

Demographic modelling of the HIV/AIDS epidemic on the Soweto population — results and health policy implications

T. Lee, T. Esterhuysen, M. Steinberg, H. Schneider

In this paper we present the results of a local HIV/AIDS demographic modelling exercise for Soweto, Johannesburg.

The Doyle model was used to project the growth of the HIV/AIDS epidemic in Soweto until the year 2010. High, medium and low AIDS scenarios are projected; these depend on reduction in the average number of sexual partners, increased condom use and effective treatment of sexually transmitted diseases.

In 1993 the HIV prevalence was estimated to be 3% for all three of the low, medium and high AIDS scenarios, but differences emerge rapidly after this. By 2010 the projected HIV seroprevalences in the high, medium and low AIDS scenarios are 24%, 15% and 8% respectively, corresponding with 343 000, 222 000 and 118 000 HIV-infected people.

By the year 2010, AIDS will have caused 135 000 - 270 000 deaths and during that year will account for 28 - 52% of all deaths. The total population will continue to increase in size, even in the high AIDS scenario, with the population growth rate ranging from 1.8% (low AIDS scenario) to 1% (high AIDS scenario) by the year 2010.

This modelling exercise has demonstrated the enormous potential impact of timely and effective implementation of currently available prevention strategies. The need to institute prevention programmes in the short term is therefore stressed. Recommendations are also made about the care of people with HIV/AIDS.

Other areas are encouraged to attempt similar exercises in order to stimulate local and regional planning of HIV/AIDS prevention and care.

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Centre for Health Policy, Department of Community Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg

T. Lee, B.A., B.Sc., M.B. CH.B., DIP. PH.C.(ED.), D.H.S.M.

H. Schneider, M.B. CH.B., D.C.H., D.T.M. & H.

Metropolitan Life, Cape Town

T. Esterhuysen, B. COMM. HONS (MATHEMATICAL STATISTICS)

National AIDS Programme, Medical Research Council, Johannesburg

M. Steinberg, B.Sc., M.B. B.Ch., D.O.H., M.Sc. (EPIDEMIOLOG.)

Data from various HIV prevalence surveys indicate that South Africa is currently undergoing a period of rapid spread of HIV infection. Combining these observations with assumptions about the natural history of the disease, mathematical models have been able to project the future of the AIDS epidemic as well as the impact of different interventions on this epidemic.

Several attempts have been made to model the future course of the HIV/AIDS epidemic in South Africa. Schall estimated that 30% of the sexually active adult black population could be HIV-infected by the years 2000 - 2005.¹ For the same population, Groeneveld and Padayachee estimated HIV prevalence rates of up to 27% by the year 2000.² The Doyle model predicts that by the year 2010, between 18% and 27% of the adult population will be HIV-infected.³

All these models project HIV spread on a national level and may be difficult to appreciate locally. Considerable regional differences in HIV prevalence have also been reported.⁴ There is a need for accurate modelling at regional and local levels in order to plan appropriate health service responses at these levels.

Following a request from the Baragwanath Hospital AIDS committee, the Centre for Health Policy, Baragwanath Hospital, Metropolitan Life (developers of the Doyle model) and the Medical Research Council established a collaborative project to model the impact of HIV/AIDS on Soweto. This paper presents the results of this demographic modelling and their implications for HIV/AIDS prevention and care in Soweto.

Methodology

There are various types of modelling methods that can be used to project the impact of AIDS on populations.^{5,6} They range from the least comprehensive (simple extrapolation and direct method) to intermediary (back-calculation and macrosimulation) to the most comprehensive (microsimulation) methods. Caution is needed in the use of any of these demographic models as their accuracy is critically dependent on the underlying assumptions and quality of the baseline data used.

The Doyle model

The Doyle model, which was used to project HIV/AIDS in Soweto, is based on macrosimulation modelling methods. It was developed to estimate the demographic impact of HIV/AIDS on South Africa as a whole, and has received wide local and international recognition. We chose this model because it is pragmatic and has undergone consistent development since its conception. The key assumptions and methodology underlying the model are described elsewhere^{3,7} and will only be covered briefly here.

The Doyle model divides the sexual behaviour of the population into four main risk categories characterised by degrees of sexual mobility and particular rates of sexually transmitted diseases (STDs). Each category has an assumed pattern of sexual contact both within and across risk categories that produces a series of smaller HIV epidemics which aggregate to form the epidemic as a whole. HIV

transmission rates in each category vary depending on the extent of infection with STDs.

Different incubation periods are used for different age groups, the average being 10.5 years.⁷

Specific prevention programme outcomes were selected and their impact on the spread of HIV assessed. The following three scenarios were selected: (i) **high HIV/AIDS** — assumes no change in the current course of the epidemic; (ii) **medium HIV/AIDS** — assumes a 40% reduction in the number of partners over the next 5 years (1992 - 1997), maintained from 1997 onwards; (iii) **low HIV/AIDS** — assumes a reduction in the number of partners, as in the medium HIV/AIDS scenario, as well as a 20% increase in effective condom use over the next 5 years (1992 - 1997), maintained from 1997 onwards, and the effective treatment of all STDs. Effective treatment implies cure of all individuals with an active STD. This effectively reduces the STD group's risk of HIV transmission to the equivalent of a lower-risk group's. In the absence of standard indicators, the 40% reduction in number of partners and the 20% increase in effective condom use were arbitrarily chosen to show that a significant change in these practices is required to make any real impact on the course of the epidemic.

Input data for the model

The model requires demographic data and seroprevalence rates as input data. There is considerable variation in population estimates for Soweto. After review of these estimates, a population of 2.1 million was settled upon.⁸ The age and sex structure was determined by indirect demographic techniques.⁸

HIV seroprevalence data from the second national antenatal clinic survey were used as inputs to the model.⁹ Extrapolations of seroprevalence produced by the model on the basis of these data corresponded well with antenatal seroprevalence data from Baragwanath Hospital. The Doyle model assumes that pregnant women have the same distribution of risk groups as the general population.

Results

In 1993, the HIV prevalence was 3% in all three scenarios. However, differences in the prevalence figures between scenarios emerge rapidly after this (Fig. 1). By 2010, the projected HIV seroprevalences in adults aged 15 - 59 years in the high, medium and low AIDS scenarios are 24%, 15% and 8% respectively; the corresponding numbers of HIV-infected people are 343 000, 222 000 and 118 000.

The growth in AIDS cases lags a few years behind HIV prevalence and by 2010 the three scenarios produce numbers of AIDS cases (all ages) of 47 000, 31 000 and 18 000 respectively.

By the year 2010, AIDS will have caused 135 000 - 270 000 deaths in Soweto. In the same year it will account for between 28% and 52% of all deaths. The changing population pyramids from 1993 to 2010 (Fig. 2) show the selective effect of the epidemic on young adults. By 2010 the number of AIDS orphans in Soweto will range from 65 700 to 137 000.

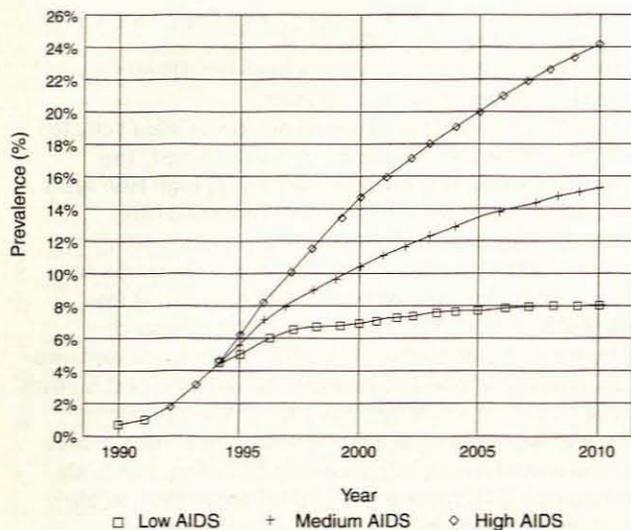


Fig. 1. HIV prevalence in Soweto adults aged 15 - 59 years.

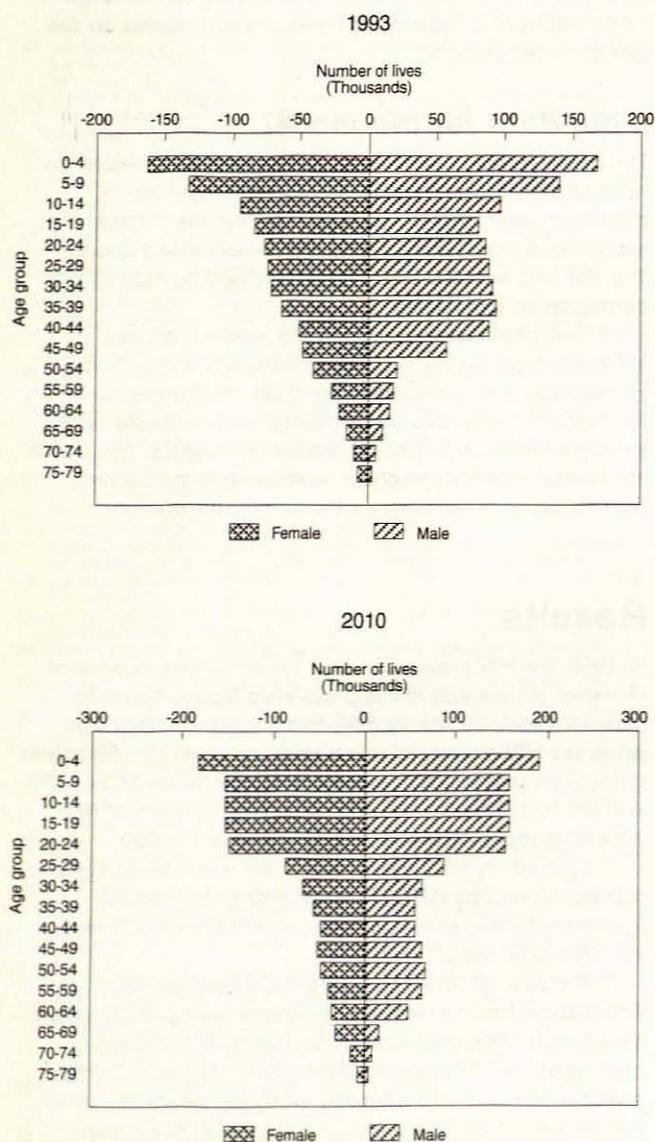


Fig. 2. Age distribution of Soweto population, 1993 and 2010.

The total population will continue to increase, even in the high AIDS scenario, with the population growth rate ranging from 1.8% (low AIDS scenario) to 1% (high AIDS scenario) by the year 2010. Table I provides a more detailed breakdown of results.

Table I. Summary of results of HIV/AIDS modelling in Soweto

Year	1993*	2000*	2010*
Total population			
No AIDS	2 070 000	2 418 000	2 980 000
Low AIDS	2 069 000	2 391 000	2 829 000
Medium AIDS	2 069 000	2 388 000	2 765 000
High AIDS	2 069 000	2 386 000	2 690 000
HIV-positives			
Low AIDS	36 000	88 000	118 000
Medium AIDS	36 000	132 000	222 000
High AIDS	35 500	185 000	343 000
AIDS cases			
Low AIDS	670	10 000	18 000
Medium AIDS	670	13 000	31 000
High AIDS	670	15 000	47 000
Cumulative AIDS deaths			
Low AIDS	1 200	31 000	135 000
Medium AIDS	1 200	35 000	196 000
High AIDS	1 200	40 000	270 000
AIDS/other deaths†			
Low AIDS	2.93%	27.67%	37.74%
Medium AIDS	2.93%	35.71%	67.96%
High AIDS	2.93%	43.82%	107.38%

* All numbers are those at the beginning of the year.

† AIDS deaths as a proportion of all other (non-AIDS) deaths.

The prevalence of tuberculosis infection in the urban black South African population is unknown but may range from 25% to 80% in the 15 - 59-year age group (B. Fourie — personal communication). If it is assumed that 50% of the Soweto population is infected with tuberculosis, and that this rate also applies to HIV-positive people, there are currently about 18 000 people in Soweto with dual TB-HIV infection. By the year 2010, this will have risen to between 59 000 and 172 000 people. With an annual incidence rate of 7.9% in dually infected people,¹⁰ it can be expected that between 4 600 and 13 600 new cases of tuberculosis will occur in HIV-infected people in Soweto in 2010.

Discussion

Health policy implications

Soweto is experiencing, and will continue to experience, a devastating AIDS epidemic, and these projections should provide the rationale for the immediate allocation of resources to control the further spread of infection. Money spent on preventive interventions at this stage of the epidemic will have a greater impact than equivalent expenditure at a later stage.¹¹

The projected effects of preventive action, specifically the reduction in numbers of sexual partners, increased condom use and effective STD treatment, have been demonstrated and are instructive to other regions. However, to have any real impact, such changes need to occur in the next 5 years, and preferably within the next 2 years.

All three areas of prevention should occur together, as the cumulative effect far exceeds the impact of any single intervention on its own. Modelling work elsewhere has also shown the synergistic effect of combining interventions.¹²

Experience of successful HIV prevention programmes is still limited, especially those required to achieve the results of the medium and low AIDS scenarios presented above. However, it is felt that these programmes would need to include at least the following aspects: (i) an AIDS education programme aimed both at the general population and at specific target groups, in particular the youth, hostel dwellers and sex-workers; (ii) improved condom promotion and distribution through the health service as well as other channels. These should include social marketing programmes which promote and distribute good quality and affordable condoms through small retail outlets; (iii) improved control of STDs through strategies such as improved case management, partner notification systems, one-to-one education and condom provision for people with STDs, community education concerning STDs and screening for asymptomatic infections.

The modelling exercise also helps to quantify the increased demand for health care which will be generated by the AIDS epidemic in Soweto. The predicted increase in tuberculosis cases will burden an already inadequately functioning tuberculosis service,^{13,14} and considerable improvements in case-finding and case-holding will be required. This is especially important if policies on tuberculosis chemoprophylaxis for HIV-infected people are introduced.

The World Health Organisation has developed guidelines for the management of HIV/AIDS.¹⁵ It recognises the need to integrate AIDS care into the existing health system, and the fact that this will have to occur without much additional funding. Vertical programmes for the care of people with HIV/AIDS are simply not affordable or sustainable in the long term.¹⁶

Projections of the economic impact of HIV suggest that hospital costs contribute most to the direct costs of HIV/AIDS care.¹⁷ A prospective study at the Somerset Hospital HIV outpatient clinic found that 69% of patient visits could have been handled at primary health care level.¹⁸

In Soweto, planning for care involves review of hospital practices related to admission and length of stay, and an increase in the capacity of primary care services to deal with HIV/AIDS on a decentralised basis. Support needs of primary care personnel must be defined, and training, management protocols and referral lines must be established.

Increased numbers of patients will require terminal care. The roles of health centres, hospices and home-based care facilities in providing this should be studied and the most cost-effective systems developed.

The projected number of orphans necessitates that the health service achieve close intersectoral collaboration with both state and non-governmental welfare organisations.

Limitations

Uncertainty about both the size and the structure of the Soweto population reduces the certainty of the HIV/AIDS projections. However, the relatively small population size used in this modelling exercise suggests that the projections are unlikely to be overestimates.

Inherent in all HIV/AIDS modelling is the difficulty in obtaining precise mathematical representation of a complex,

dynamic and interdependent human problem.¹⁹ In addition, the values and ranges of many of the major biological and behavioural variables affecting the spread of HIV are uncertain.²⁰

The preventive actions identified by the model require important shifts in social and cultural norms, and the diversion of considerable resources towards AIDS prevention. These may be difficult to achieve in the short term.

Modelling of the AIDS epidemic and not of other diseases results in a form of 'vertical modelling' which, although it provides a convincing lobby for AIDS funding, does not place this in the context of other health priorities.

Despite the above limitations, other regions are encouraged to develop their own projections. Information required includes: (i) total population size with age and sex distribution; (ii) total (or preferably age-specific) fertility rates; (iii) age-specific mortality rates; and (iv) HIV seroprevalence data.

Regional projections are important not only because of the regional differences in the HIV epidemic, but also because health service planning tends to occur at regional and district levels. By demonstrating the future impact of AIDS, the projections may also facilitate the mobilisation of resources towards HIV/AIDS prevention and care at a stage when the epidemic is still relatively invisible. Finally, the projections also serve as targets against which the health service can judge the success of its interventions.

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REFERENCES

- Schall R. On the maximum size of the AIDS epidemic among the heterosexual black population in South Africa. *S Afr Med J* 1990; **78**: 507-510.
- Groeneveld H, Padayachee GN. A stochastic model for medium-term estimation of the prevalence of HIV infection in the South African heterosexual population. *S Afr Med J* 1992; **81**: 67-70.
- Dolye PR. The impact of AIDS on the South African population. In: Broomberg J, ed. *AIDS in South Africa: The Demographic and Economic Implications* (Part I). Johannesburg: Centre for Health Policy, University of the Witwatersrand, 1991.
- Department of National Health and Population Development. Third national HIV survey of women attending antenatal clinics, South Africa, October/November 1991. *Epidemiol Comments* 1993; **20** (3): 35-47.
- Padayachee GN, Schall R. Short-term predictions of the prevalence of human immunodeficiency virus infection among the black population in South Africa. *S Afr Med J* 1990; **77**: 329-333.
- Padayachee GN, Groeneveld H. Statistical approaches to determining the current extent and future prevalence of HIV infection in South Africa (Editorial). *S Afr Med J* 1992; **81**: 57.
- Doyle P. *Update of an HIV/AIDS Model* (In preparation). Cape Town: Metropolitan Life.
- Chimere-Dan O. Selected demographic estimates for Soweto 1992 (Unpublished data). Department of Sociology, University of the Witwatersrand, Johannesburg, 1993.
- Department of National Health and Population Development. Second national HIV survey of women attending antenatal clinics, South Africa, October/November 1991. *Epidemiol Comments* 1992; **19**(5): 80-92.
- Selwin PA, Hartel D, Lewis VA, et al. A prospective study of the risk of tuberculosis among intravenous drug users with human immunodeficiency virus infection. *N Engl J Med* 1989; **320**: 545-550.
- Rowley JT, Anderson RM, Ng TW. Reducing the spread of HIV infection in sub-Saharan Africa: some demographic and economic implications. *AIDS* 1990; **4**: 47-56.
- Potts M, Anderson R, Boily M. Slowing the spread of human immunodeficiency virus in developing countries. *Lancet* 1991; **338**: 608-613.
- Saunders LD, Irwig LM, Wilson TD, Kahn A, Groeneveld H. Tuberculosis management in Soweto. *S Afr Med J* 1984; **66**: 330-333.
- Edginton ME, Price M. A record review of patients notified with TB to two clinics in part of Soweto in 1991. Poster presented at the 11th Epidemiological Conference, Johannesburg, 3 - 4 August 1992.
- World Health Organisation. *Clinical Management Guidelines for HIV Infection in Adults*. Geneva: WHO, 1990.
- Tarimo E, Fowkes FGR. District health systems: strengthening the backbone of primary health care. *World Health Forum* 1989; **10**: 74-49.
- Broomberg J, Steinberg M, Masobe P, Behr G. The economic impact of AIDS in South Africa. In: Broomberg J, ed. *AIDS in South Africa: The Demographic and Economic Implications* (Part II). Johannesburg: Centre for Health Policy, University of the Witwatersrand, 1991.
- Metriken AS, Zwarenstein M, Steinberg M, Van Der Vyver E. Appropriate levels of outpatient care for patients with HIV/AIDS. Paper presented at the 12th Epidemiology Association of South Africa (ESSA) Conference, Durban, 29 - 30 September 1993.
- United Nations/World Health Organisation. *The AIDS Epidemic and its Demographic Consequences*. New York: United Nations/World Health Organisation, 1991.
- Chin J, Remenyi MA, Morrison F, et al. The global epidemiology of the HIV/AIDS pandemic and its projected demographic impact in Africa. *World Health Stat Q* 1992; **45**: 220-227.

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