Methods

Total number of deaths

The usual BOD approach is to make use of vital registration data, adjusted for under-registration. Given the lack of recent complete vital statistics and the rapid changes under way, the South African National Burden of Disease Study used a modelling approach to estimate the total number of deaths. The SA NBD Study made use of the AIDS and demographic model, ASSA2000, developed by the Actuarial Society of South Africa (ASSA, 2002). This provincial study has made use of the same model to estimate the total number of deaths, applied at province level.

The ASSA2000 model is a demographic component projection model that incorporates behavioural and epidemiological dynamics of heterosexual transmission of HIV. It is used to project overall mortality, the population size and the number of deaths due to HIV/AIDS for each province. The model treats the population of each province as one group and models the demographic impact of HIV/AIDS for each age group (young: under 15, adult: 15-59, and old: 60+ years) by iteratively computing the population changes based on demographic, behavioural and epidemiological parameters for each year starting at 1985. The model assumes that the adult population (those aged 15-59 at the start of the epidemic and those turning 14 in each subsequent year) can be divided into four risk groups:

PRO	–	a small, high-risk group comprising sex workers and clients;
STD	–	a much larger group, assumed to be at similar risk of transmitting/ contracting the virus as people who regularly contract STDs;
RSK	–	an even larger group who are at risk because of their sexual behaviour, but do not have an STD;
NOT	–	a similarly sized group who are assumed never to be at risk.

In the ASSA2000 model it is assumed that the median term to death is 11 years for people infected with HIV when they are less than 25 years old, and 10 years when infected at an age older than 25 years. It assumes that 25% of babies born to HIV-positive mothers are infected at birth and that these children have a mortality rate of 30% per annum. It assumes that a further 10% of babies contract the virus 3 or more months after birth through breast milk and have a median term to death of 6 years.

The basic mortality assumptions of the model are that for adults, the level of the non-HIV mortality has been set to the level estimated for 1985 by Dorrington *et al.* (1999). These estimates are derived through the synthesis of the official life tables for whites, coloureds and Indians published by the national statistical office together with the estimated life table for blacks. Detailed analysis of all the mortality data for the period 1985 onwards, based on vital registration, survey and Census data, suggests that the level of adult mortality has been stable over the period until the late 1990s when it started to increase, in step with the HIV/AIDS epidemic (Timæus *et al.*, 2000).

Child mortality estimates from the 1996 Census and the 1998 Demographic and Health Survey (SADHS) both show a reversal of the downward trend, although there are differences in the estimated levels (Nannan *et al.*, 2000). Adjustments are made to both sets of estimates due to differences and inherent biases in the different methodologies. A small upward adjustment is made to the DHS and a downward adjustment to the Census data which appear too high due to the inclusion of stillbirths incorrectly classified as live births who have died (Moultrie and Timæus, 2002).

The population in ASSA2000 is projected from a base of 36 million in 1985, consistent with a projection from the 1970 Census, considered to be one of the more reliable censuses taken in Apartheid South Africa, albeit for segregated population groups. The population projection for 1996 was 41.5 million, larger than the Statistics South Africa figure of 40.4 million, which is considered to have under-counted young children and working-age men. The fertility has been assumed to follow the age pattern observed in the DHS and to continue the declining trend. The impact of HIV on fertility is estimated from the literature.

The ASSA2000 model has been calibrated to reproduce the antenatal clinic data since these provide a continuous series concerning the HIV/AIDS epidemic in South Africa. An adjustment is made to the

antenatal prevalence since it is assumed to be higher than the community prevalence as it is based on women who have clearly had unprotected sex. In addition, the model has been calibrated to estimates of the total mortality based on the death data recorded by the Department of Home Affairs to the middle of 2001, after correcting for under-reporting and deaths without Identity Documents (Dorrington *et al.*, 2001).

The projected number of people, number of deaths and other indices of mortality are shown for each province in Table A1 of Appendix A. The SA NBD estimate of the total number of deaths was 14 179 more than the sum of the provincial estimates as it would have been exceedingly difficult to constrain the provincial models to match the national demographic parameters exactly at the same time as fitting the provincial demographic and epidemiological parameters. This difference on a total of 556 585 is considered small and has been ignored. The life expectancy and the probability of death for selected age ranges were calculated using a standard period life table approach. The number of deaths is for the 12-month period starting mid-2000 which is referred to as the year 2000 in this report, as was done in the SA NBD study.

Cause of death list

A South African National Burden of Disease (NBD) list was developed for the South African NBD study (Bradshaw *et al.*, 2003) from the list of the 1990 Global Burden of Disease Study (Murray and Lopez, 1996a and 1996b), and the ICD-10 codes are shown in Table A2 of Appendix A. The codes of the diseases included in the South African list are prefixed ZA.

Mortality is divided into three broad groups of causes of death:

- Group I are the pre-transitional causes: communicable diseases, maternal causes, perinatal conditions, and nutritional deficiencies. HIV/AIDS is part of Group I but is kept separate in the South African NBD analysis due to the size of the burden that it contributes in South Africa.
- Group II are the non-communicable causes.
- Group III are the injuries.

Each group is divided into several major categories of causes of death, such as respiratory infections, cardiovascular diseases and intentional and unintentional injuries. In some cases, where specific diseases may be of particular interest (such as the childhood cluster (ZA5)), the disease codes are further disaggregated (in this case into pertussis, polio, diptheria, measles, tetanus and rubella (ZA5a-ZA5f)).

The level of aggregation of causes of death influences the ranking of diseases; the aggregation therefore needs to be done according to specific criteria. The Global Burden of Disease Study selected the specific diseases or disease clusters listed in the final level of disaggregation on the basis of three criteria: the number of deaths due to the specific cause, the level of health service provided for the particular cause, and the prominence of the cause in the current health policy debate. Similar criteria were used in the development of the South African NBD list.

The International Classification of Diseases (ICD-10) defines the underlying cause of death as *"the disease or injury which initiated the train of morbid events leading directly to death"* (WHO, 1992). South African cause of death statistics are coded to ICD-10, but sometimes fail to correctly classify the underlying cause due to incomplete information on the death certificate (Bah, 2003). The NBD study attempts to estimate such underlying causes.

Estimate of AIDS deaths

In the case of AIDS, the ICD-10 classifies a death as having HIV as an underlying cause when HIV is present and the person dies from a subsequent co-morbidity mediated by the HIV (codes B20 through B24). However, a relatively low proportion of HIV-related deaths are reported in the sample of deaths, together with an increased proportion of deaths due to pneumonia and tuberculosis. This suggests that there is misclassification of AIDS deaths to the immediate cause of death. Based on the distinctive age pattern in the increase in death rates, Groenewald *et al.* (forthcoming) have identified nine conditions which appear to include AIDS cases. Since the cause of death statistics under-represent the number of AIDS deaths, the ASSA2000 model is used to estimate the number in each province based on the epidemiological data.

A more recent version of the ASSA model (ASSA2002) has been developed that incorporates more empirical data. However, this model has not been finalised for the provincial projections and is not available for this study. It should be noted that the revised model projects a lower future impact of the HIV epidemic than the earlier model, as a result of the new data that include population-based prevalence and changes in behaviour, as well as changes such as the introduction of antiretroviral treatment and adjustments in the assumptions about the impact of HIV on fertility levels. However, since both models have been calibrated to the historical data on overall levels of mortality, the differences between the models when used for the year 2000 are small. Nationally ASSA2000 estimated that 29.8% of deaths were due to HIV/AIDS in the year 2000 while the revised model ASSA2002 estimated that 28.6% of the deaths for that year were due to HIV/AIDS.

Estimates of other natural causes of death

The cause of death data from the 12% sample for the years 2000 and 2001 were used to estimate the number of deaths due to natural causes, with adjustments for misclassification. The ill-defined causes within a disease category, such as cancers of unknown site or ill-defined perinatal conditions, were redistributed proportionally within each age and sex group to the specified diseases in that disease category, using the same method applied in the NBD study. In addition, the broad group of ill-defined conditions was redistributed proportionally within each age and sex group to all the specified conditions. An adjustment was also made for the nine conditions which appear to include misclassified AIDS deaths (Groenewald *et al.*, forthcoming).

The number of AIDS deaths classified to other conditions was estimated by examining the increase in the age-specific death rates between 1996 and 2000/01 (Groenewald *et al*., forthcoming). The number of misclassified AIDS deaths was subtracted from the nine conditions that showed a clear increase in age-specific mortality rates following the distinct HIV age pattern (tuberculosis, pneumonia, diarrhoea, meningitis, other respiratory diseases, non-infective gastroenteritis, other infectious and parasitic diseases, deficiency anaemias and protein-energy malnutrition) to estimate the number of deaths due to these conditions that were not directly related to HIV.

The cause-specific death rates were calculated for 1996 and 2000/1 by age and sex using the cause of death profile from data provided by SSA applied to the ASSA2000 projections of the total number of deaths and the South African population by age and gender for the years analysed. This corrects for underestimation in the 1996 Census as well as for incomplete registration of deaths in a consistent manner across all years.

Both data sets, coded by SSA using the ICD-10 classification at three character level (WHO, 1992) were aggregated according to the South African Burden of Disease List for analysis (Bradshaw *et al.*, 2003). The use of ICD-10 at three character level made it impossible to estimate the number of deaths due to 'cot death'. In ICD-10 "Sudden infant death syndrome" is included in code R95 with other ill-defined and unspecified causes, making it impossible to identify "Sudden infant death syndrome" cases alone. The 1996 cause of death data coded by SSA to both ICD-9 and ICD-10 show that all 197 cot deaths according to ICD-9 (code 699) were coded as R95 in ICD-10. However, a further 1527 cases of "Other ill-defined and unspecified causes of mortality" (code 799 in ICD-9) were also coded as R95. All of the deaths coded to R95 were treated as ill-defined and reallocated to specified causes of death as described above.

Table 1 shows a comparison of the number of AIDS deaths estimated by adding the excess deaths observed in the nine selected conditions to the HIV deaths, compared with the number estimated using the ASSA2000 model. The increase in the tuberculosis death rates in the Western Cape did not follow the HIV/AIDS pattern, but suggested that there was a general increase in the death rates due to this disease over all ages. Careful examination of the data suggested that taking 70% of the increase as HIV-related would be a more suitable estimate. Nationally, when added to the deaths classified as HIV-related on the death certificate, the total accounts for 94% of the ASSA2000 model estimate of the number of AIDS deaths in 2000. This proportion varies by province and should be investigated further in the process of finalising the revised provincial models. At national level, the deaths that accounted for the increase in the nine indicator conditions accounted for 61% of the total deaths due to HIV/AIDS.

Province	HIV plus excess in nine indicator conditions (A)	ASSA2000 (B)	Ratio of A:B
Eastern Cape	17 267	16 316	105.8
Free State	12 118	11 897	101.9
Gauteng	30 381	34 141	89.0
KwaZulu-Natal	48 387	53 848	89.9
Limpopo	12 642	13 142	96.2
Mpumalanga	14 395	16 266	88.5
Northern Cape	1473	1361	108.3
North West	13 441	13 553	99.2
Western Cape*	3545	3507	101.1
Sum of provinces	153 650	164 032	93.7
South Africa (SA NBD)	155 800	165 792	94.0

Table 1. The estimated number of deaths due to HIV/AIDS compared with model estimate using ASSA2000

***Only 70% of the increased mortality due to tuberculosis has been included.**

Estimate of injury deaths

The total number of injury deaths was estimated using the proportion of injury deaths observed in the 12% sample in each age and sex group of each province applied to the total number of deaths estimated for that age and sex group. The national profile of the cause of death for fatal injuries from the National Mortality Surveillance System (NIMMS) data was then applied to the total number of injury deaths (Burrows *et al*., 2001). The national profile was applied due to the uncertainty of the variations observed in the NIMSS profile at provincial level, and the similarity observed previously between the NIMSS data and those seen in the demographic surveillance sites of Agincourt and the Africa Centre (ACDIS). The SSA sample of deaths could not be used for the injury profile as most of the injuries are reported without details about the manner of death. The majority of the injuries in the sample are therefore undetermined unnatural causes and it is difficult to interpret those that are specified. Complete compliance with the Inquest Act precludes pathologists from providing details about the manner of death at the time of registration of the death. However, some pathologists do provide sufficient information on the 2nd page of the death notification, a confidential form. This unresolved ambiguity in the requirements of the law needs to be reconsidered.

Age-standardised rates

The age-specific rates have been calculated using population estimates from ASSA2000. These have been used to calculate age-standardised rates by applying the WHO world population standard (Ahmad *et al.*, s.a.).

Years of life lost

Years of life lost (YLLs) have been calculated using the same method adopted in the South African NBD study, which follows the method used in the Global Burden of Disease studies (Murray and Lopez, 1996a; Murray *et al.*, 2001; WHO, 2003). The same standard life expectancy, discounting rate and age weighting have been used for the calculation of the YLLs.

Effectively, this standard life expectancy can be represented by a model life table, Coale and Demeny West Level 26, with a life expectancy at birth of 82.5 years for females (Coale and Demeny, 1966; Coale and Guage, 1989). An arbitrary biological male/female difference of life expectancy at birth of 2.5 years is used. This standard has a life expectancy at birth for males of 80 years, modelled on the West Level 25 life table for females. The discount rate of 3% per YLL is applied, and implies that individuals prefer time lived now rather than some time in the future. This rate is recommended by the International Panel on Cost Effectiveness in Health and Medicine (Gold *et al*., 1996). A continuous age-weighting function used for this analysis assigns a greater value to a year of life lived in a young or middle-aged adult versus the very young or elderly. Age weighting does not imply preference for any age group, since it is assumed that an individual's life span encompasses all ages.