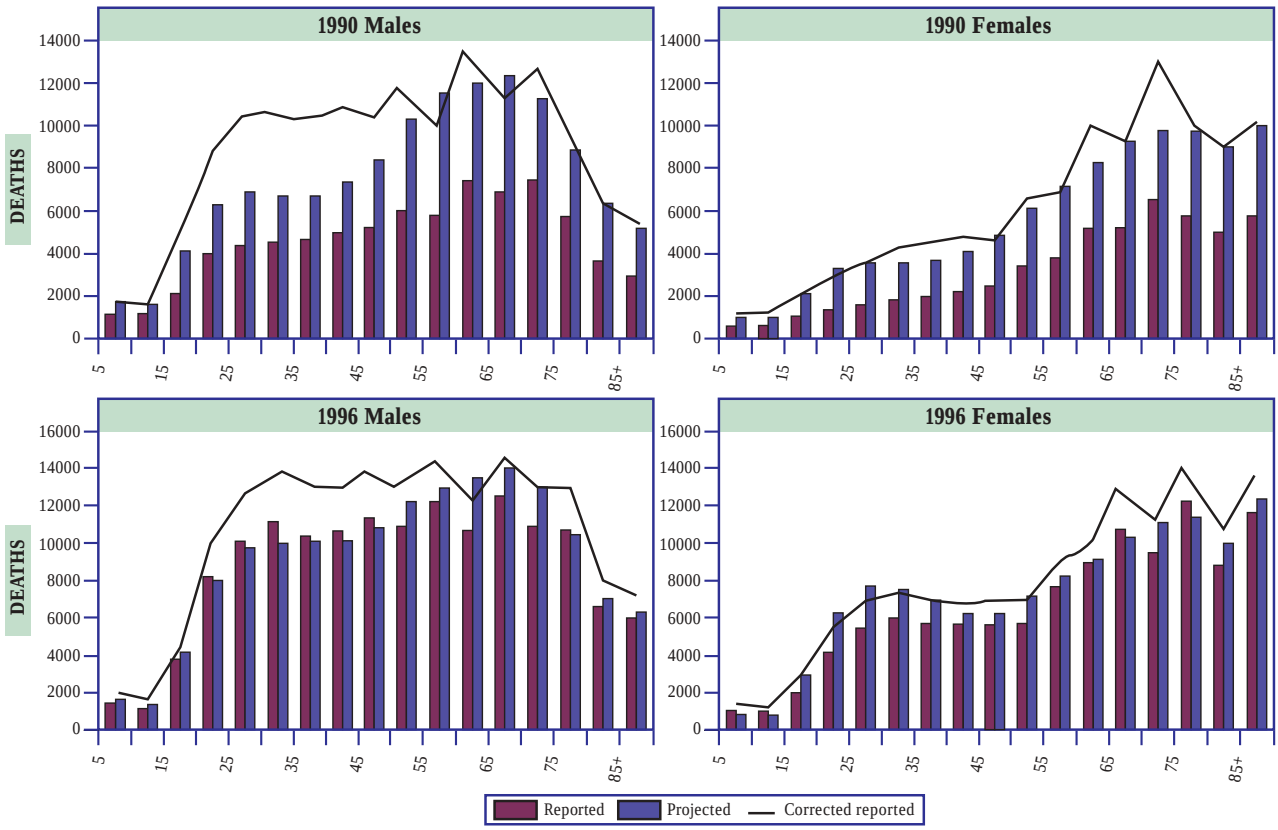
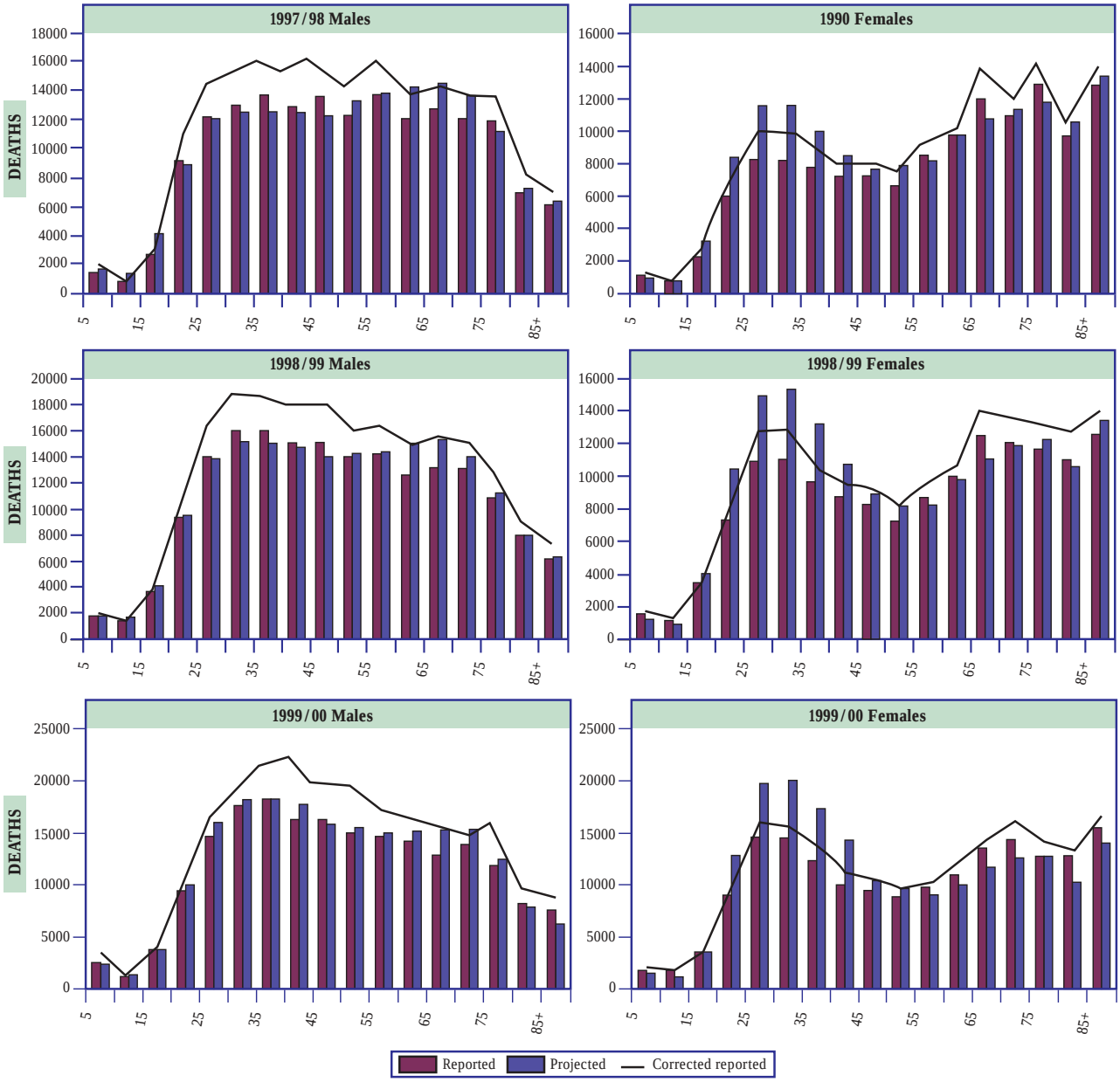


Figure 10 (continued): Comparison of reported deaths (DHA) with model projections 1996 to 1999/00



the exception of those for 1992, that there has been a slow increase in adult death rates. In the case of men, there was an increase over the 20-29 year age range in the early 1990's, followed by an increase in the age range 29-59 in the most recent years. In the case of women, there was a slight increase up until 1996, followed by a marked increase in the 20-49 year age range over the last two years, with the emergence of a young adult peak.

The relative rates for selected later years, compared with the rates for 1985, are shown in Figure 12. The later years have been selected as it is during the last few years that rapid change has occurred. It can be seen from these plots that the rate for women aged 25-29 is now more than 3 times higher than in 1985. The increase in the death rate for men in the 30-40 year age range is lower, mainly reflecting higher baseline mortality.

Comparison of reported deaths and model projections

Figure 11.1: Age-specific mortality rates for males 1985 - 2000

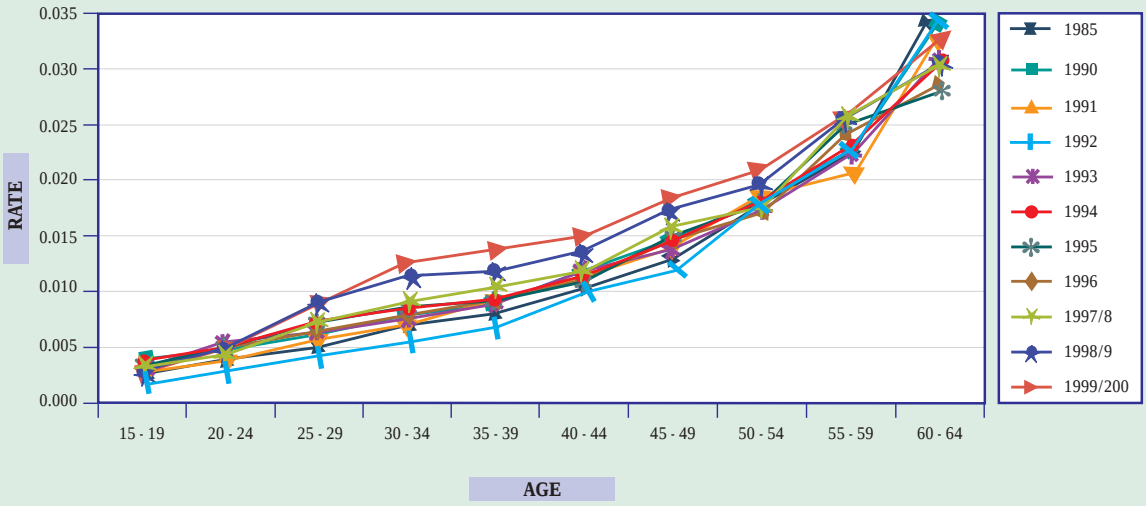


Figure 11.2: Age-specific mortality rates for females 1985 - 2000

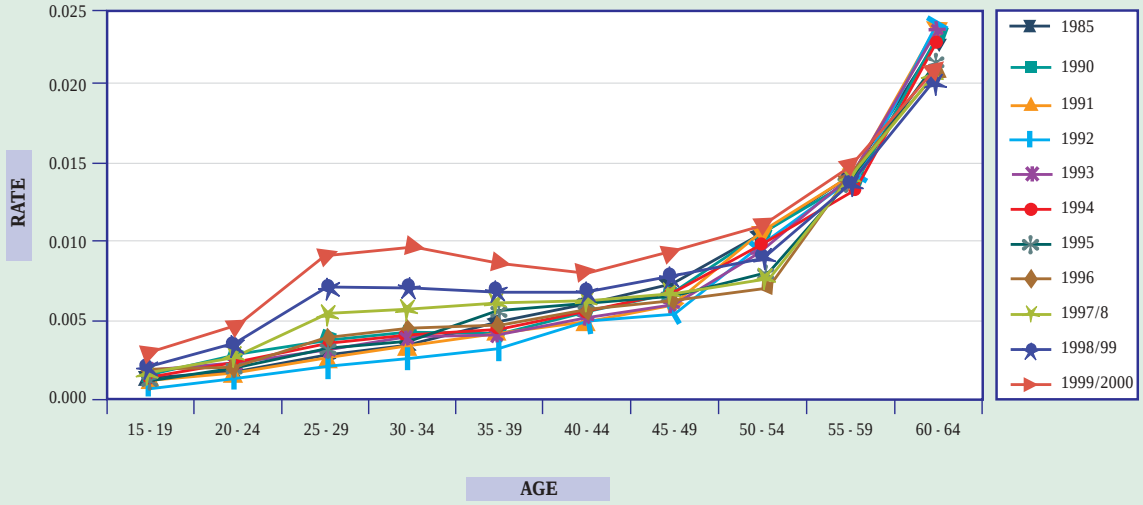


Figure 12.1: Relative mortality rates for males 1994 - 2000 compared to 1985

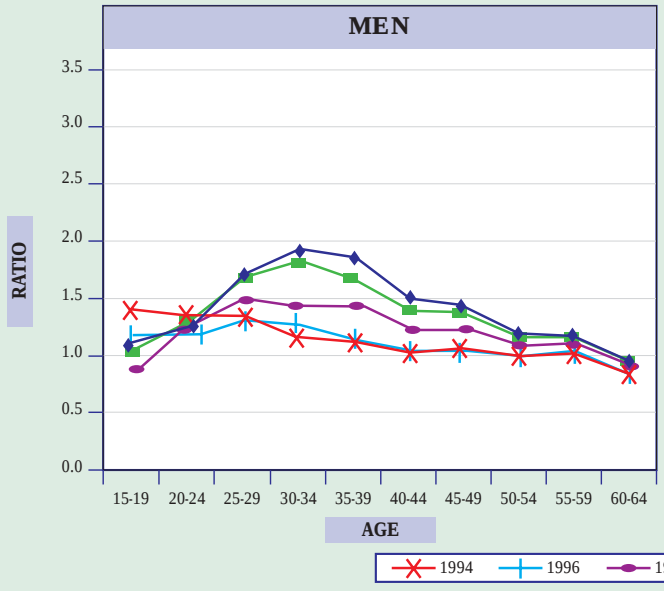
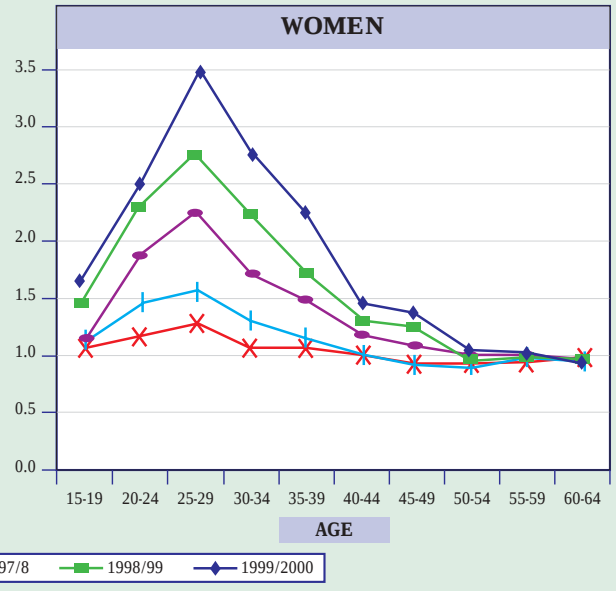
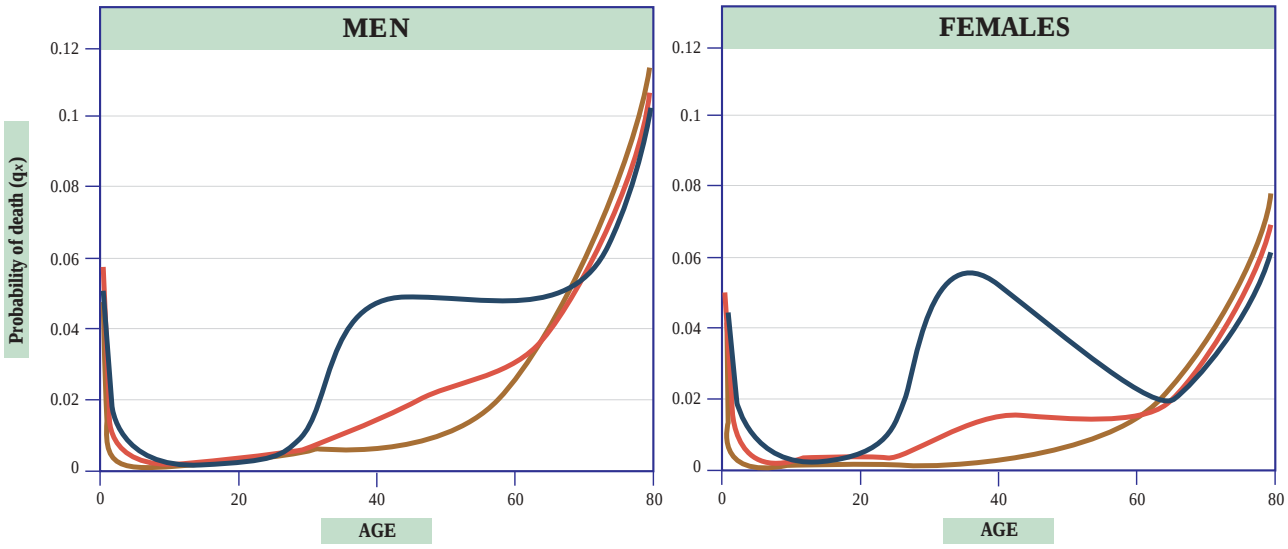


Figure 12.2: Relative mortality rates for females 1994 - 2000 compared to 1985



The patterns exhibited by the registration statistics are consistent with the projected patterns from the ASSA600 model shown in Figure 13. This pattern of mortality increase is not unique to the ASSA model but has been predicted by other models of the AIDS epidemic[29]. It is therefore reasonable to interpret the rise in the mortality of young and middle-aged adults in South Africa since the late 1980's as being largely, if not entirely, a consequence of HIV/AIDS.

Figure 13: Mortality rates for males and females for 1990, 2000 and 2010 ASSA600



Estimates of the number of deaths due to AIDS

In 1996, the most recent year for which we have cause of death details, a total of 7031 deaths had AIDS recorded as the underlying cause (ICD-9 code 209)[12]. Of these deaths, 6045 were age 15 years or older, accounting for 2.1% of the adult deaths reported in 1996.

There are two ways in which the proportion of deaths that are AIDS deaths can be estimated from the information presented in this study. The first is to use the estimates of AIDS and non-AIDS deaths from the ASSA600 model. Alternatively, if it is assumed that the excess mortality in the reported deaths, adjusted for under reporting that has occurred since 1985, is all AIDS-related, it is possible to estimate AIDS deaths from the registration statistics. Both these approaches are used and their limitations are discussed.

The ASSA600 forecast assumes that the underlying death rates from non-AIDS related causes has improved at a rate of 2.5-3% per year since 1985 in the young adult ages. This is in keeping with the Global Burden of Disease[30] projections of future mortality. Based on this forecast, the proportion of adult deaths related to AIDS has increased steadily from less than 10% in 1995/96 to 40% in 2000/01 (Table 6). Alternatively if the excess mortality, above that in 1985, is taken as AIDS related, then approximately 39% of adult deaths aged 15-49 and 17% of all adult deaths in 1999/00 were due to HIV/AIDS.

Table 6: Percentage of adult (15+) deaths due to aids estimated from ASSA600

Year Starting 1 July	% of deaths due to AIDS
1995	9%
1996	14%
1997	19%
1998	26%
1999	33%
2000	40%

Thus probably somewhere between 17% and 33% of adult (15+) deaths in 1999/2000 were due to HIV/AIDS. However, as was mentioned earlier the ASSA600 model probably underestimates the non-AIDS deaths and exaggerates, the AIDS deaths. So we can probably narrow the range to 17% to 25%. Comparison of the proportion of adult deaths in 1996 that were reported as AIDS (2.1%) with the estimated proportion based on ASSA600 (11%) shows that despite the exaggeration in ASSA600 there is probably substantial under-reporting of AIDS as an underlying cause of death. We estimate that around a third of AIDS deaths are recorded as such.

Deciding whether the excess deaths (over and above what would have been expected on the basis of 1985 mortality rates) are due to HIV/AIDS is obviously difficult in the absence of accurate information as to the cause of death. A number of alternative explanations have been proposed for these patterns of death[31].We examine each of these in some detail below to show that none offer a plausible alternative. Following this we cite additional evidence in support of our interpretation.

Alternative explanation

Several alternative explanations for the observed pattern of mortality change have been suggested.

(a) The 1990 death statistics are not geographically comparable with those of 1999/2000 and the addition of more rural African deaths could account for the change in the patterns of observed mortality.

The adjustment we have made for under-reporting in the 1990 data covers both under-reporting within the former RSA and the missing TBVC homeland data. As can be seen in Figures 14.1 and 14.2, while the adjustment affects the overall number of deaths, it does not significantly alter the age pattern of adult deaths in 1990, and hence the missing rural African deaths could not account for the observed change in pattern of mortality.

Figure 14.1: Age distribution of total male deaths (5 years and older), reported and corrected for under-reporting for 1990

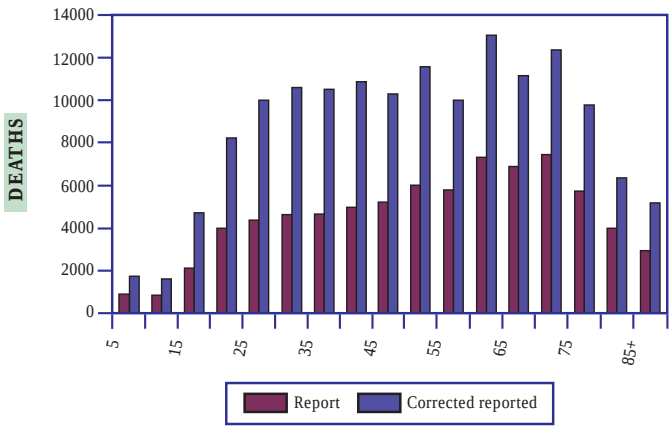
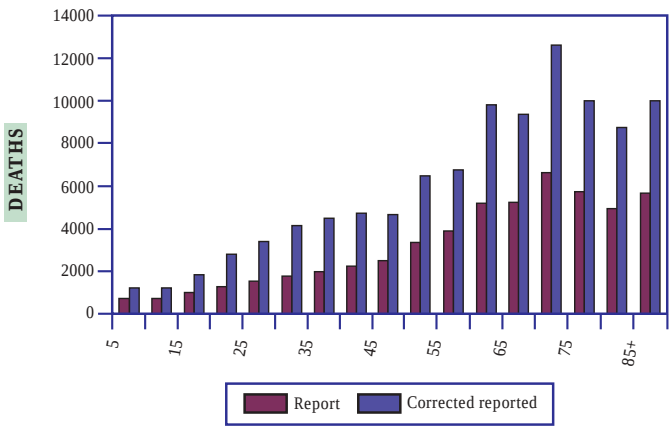


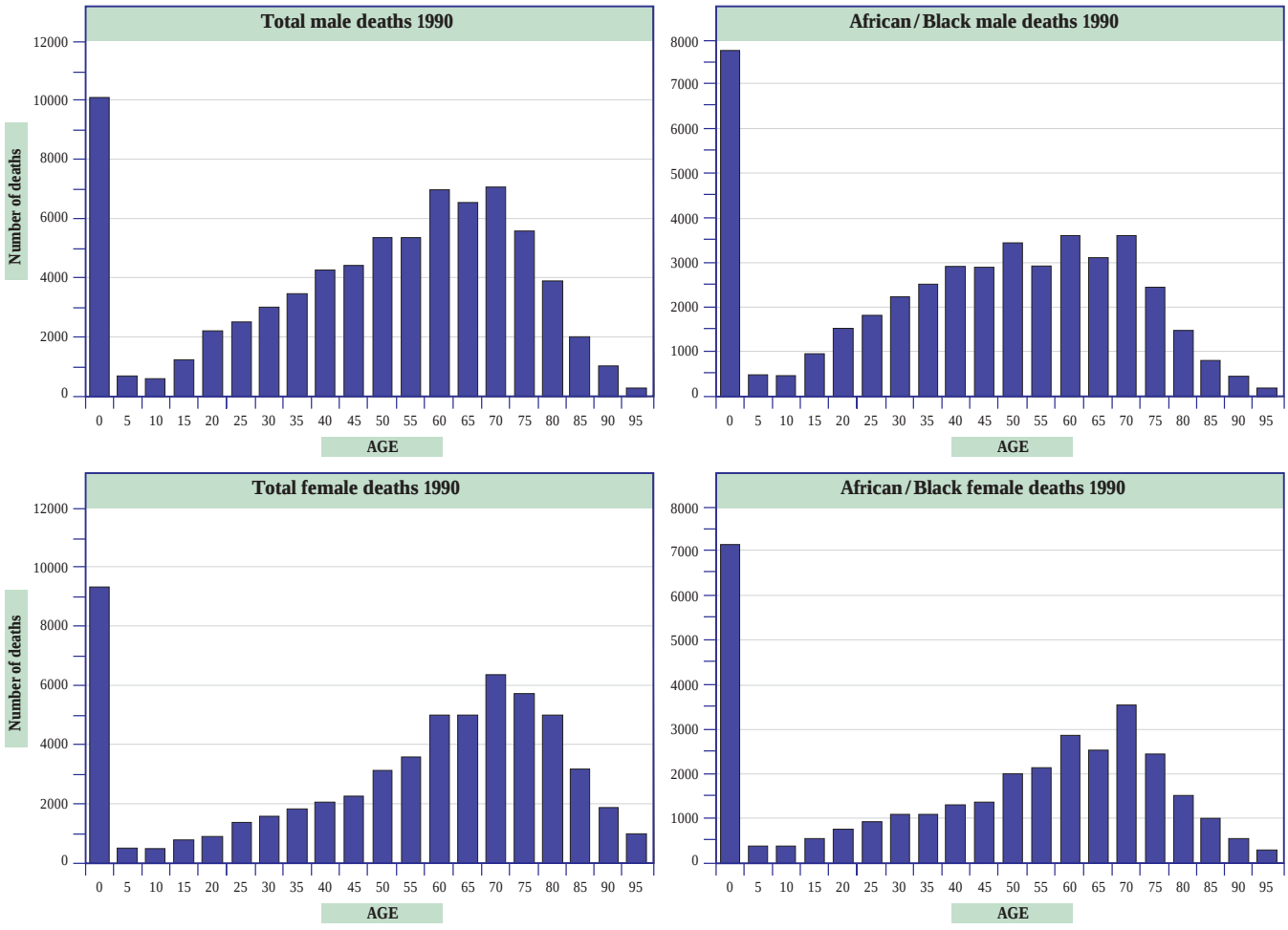
Figure 14.2: Age distribution of total female deaths (5 years and older), reported and corrected for under-reporting for 1990



(b) *The age distribution of deaths among Africans and those among non-Africans are different. The age distribution of the African population is younger than that of the other population groups and deaths of Africans therefore occur at younger ages than those of the other population groups. Since the 1990 data under-represented Africans, this could account for the difference between the patterns in 1999/00 and 1990.*

It is true that, on the whole, deaths in Africans tend to occur at younger ages than those of the other population groups. This is as a result of Africans' shorter life expectancy and the age structure of the population. However, the age distribution of the deaths of Africans in 1990 shows the mode for the adult deaths is still in old age for both men and women. Thus the under-representation of Africans cannot account for the differences observed in 1999/2000, particularly in the case of females, where the age distribution of adult deaths has become bi-modal and the peak for the younger adults is higher than the peak for the older women. In the case of men, the mode of the adult deaths has shifted from the older ages to the younger ages. Furthermore, the age distribution of the people living in the homelands is biased towards the very young and the very old, making it unlikely that inclusion of them in the statistics could explain the relative increase among young adults. Figure 15 shows the age distributions for the deaths reported in 1990 and the African deaths reported in 1990. Comparing these with the deaths recorded on the register in 1999/2000 it is clear that the 1999/00 profile is indeed a drastically new profile.

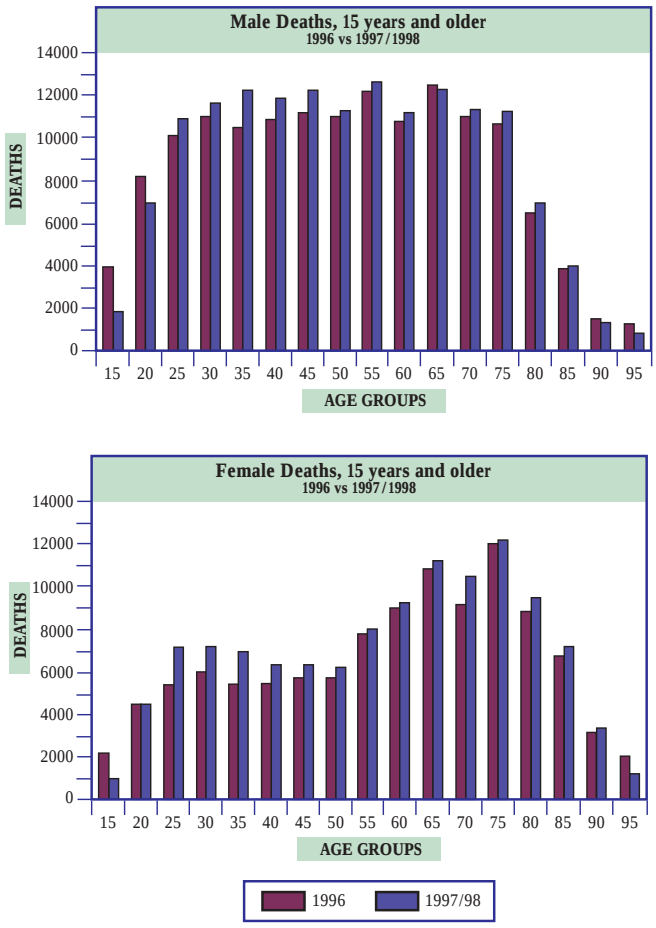
Figure 15: Age distribution of total reported and African/Black reported deaths 1990



(c) *The latest data are derived from a different source from that of the earlier data and this may cause a bias.*

The break between the Stats SA and DHA data series occurs between 1996 and 1997/98. There is currently no period of overlap between the data sources which would enable a definitive comparison between the two. However, the data for 1996 from Stats SA and the data for 1997/98 from DHA (Figure 16) exhibit a very consistent age pattern for both men and women. The DHA data contain fewer deaths in the two younger age groups, which can be ascribed to the large numbers of young persons who have not yet obtained an ID document. This has been taken into account in the estimates of the rates.

Figure 16: Comparison of 1996 Stats SA deaths and Home Affairs 1997/98 deaths



(d) *The change in mortality is caused by political violence.*

Figures compiled by the SA institute of Race Relations[32], from contemporary newspaper reports and monitors (not from official mortality data) illustrate the rise and fall of deaths from political violence in South Africa (including the TBVC states) during the period covered by this report (Table 7). The number of deaths from political violence had declined to the level of a decade earlier by the time that AIDS deaths begin to emerge.

Table 7: Deaths from political violence in South Africa (including TBVC states) [32]

1985	879
1986	1298
1987	661
1988	1149
1989	1403
1990	3699
1991	2706
1992	3347
1993	3794
1994	2476
1995	1044
1996	683
1997	470

Discussion

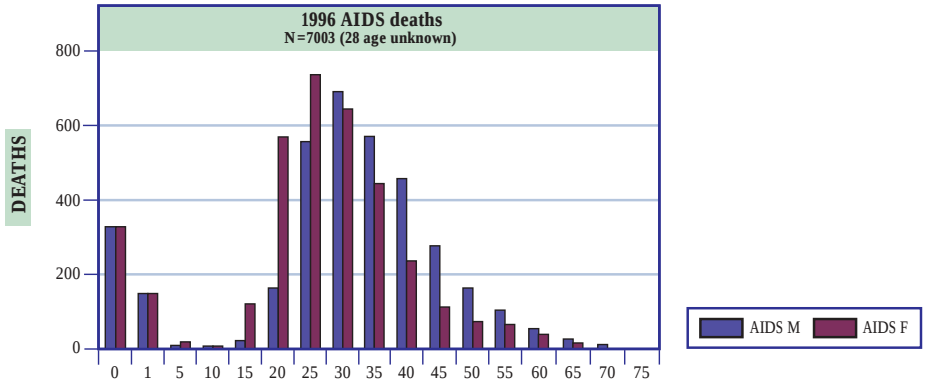
Additional supporting evidence

Additional evidence supporting the hypothesis of increased AIDS deaths among the young adults can also be found in the following:

(i) *Age distribution of reported AIDS deaths*

The age distributions of the AIDS deaths recorded by Stats SA in 1996[12] are presented in Figure 17. While there is clear under-reporting of AIDS deaths, the age distributions are in agreement with the ASSA600 model, with female deaths peaking at 25-29 years and males peaking at 30-35 years.

Figure 17: Age distribution of reported AIDS deaths, South Africa 1996 [12]



(ii) *The confidential enquiry into maternal deaths*

The 1999 confidential enquiry into maternal deaths of the Department of Health[33] states:

"The impact of the AIDS epidemic is clearly demonstrated, AIDS being the commonest cause of maternal death at all levels of care in South Africa".

The report further states that only 35.5% of maternal deaths had previously undergone HIV testing, but 68% of these were positive. Although it is unlikely that this was a randomly chosen sample, such high prevalence is a strong indication of an association between HIV and maternal deaths.

(iii) *Data from Durban cemeteries*

The numbers of burials in Durban cemeteries has increased dramatically in recent years (Table 8). According to the Director of cemeteries and crematoria for the Durban North and South Central area, in the early 1990s most of the people buried were victims of violence, but since 1996 the trend has changed with most of those being buried being young people who died from a short natural illness[34].

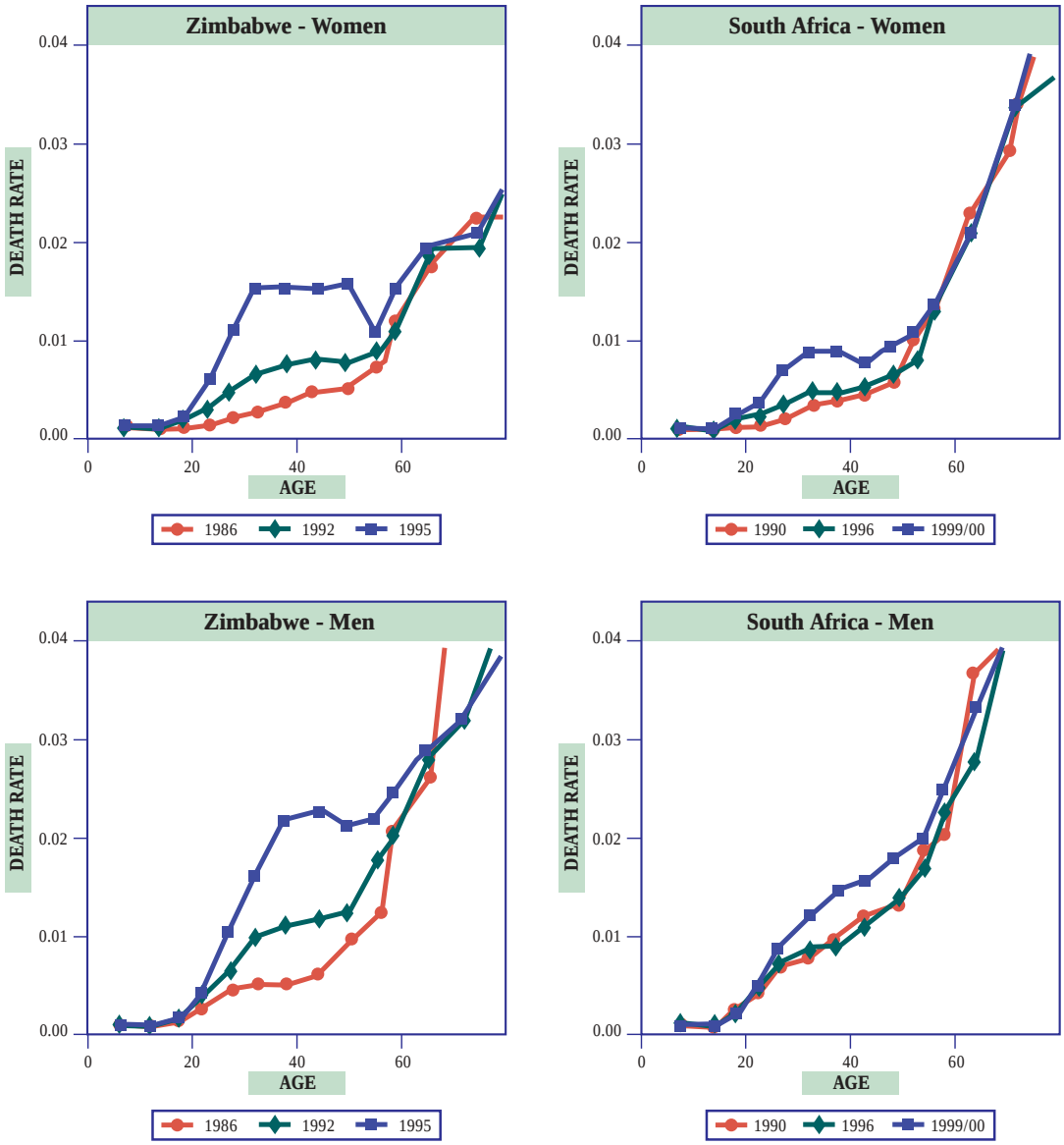
Table 8: Burials in Durban cemeteries and crematoria

1996/7	5678
1997/8	6476
1998/9	11427
1999/0	13323

(iv) *Comparison with mortality in Zimbabwe*[35]

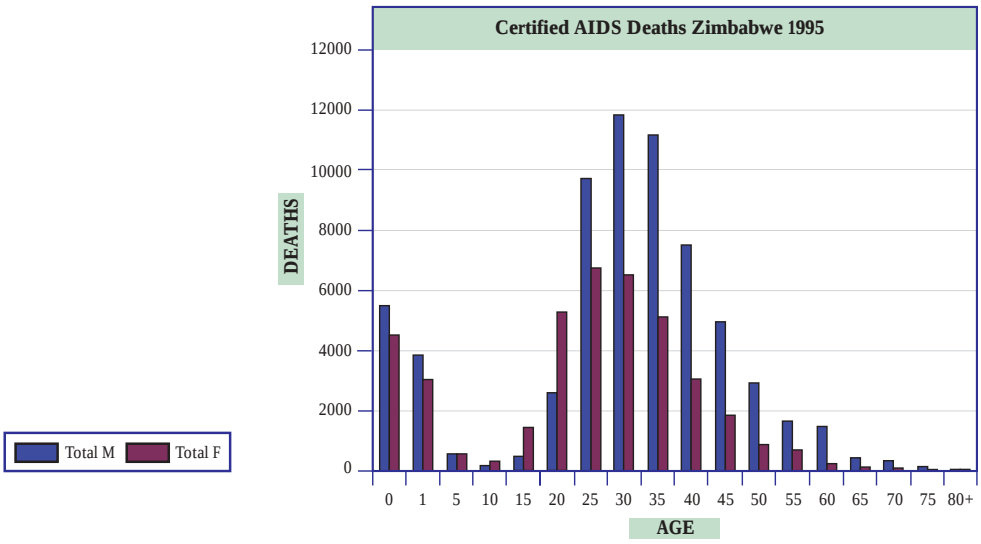
From Figure 18 we can see that the pattern of mortality rates in South Africa is consistent with those in Zimbabwe some eight years earlier.

Figure 18: Comparison of corrected mortality rates, Zimbabwe 1986 to 1995 and South Africa 1990 to 2000[36,17]



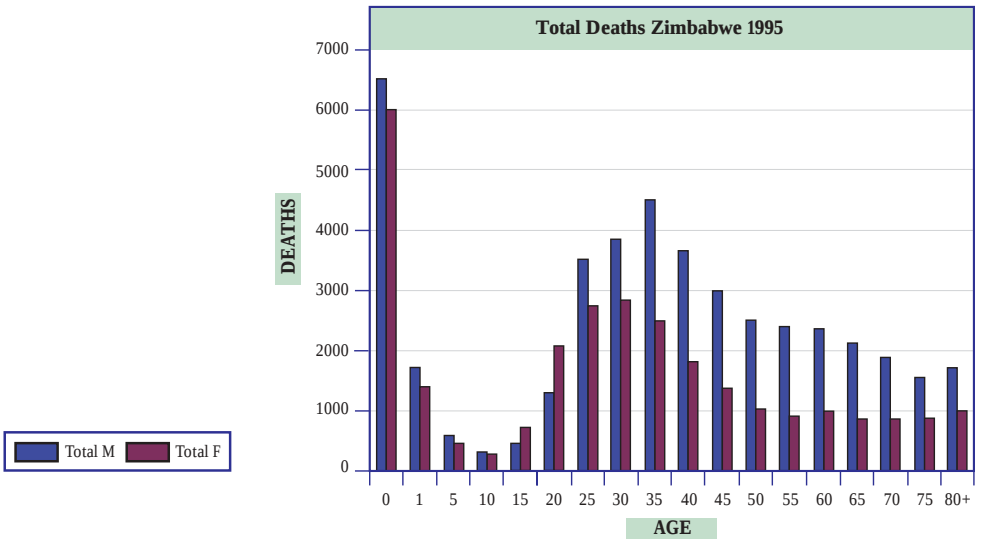
From Figure 19 we see that the pattern of certified AIDS deaths in Zimbabwe is entirely consistent with the excess deaths being projected in South Africa by the model, with the peak in the 25-29 year age group for females and five years later for males, and with a longer 'tail' for males (although male deaths exceed female deaths).

Figure 19: Age distribution of certified AIDS deaths, Zimbabwe 1995[35]



Although the certified AIDS deaths undoubtedly under-record AIDS mortality in Zimbabwe, the pattern of the total deaths there (Figure 20) is consistent with that from the ASSA model for South Africa some eight years further on. This is consistent with Figure 18.

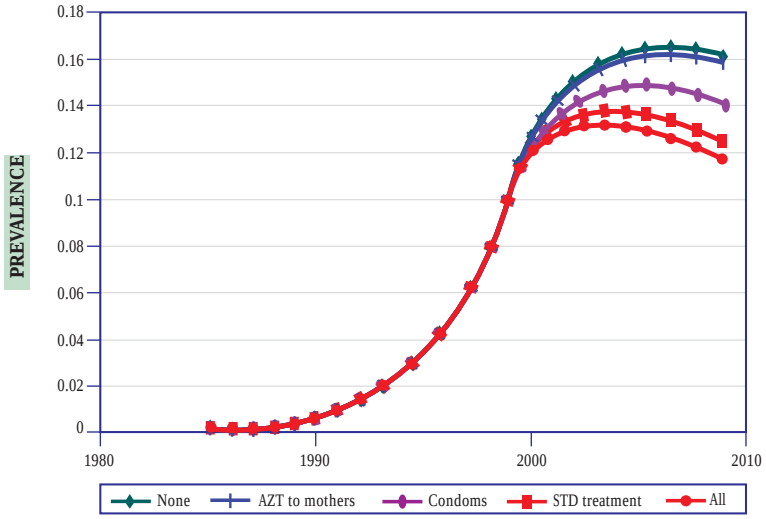
Figure 20: Age distribution of total deaths, Zimbabwe 1995[35]



Considering these different sources of information, it seems highly probable that about 40% of the adult South African 1999/00 mortality in the 15-49 age group is due to HIV/AIDS.

In the face of such depressing figures it is easy to assume that nothing can be done. Although the ASSA600 model does not lend itself readily to investigating the effect of interventions and behavioural change on the course of the epidemic, Figure 21 gives an idea of the impact of three possible interventions (assumed to have been implemented in 1998) on the prevalence of HIV in the population. The first scenario assumes that AZT is given to pregnant mothers with partial success resulting in a 25% decrease in mother to child transmissions. The second scenario assumes that the rate of sexual transmission is reduced by a quarter through the use of condoms. The third assumes that a national campaign manages to cure half of those with STDs. The impact of all three interventions together is also presented for comparison.

Figure 21: The projected prevalence of HIV with interventions



Two conclusions can be drawn from these figures. The first is that the impact of an intervention in mother to child transmission (MTC) on the overall prevalence is unlikely to be significant if the babies saved will ultimately go on to get infected. However, the aim of interventions is not specifically to reduce prevalence but rather incidence or deaths and thereby to reduce the suffering of the sick and dying. As this is above all true of reducing MTC transmission, impact on prevalence is not really an appropriate criterion for evaluating this intervention.

The second is that interventions can make a significant difference to the course of epidemic, although it will still exact a heavy toll. However, one must not lose sight of the fact that over 5 million people are currently infected and likely to die over the next 10 years.

Unfortunately the ASSA600 model was not designed to model the impact of antiretroviral therapies. Provided these drugs could be implemented successfully they could have a significant impact on the future prevalence levels.

Recommendations

Although we are still experiencing some difficulty in estimating the full extent of under-reporting of deaths recorded by the DHA, this report has shown the feasibility and usefulness of establishing a rapid mortality surveillance system using the DHA death data. It would be very useful if this system could be formalised and the data released by Stats SA to inform all researchers and policymakers as rapidly as possible.

These data provide a very useful check on the early ANC survey data which appear to have exaggerated the extent of the epidemic in the early years. Obviously any projections which do not allow for this bias are likely to overstate mortality for some years to come.

As there appears to be increasing evidence that some of the provinces are experiencing very different epidemics[37] from the national average, it is important to extend this research to the provincial level as soon as possible. Although, ideally, one should model the impact at a sub-provincial level (as there is evidence to suggest that the spread within a province is anything but uniform) it would be an extremely difficult task and there is, at the moment, insufficient data to create useful models.

Other further work planned is:

(i) investigate the quality of the cause of death information in the rapid data by comparison with other data sources

(ii) improve the demographic model after detailed analysis of the antenatal data

(iii) obtain alternative sources of information such as a sample of the death certificates to get a recent estimate of the cause of death

(iv) develop the model to better model interventions and behavioural change

(v) develop the model to allow for the socio-demographic and geographic heterogeneity in the population.

APPENDIX A Death Data

Table A1: Number of registered deaths according to year of occurrence and year of reporting, 1985 - 1996

Year	Reported+	Occurrence++
1985	160 901	168 938
1986	159 614	190 959
1987	182 442	181 893
1988	197 417	189 841
1889	183 140	170 670
1990	148 658	152 283
1991	176 475	172 011
1992	177 841	178 902
1993	201 273	194 882
1994	213 279	234 982
1995	268 025	265 375
1996	327 253	293 353

+ These figures were derived directly from the detailed electronic death records rather than the published reports.This resulted in minor differences in the 1985 and 1987 figures.

++ Deaths by the year in which they occurred up to and including all deaths included in the electronic records upon which the 1996 report was based.

Table A2: Total deaths by year occurred by sex and age++

	1985			1986			1987		
	Males	Females	Total	Males	Females	Total	Males	Females	Total
0-4	15440	13961	29401	16984	15384	32368	15620	14154	29774
5-9	1005	801	1806	1330	950	2280	1254	929	2183
10-14	995	638	1633	1298	805	2103	1123	809	1932
15-19	2149	1115	3264	3033	1269	4302	2527	1202	3729
20-24	4251	1542	5793	5948	1880	7828	4853	1680	6533
25-29	4693	1719	6412	6594	2132	8726	5692	1935	7627
30-34	4615	1981	6596	6362	2415	8777	5595	2124	7719
35-39	4675	2118	6793	5911	2434	8345	5573	2452	8025
40-44	4952	2498	7450	5965	2694	8659	5648	2637	8285
45-49	5584	2985	8569	6371	3145	9516	6328	3185	9513
50-54	6261	3467	9728	6897	3585	10482	6734	3697	10431
55-59	6698	3744	10442	7255	4111	11366	7246	4170	11416
60-64	7794	4977	12771	8326	5451	13777	8156	5514	13670
65-69	8837	6344	15181	9698	6955	16653	9237	6680	15917
70-74	7798	6259	14057	8114	6647	14761	7964	6482	14446
75-79	5942	5626	11568	6035	6015	12050	5914	5990	11904
80-84	3850	4787	8637	4328	5289	9617	4161	5264	9425
85+	3002	5835	8837	3164	6185	9349	3326	6038	9364
Total	98541	70397	168938	113613	77346	190959	106951	74942	181893

+ + Deaths by the year in which they occurred up to and including all deaths included in the electronic records upon which the 1996 report was based

Table A2 (contd.) Total deaths by year occurred by sex and age++

	1988			1989			1990		
	Males	Females	Total	Males	Females	Total	Males	Females	Total
0-4	15637	14050	29687	13607	11899	25506	10726	9626	20352
5-9	1133	933	2066	977	754	1731	787	577	1364
10-14	1042	692	1734	925	634	1559	747	564	1311
15-19	2561	1188	3749	2268	1020	3288	2184	899	3083
20-24	4862	1647	6509	4241	1536	5777	3909	1341	5250
25-29	5892	1991	7883	5110	1858	6968	4384	1607	5991
30-34	5909	2198	8107	5096	2097	7193	4623	1948	6571
35-39	5973	2582	8555	5397	2389	7786	4715	2056	6771
40-44	6163	2801	8964	5724	2704	8428	5065	2332	7397
45-49	6701	3325	10026	6042	3067	9109	5163	2542	7705
50-54	7099	3932	11031	6761	3828	10589	5951	3513	9464
55-59	7604	4484	12088	6870	4258	11128	5773	3817	9590
60-64	8718	5773	14491	7978	5439	13417	7223	5149	12372
65-69	9189	6692	15881	7664	5771	13435	6802	5114	11916
70-74	8696	7191	15887	7635	6655	14290	7256	6512	13768
75-79	6714	6489	13203	6372	6326	12698	5779	5813	11592
80-84	4335	5552	9887	3730	5004	8734	3810	5084	8894
85+	3615	6478	10093	3109	5925	9034	3082	5810	8892
Total	111843	77998	189841	99506	71164	170670	87979	64304	152283

	1991			1992			1993		
	Males	Females	Total	Males	Females	Total	Males	Females	Total
0-4	12483	10899	23382	12842	10819	23661	12310	10521	22831
5-9	920	639	1559	801	579	1380	1036	775	1811
10-14	867	616	1483	789	587	1376	1035	716	1751
15-19	2367	1006	3373	1731	981	2712	3008	1517	4525
20-24	4152	1571	5723	3215	1469	4684	5735	2025	7760
25-29	4864	1862	6726	3991	1808	5799	6380	2482	8862
30-34	5252	2148	7400	4483	2177	6660	6517	2787	9304
35-39	5479	2462	7941	5013	2432	7445	6699	2975	9674
40-44	5839	2656	8495	5662	2936	8598	6846	3329	10175
45-49	6005	2859	8864	5843	3063	8906	6785	3449	10234
50-54	6957	4030	10987	7275	4035	11310	7754	4432	12186
55-59	6531	4438	10969	7320	4716	12036	7689	4921	12610
60-64	8014	5873	13887	8605	6306	14911	8422	6499	14921
65-69	7769	5665	13434	8650	6316	14966	8774	6459	15233
70-74	8260	7326	15586	9684	8285	17969	8843	7491	16334
75-79	6174	6061	12235	6815	6758	13573	7112	7379	14491
80-84	4384	5785	10169	5022	6588	11610	4852	6446	11298
85+	3404	6394	9798	4024	7282	11306	3717	7165	10882
Total	99721	72290	172011	101765	77137	178902	113514	81368	194882

APPENDIX A Death Data

Table A2 (contd.) Total seaths by year occurred by sex and age[++]

	1994			1995			1996		
	Males	Females	Total	Males	Females	Total	Males	Females	Total
0-4	13720	11729	25449	15336	13304	28640	15828	14063	29891
5-9	1233	938	2171	1404	1101	2505	1619	1134	2753
10-14	1234	862	2096	1295	1003	2298	1445	1044	2489
15-19	3566	1730	5296	3711	1987	5698	3870	2199	6069
20-24	7188	2789	9977	7905	3626	11531	8312	4444	12756
25-29	8265	3410	11675	9304	4392	13696	10162	5629	15791
30-34	8425	3683	12108	9901	4777	14678	11188	5935	17123
35-39	8240	3907	12147	9628	4660	14288	10598	5655	16253
40-44	8752	4376	13128	9888	4855	14743	10846	5623	16469
45-49	8880	4398	13278	10546	5183	15729	11404	5762	17166
50-54	9210	5265	14475	10217	5409	15626	10969	5808	16777
55-59	9598	5742	15340	11125	6924	18049	12202	7693	19895
60-64	9637	7556	17193	9919	8051	17970	10788	8969	19757
65-69	10187	8158	18345	11712	9766	21478	12475	10893	23368
70-74	9843	8241	18084	10142	8796	18938	11032	9525	20557
75-79	8287	8942	17229	9434	10140	19574	10786	12195	22981
80-84	6053	7855	13908	6447	8265	14712	6691	8909	15600
85+	4460	8623	13083	5033	10189	15222	5930	11728	17658
Total	136778	98204	234982	152947	112428	265375	166145	127208	293353

Table A3: Death by cause by year occurred[++]

	Males					1985	Females				
	Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total		Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total
0-4	7707	2256	1305	139	11407		6853	1999	1275	130	10257
5-9	1728	1265	556	484	4033		1560	1261	523	360	3704
10-14	180	247	133	445	1005		158	242	97	304	801
15-19	143	250	121	481	995		109	219	98	212	638
20-24	129	350	189	1481	2149		197	390	163	365	1115
25-29	228	517	297	3209	4251		278	447	226	591	1542
30-34	305	777	383	3228	4693		275	647	256	541	1719
35-39	421	1132	589	2473	4615		245	858	365	513	1981
40-44	455	1623	665	1932	4675		272	1105	362	379	2118
45-49	511	2182	772	1487	4952		276	1505	390	327	2498
50-54	566	2968	876	1174	5584		248	1993	493	251	2985
55-59	610	3886	924	841	6261		226	2431	595	215	3467
60-64	542	4453	1103	600	6698		229	2725	652	138	3744
65-69	544	5452	1295	503	7794		282	3706	853	136	4977
70-74	556	6135	1763	383	8837		304	4387	1533	120	6344
75-79	392	5526	1640	240	7798		235	4419	1495	110	6259
80-84	258	4292	1262	130	5942		205	3991	1353	77	5626
85+	293	4483	1951	125	6852		310	6821	3354	137	10622
Total	15568	47794	15824	19355	98541		12262	39146	14083	4906	70397

+ + Deaths by the year in which they occurred up to and including all deaths included in the electronic records upon which the 1996 report was based

Table A3 (contd.) Death by cause by year occurred[++]

	Males					1986	Females				
	Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total		Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total
0-4	8330	2187	1255	226	11998		7370	2101	1180	194	10845
5-9	2047	1465	649	825	4986		1817	1535	657	530	4539
10-14	228	270	139	693	1330		195	229	111	415	950
15-19	148	276	92	782	1298		146	271	85	303	805
20-24	128	350	176	2379	3033		199	362	170	538	1269
25-29	169	554	278	4947	5948		257	540	228	855	1880
30-34	283	732	404	5175	6594		262	689	267	914	2132
35-39	421	1156	587	4198	6362		298	903	370	844	2415
40-44	483	1579	643	3206	5911		268	1119	378	669	2434
45-49	552	2274	718	2421	5965		240	1515	413	526	2694
50-54	606	2975	927	1863	6371		245	2012	471	417	3145
55-59	566	3904	985	1442	6897		261	2398	607	319	3585
60-64	540	4539	1187	989	7255		213	2964	691	243	4111
65-69	585	5610	1372	759	8326		301	3935	945	270	5451
70-74	647	6497	1985	569	9698		341	4629	1754	231	6955
75-79	430	5638	1685	361	8114		276	4579	1647	145	6647
80-84	282	4353	1204	196	6035		213	4220	1466	116	6015
85+	305	4771	2207	209	7492		342	7109	3803	220	11474
Total	16750	49130	16493	31240	113613		13244	41110	15243	7749	77346

	Males					1987	Females				
0-4	7624	2289	1178	226	11317		7137	1922	1038	156	10253
5-9	1764	1313	551	675	4303		1613	1304	539	445	3901
10-14	216	282	150	606	1254		219	227	137	346	929
15-19	110	274	127	612	1123		134	256	124	295	809
20-24	148	402	160	1817	2527		152	384	164	502	1202
25-29	177	546	275	3855	4853		263	520	214	683	1680
30-34	267	830	404	4191	5692		259	667	284	725	1935
35-39	403	1240	506	3446	5595		249	879	318	678	2124
40-44	508	1763	664	2638	5573		267	1224	390	571	2452
45-49	589	2380	764	1915	5648		258	1587	403	389	2637
50-54	606	3157	943	1622	6328		250	2040	522	373	3185
55-59	573	4037	1040	1084	6734		209	2614	579	295	3697
60-64	588	4708	1163	787	7246		229	2974	745	222	4170
65-69	574	5755	1258	569	8156		286	4031	982	215	5514
70-74	613	6432	1759	433	9237		330	4731	1433	186	6680
75-79	442	5665	1584	273	7964		272	4646	1442	122	6482
80-84	276	4362	1119	157	5914		201	4334	1336	119	5990
85+	319	4880	2124	164	7487		398	7267	3429	208	11302
Total	15797	50315	15769	25070	106951		12726	41607	14079	6530	74942

Table A3 (contd.) Death by cause by year occurred[++]

	Males					1988	Females				
	Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total		Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total
0-4	8606	2263	311	232	11412		7745	2036	290	158	10229
5-9	1530	1495	539	661	4225		1439	1400	520	462	3821
10-14	147	299	120	567	1133		170	266	121	376	933
15-19	112	282	113	535	1042		120	234	102	236	692
20-24	145	411	139	1866	2561		192	393	163	440	1188
25-29	186	533	229	3914	4862		246	509	209	683	1647
30-34	300	822	381	4389	5892		275	659	303	754	1991
35-39	437	1258	525	3689	5909		292	933	300	673	2198
40-44	573	1816	749	2835	5973		309	1278	448	547	2582
45-49	597	2569	883	2114	6163		276	1643	422	460	2801
50-54	667	3440	1051	1543	6701		263	2141	562	359	3325
55-59	689	4196	1100	1114	7099		303	2784	578	267	3932
60-64	619	5039	1190	756	7604		221	3226	803	234	4484
65-69	681	6023	1387	627	8718		331	4193	1053	196	5773
70-74	643	6496	1617	433	9189		293	4864	1384	151	6692
75-79	530	6154	1725	287	8696		328	5049	1679	135	7191
80-84	332	4833	1373	176	6714		260	4617	1494	118	6489
85+	328	5323	2117	182	7950		379	7828	3584	239	12030
Total	17122	53252	15549	25920	111843		13442	44053	14015	6488	77998

	Males					1989	Females				
0-4	8157	1937	90	209	10393		7165	1724	72	159	9120
5-9	1022	1173	471	548	3214		977	973	423	406	2779
10-14	134	232	125	486	977		111	236	120	287	754
15-19	108	256	106	455	925		100	221	102	211	634
20-24	125	365	172	1606	2268		164	344	154	358	1020
25-29	160	538	264	3279	4241		237	504	203	592	1536
30-34	295	745	381	3689	5110		266	604	294	694	1858
35-39	418	1201	589	2888	5096		271	801	391	634	2097
40-44	564	1626	787	2420	5397		267	1172	432	518	2389
45-49	585	2403	953	1783	5724		254	1490	528	432	2704
50-54	655	3059	1031	1297	6042		261	1923	545	338	3067
55-59	636	3950	1141	1034	6761		267	2513	766	282	3828
60-64	546	4386	1216	722	6870		247	2954	868	189	4258
65-69	600	5380	1509	489	7978		323	3850	1092	174	5439
70-74	468	5341	1473	382	7664		271	4068	1302	130	5771
75-79	470	5247	1680	238	7635		279	4506	1735	135	6655
80-84	306	4491	1384	191	6372		273	4237	1695	121	6326
85+	259	4502	1869	209	6839		352	7064	3304	209	10929
Total	15508	46832	15241	21925	99506		12085	39184	14026	5869	71164

Table A3 (contd.) Death by cause by year occurred[++]

	Males					1990	Females				
	Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total		Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total
0-4	5813	1613	709	202	8337		5161	1502	718	143	7524
5-9	735	802	390	462	2389		677	701	388	336	2102
10-14	86	186	124	391	787		74	171	101	231	577
15-19	76	168	114	389	747		76	195	114	179	564
20-24	119	302	172	1591	2184		138	260	167	334	899
25-29	155	409	217	3128	3909		237	376	223	505	1341
30-34	237	611	290	3246	4384		243	536	284	544	1607
35-39	375	1007	528	2713	4623		268	776	377	527	1948
40-44	467	1412	685	2151	4715		283	961	394	418	2056
45-49	554	2006	893	1612	5065		226	1292	461	353	2332
50-54	508	2447	944	1264	5163		209	1561	519	253	2542
55-59	561	3253	1216	921	5951		238	2284	762	229	3513
60-64	459	3609	1124	581	5773		202	2565	872	178	3817
65-69	536	4658	1513	516	7223		251	3377	1338	183	5149
70-74	413	4652	1444	293	6802		241	3514	1226	133	5114
75-79	418	4636	1948	254	7256		280	4062	2044	126	6512
80-84	282	3953	1396	148	5779		193	3831	1673	116	5813
85+	290	4310	2134	158	6892		355	6503	3820	216	10894
Total	12084	40034	15841	20020	87979		9352	34467	15481	5004	64304

	Males					1991	Females				
0-4	6246	1863	1405	192	9706		5362	1631	1330	168	8491
5-9	848	914	476	539	2777		783	859	440	326	2408
10-14	106	202	135	477	920		80	179	110	270	639
15-19	66	245	145	411	867		78	200	139	199	616
20-24	119	332	226	1690	2367		158	295	196	357	1006
25-29	192	487	343	3130	4152		265	446	297	563	1571
30-34	288	704	437	3435	4864		303	584	355	620	1862
35-39	482	1132	643	2995	5252		295	813	425	615	2148
40-44	560	1689	869	2361	5479		312	1162	513	475	2462
45-49	680	2233	1136	1790	5839		249	1466	567	374	2656
50-54	642	2831	1241	1291	6005		247	1697	602	313	2859
55-59	692	3744	1480	1041	6957		276	2547	947	260	4030
60-64	547	3943	1405	636	6531		249	2984	1032	173	4438
65-69	583	5064	1829	538	8014		299	3818	1537	219	5873
70-74	518	5129	1819	303	7769		231	3839	1457	138	5665
75-79	493	5308	2196	263	8260		315	4653	2193	165	7326
80-84	280	4095	1646	153	6174		213	3999	1740	109	6061
85+	321	4785	2471	211	7788		423	7123	4344	289	12179
Total	13663	44700	19902	21456	99721		10138	38295	18224	5633	72290

Table A3 (contd.) Death by cause by year occurred[++]

	Males					1992	Females				
	Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total		Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total
0-4	6015	1881	1831	259	9986		5054	1513	1617	171	8355
5-9	865	984	623	384	2856		753	828	596	287	2464
10-14	123	196	162	320	801		83	174	135	187	579
15-19	81	214	177	317	789		91	186	154	156	587
20-24	112	345	274	1000	1731		168	297	265	251	981
25-29	207	450	369	2189	3215		273	503	318	375	1469
30-34	323	787	515	2366	3991		298	623	439	448	1808
35-39	468	1199	763	2053	4483		354	862	549	412	2177
40-44	646	1701	1030	1636	5013		335	1136	624	337	2432
45-49	720	2404	1340	1198	5662		316	1664	679	277	2936
50-54	671	2947	1405	820	5843		255	1836	746	226	3063
55-59	748	4007	1814	706	7275		261	2600	973	201	4035
60-64	683	4350	1794	493	7320		270	3027	1241	178	4716
65-69	627	5448	2132	398	8605		330	4060	1782	134	6306
70-74	543	5629	2231	247	8650		278	4132	1786	120	6316
75-79	569	6024	2870	221	9684		332	5005	2821	127	8285
80-84	302	4375	1999	139	6815		254	4344	2068	92	6758
85+	366	5628	2867	185	9046		464	8227	4952	227	13870
Total	14069	48569	24196	14931	101765		10169	41017	21745	4206	77137

	Males					1993	Females				
0-4	5908	1852	1170	388	9318		5025	1627	1047	327	8026
5-9	916	956	451	669	2992		787	812	419	477	2495
10-14	104	208	141	583	1036		109	176	117	373	775
15-19	89	248	149	549	1035		89	255	135	237	716
20-24	141	419	230	2218	3008		233	456	251	577	1517
25-29	234	543	326	4632	5735		327	564	297	837	2025
30-34	349	839	443	4749	6380		370	735	390	987	2482
35-39	518	1189	571	4239	6517		388	1037	457	905	2787
40-44	652	1782	875	3390	6699		369	1261	536	809	2975
45-49	765	2524	1065	2492	6846		343	1727	681	578	3329
50-54	752	3222	1238	1573	6785		297	2030	661	461	3449
55-59	802	4158	1467	1327	7754		312	2871	837	412	4432
60-64	724	4622	1503	840	7689		316	3261	1024	320	4921
65-69	677	5344	1737	664	8422		349	4342	1544	264	6499
70-74	607	5841	1870	456	8774		295	4424	1531	209	6459
75-79	506	5906	2070	361	8843		307	4993	2027	164	7491
80-84	361	4739	1809	203	7112		286	4819	2144	130	7379
85+	360	5459	2518	232	8569		449	8301	4566	295	13611
Total	14465	49851	19633	29565	113514		10651	43691	18664	8362	81368

Table A3 (contd.) Death by cause by year occurred[++]

	Males					Females				
1994	Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total	Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total
0-4	6886	2240	1065	469	10660	5774	2048	926	381	9129
5-9	765	1047	409	839	3060	694	905	373	628	2600
10-14	136	266	107	724	1233	112	214	111	501	938
15-19	110	276	95	753	1234	120	280	96	366	862
20-24	183	447	175	2761	3566	290	511	196	733	1730
25-29	309	704	291	5884	7188	469	885	296	1139	2789
30-34	560	1184	390	6131	8265	543	1222	408	1237	3410
35-39	810	1746	602	5267	8425	580	1441	469	1193	3683
40-44	982	2351	879	4028	8240	518	1815	596	978	3907
45-49	1128	3282	1180	3162	8752	502	2352	714	808	4376
50-54	1140	4082	1276	2382	8880	419	2752	657	570	4398
55-59	1042	5191	1364	1613	9210	409	3578	836	442	5265
60-64	1000	5931	1518	1149	9598	358	4033	975	376	5742
65-69	849	6482	1533	773	9637	442	5367	1423	324	7556
70-74	763	7046	1805	573	10187	439	5782	1694	243	8158
75-79	667	6899	1834	443	9843	389	5870	1776	206	8241
80-84	480	5733	1786	288	8287	414	6025	2315	188	8942
85+	534	7031	2691	257	10513	654	10656	4924	244	16478
Total	18344	61938	19000	37496	136778	13126	55736	18785	10557	98204

	Males					Females				
1995										
0-4	7197	2668	1177	521	11563	6255	2405	1040	435	10135
5-9	1084	1260	486	943	3773	913	1131	445	680	3169
10-14	174	278	138	814	1404	141	261	129	570	1101
15-19	129	292	136	738	1295	138	281	128	456	1003
20-24	191	436	197	2887	3711	385	544	240	818	1987
25-29	389	817	318	6381	7905	693	1286	439	1208	3626
30-34	770	1457	552	6525	9304	857	1611	606	1318	4392
35-39	1113	2199	782	5807	9901	886	1964	677	1250	4777
40-44	1288	2921	1059	4360	9628	741	2112	698	1109	4660
45-49	1457	3757	1334	3340	9888	650	2564	756	885	4855
50-54	1493	4798	1598	2657	10546	512	3207	817	647	5183
55-59	1301	5560	1645	1711	10217	488	3602	804	515	5409
60-64	1283	6721	1840	1281	11125	501	4746	1237	440	6924
65-69	921	6598	1656	744	9919	518	5568	1546	419	8051
70-74	976	7798	2245	693	11712	529	6771	2123	343	9766
75-79	756	6910	2020	456	10142	407	6178	1957	254	8796
80-84	636	6337	2145	316	9434	509	6680	2756	195	10140
85+	618	7469	3100	293	11480	672	11532	5853	397	18454
Total	21776	68276	22428	40467	152947	15795	62443	22251	11939	112428

APPENDIX A Death Data

Table A3 (contd.) Death by cause by year occurred[++]

	Males					1996	Females				
	Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total		Infection / Maternal	Non-communicable	Ill-defined	Injuries	Total
0-4	7913	2748	746	477	11884		6924	2589	663	437	10613
5-9	964	1499	549	932	3944		934	1378	489	649	3450
10-14	190	348	164	917	1619		155	302	117	560	1134
15-19	163	331	129	822	1445		148	337	119	440	1044
20-24	222	501	197	2950	3870		385	703	238	873	2199
25-29	512	1025	360	6415	8312		1046	1657	542	1199	4444
30-34	1112	1910	638	6502	10162		1262	2228	739	1400	5629
35-39	1679	2842	968	5699	11188		1326	2522	784	1303	5935
40-44	1708	3492	1044	4354	10598		1028	2686	752	1189	5655
45-49	1691	4376	1302	3477	10846		816	3091	781	935	5623
50-54	1744	5613	1480	2567	11404		657	3600	788	717	5762
55-59	1469	6169	1511	1820	10969		524	3984	756	544	5808
60-64	1446	7705	1737	1314	12202		577	5518	1097	501	7693
65-69	1110	7389	1475	814	10788		576	6593	1386	414	8969
70-74	1057	8699	2033	686	12475		605	7919	1949	420	10893
75-79	826	7895	1839	472	11032		500	6995	1738	292	9525
80-84	759	7559	2103	365	10786		634	8472	2754	335	12195
85+	704	8736	2823	358	12621		828	14067	5232	510	20637
Total	25269	78837	21098	40941	166145		18925	74641	20924	12718	127208

Table A4: Deaths from Department of Home Affairs adjusted for missing IDs

	1997/98			1998/99			1999/00		
	Males	Females	Total	Males	Females	Total	Males	Females	Total
0-4**	23976	19321	43297	27241	23388	50629	34770	29427	64197
5-9**	1596	1106	2702	1893	1456	3348	2290	1704	3993
10-14**	814	809	1623	1166	1120	2286	1295	1458	2753
15-19	2941	2479	5420	3598	3265	6864	3932	4026	7958
20-24	9097	6028	15125	9360	7445	16804	9412	8764	18176
25-29	12164	8512	20676	13980	11132	25112	14897	14664	29561
30-34	12892	8440	21332	15845	11240	27085	17851	14309	32160
35-39	13625	7830	21455	15893	9608	25501	18563	12619	31182
40-44	13062	7166	20228	15112	8598	23709	16960	10337	27297
45-49	13550	7095	20644	15193	8227	23420	16836	9591	26427
50-54	12365	6672	19038	13826	7416	21242	15272	8745	24017
55-59	13593	8555	22149	14169	8872	23041	14820	9328	24149
60-64	12010	9528	21538	12708	9964	22672	14033	10992	25025
65-69	12716	11949	24665	13155	12486	25641	13162	13143	26305
70-74	11932	10972	22904	12987	12042	25029	13739	13763	27503
75-79	11784	12725	24510	10971	11730	22701	11242	12391	23634
80-84	7136	9732	16868	7757	11241	18998	8300	12308	20607
85+	6319	12611	18930	6274	12668	18942	7587	15201	22788
Total	191574	151531	343105	211128	171897	383025	234962	202771	437733

**These figures are of limited reliability because of the low proportion with IDs.

APPENDIX B: Processing Population Register Data

Data source

Copies of the log files for transactions entered on the population register regarding deaths for the period 1997 to date have been obtained through different channels. Different sources were necessary since the Department of Home Affairs only retains their log tapes for a 12-month period, and an extraction of deaths from the full Population Register was not practical.

i) The first set of data was obtained from Stats SA who had been provided with a 12-month set of the deaths from the log file for the period 1997/98.

ii) The second set of data for the period 1998/99 was obtained from the Department of Health who had also obtained a copy of the DHA log files. The Department of Health cleaned their data files and removed all duplicate records.

iii) Data from April 1999 onwards has been obtained directly from the Department of Home Affairs.

Multiple records

Multiples were identified in the combined data and any that had the identical ID number were removed, keeping the latest record only. Multiples arise from the fact that when any administrative amendments regarding the death registration are made to the record on the Population Register, it is logged.

Age

The ID number has 13 characters. The first 6 digits reflect the date of birth. In the first two data sets, the age is calculated by subtracting the date of birth component of the ID variable from the date of death. A few cases have non-standard ID numbers, thus the date of birth details could not be taken from the ID number and age could not be calculated for them.

The data sets obtained directly from the Department of Home Affairs also contain the actual date of birth of the deceased. Where in some cases, only the year of birth was available, age was calculated by subtracting the year of birth from the year of death.

The ID number does not indicate the century of birth. However for all deaths, with a date of birth of the deceased being 2000, we have a corresponding date of birth as a separate field.

Sex

Digits 7 to 10 of the ID number indicate the sex of the person (combined with a serial number).

Codes 0000 to 4999 represent females and 5000 to 9999 males.

Cause of death

The text in the cause of death field was analysed and the terms that occurred relatively frequently (more than 10 times in a year) were examined and identified as external or natural causes. Those terms that occurred infrequently were taken as natural causes without examination. The majority of the external causes were recorded as "non-natural" or "Onnatuurlik" but there was a range of specific causes such as "MVA", "head injuries", "wond", "wound", "gun", "shot", "murder", "trauma", etc. Cause of death was either in Afrikaans or English, while the words were spelled in various ways. This was all taken into account when assessing the external causes of death.

Cleaning the data

The data for June 1999 - May 2000 contained some illegal characters for some variables. In these cases, the complete record was examined for obvious problems such as a consistent column shift and was then realigned. In 4 cases the sex could not be identified due to illegal characters in the ID number. When the illegal characters appeared in the date of birth variable, it was possible to correct it by using the date of birth component of the ID variable and vice versa.

The number of exclusions from each data source of the data is summarized in Table B1.

APPENDIX B: Processing Population Register Data

Table B1: The number of records excluded for analysis according to source

Source	Period	Total Records	Multiples excluded	Records Cleaned	Sex unknown	Age unknown	Record for analysis
i)	June 1997 - July 1988	284 391	4 973	279 418	-	2 061	277 357
ii)	June1998 - May 1999	314 881	-	314 881	-	1 895	312 986
iii)	June 1999 - May 2000	360 217	8 461	351 756	4	-	351 752
	June 2000 - Sept 2000	131 038	1 362	129 676	-	-	129 676

Data included in analysis

The three sources for data from Home Affairs indicted above were pooled, and three 12-month periods extracted. Since deaths can take up to two months to be registered we decided to start the first 12-month period in August 1997. This means that the first two periods overlap for the month of July 1998. It should also be noted that while the final period is until June 2000, it includes deaths which occurred in that month but appear on the log tapes up until September 2000.

Only deaths in the age range 15-99 are included in the analysis. The numbers of deaths in each period are shown in Table B2.

Table B2: Composition of annual data sets 1997 to 2000

Period	Total All ages	Male 15 - 99	Female 15 - 99	Total 15 - 99
Aug 1997 - July 1998	278 311	150 878	119 085	269 963
July 1998 - June 1999	306 741	164 873	132 470	297 343
July 1999 - June 2000	343 535	179 109	153 514	332 623

APPENDIX C

Brief description of the workings of the ASSA600 model

The ASSA600 model only models the heterosexual (i.e. Pattern II) spread of HIV and subsequent AIDS deaths. It models the epidemic for the country as a whole and does not distinguish between the different population groups. (The ASSA2000 update extends the model to allow for different population groups and models the provinces separately).

In ASSA600, the population is divided into groups differentiated by their level of exposure to the risk of a heterosexual epidemic.These risk groups are:

- PRO: Sex workers and their clients.
- STD: Individuals regularly infected with sexually transmitted diseases (STDs)
- RSK: Individuals exposed to risky sexual behaviour but not infected with STDs
- NOT: Individuals who are not at risk of HIV infection.

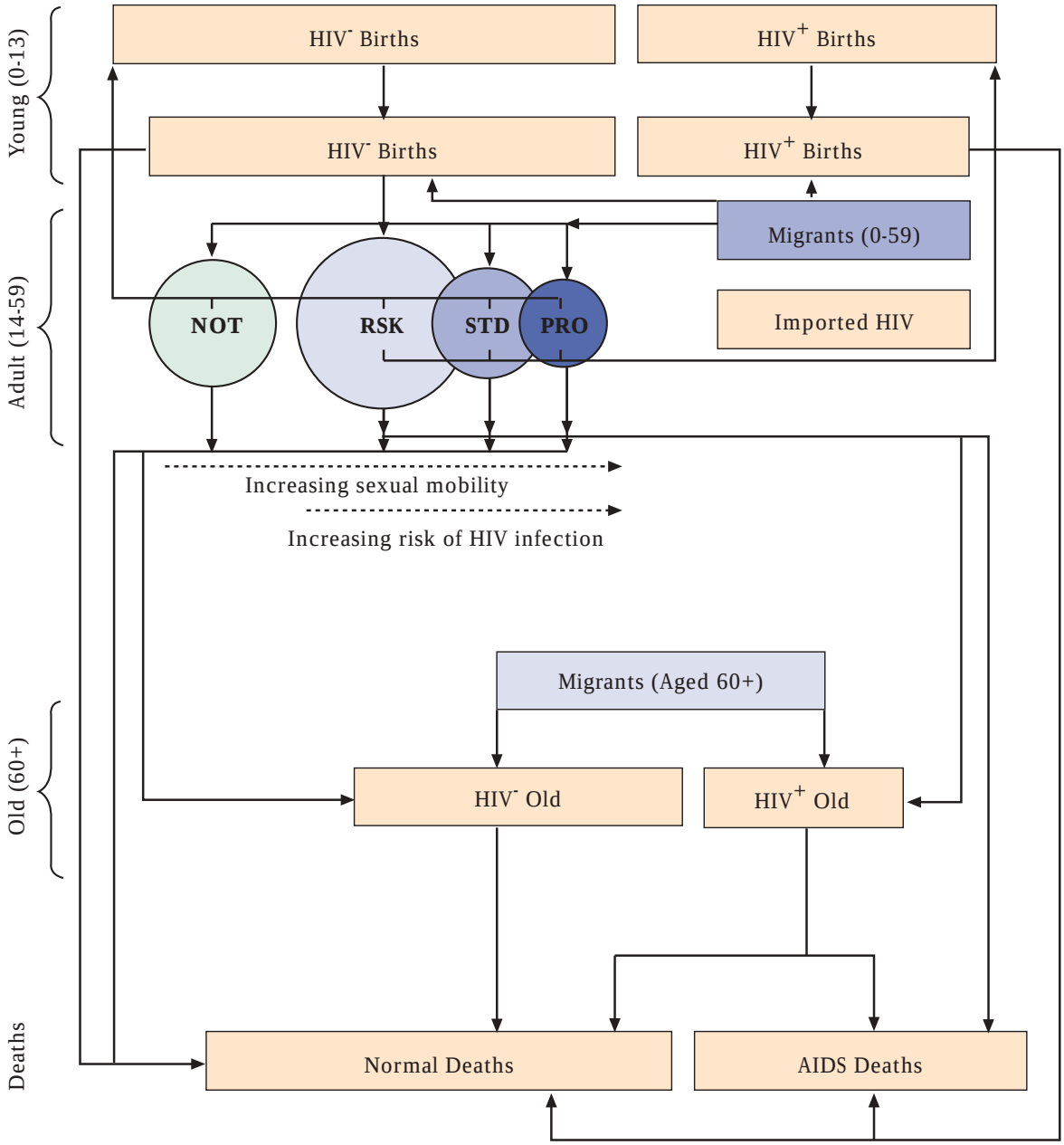
"Sexual activity" in this context is a combination of "number of new contacts" and "probability of successful infection" with each new contact. Rather than model number of contacts and probability infection during a single sexual encounter, the model uses a "force of infection" to model the spread of HIV within each risk group and between a risk group and the neighbouring risk group.

The population is therefore divided into the following groups, with each group's calculation done on a separate worksheet within the workbook:

Young:	All individuals aged 0 to 13.The only infections assumed are those arising at birth. On their 14th birthday individuals are allocated into the various other risk groups according to the assumed proportions in the population as a whole.
FemPRO:	Female members of the PRO risk group subdivided by duration since infection up to age 59
FemSTD:	Female members of the STD risk group subdivided by duration since infection up to age 59
FemRSK:	Female members of the RSK risk group subdivided by duration since infection up to age 59
FemNOT:	Female member of the NOT group up to age 59
FemOLD:	On their 60th birthdays all individuals are allocated to the OLD class.The duration since infection classification still applies although no further infections or fertility occur beyond this age. The OLD worksheets are just a run-off of the population. No one is assumed to survive beyond age 90.
MaleXXX:	The same structure as the FemXXX but with no births.

APPENDIX C

Figure C1: A schematic diagram of the ASSA AIDS Model



APPENDIX D

Percentage under-registration of adult (15+) deaths: ASSA600 vs specific effort to determine the extent of under-registration

Table D1: Number of deaths, completeness of registration of deaths 15 years and older by year of occurrence

Year	Number of adult deaths registered	Completeness according to Timæus *et al* [17]	Completeness according to ASSA600
1989	141 876	60%	66%
1990	129 256	54%	59%
1991	145 587	59%	65%
1992	152 485	61%	66%
1993	168 489	57%	71%
1994	205 266	73%	83%
1995	231 932	79%	89%
1996	258 220	85%	93%
1997/98+	295 483	87%	94%
1998/99+	326 761	87%	94%
1999/2000+	366 790	89%	94%

+ deaths from the Population Register, scaled up to allow for deaths reported but not on the Population Register

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