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**Infant and child mortality in South Africa  
in the context of a high HIV prevalence:  
An investigation into changing mortality patterns  
at a fine age resolution.**

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## **Abstract**

South Africa has very high levels of HIV prevalence, with some provinces having among the highest levels in the world. Within this context it is imperative to have a clear understanding of how the epidemic is affecting infants and children in the population and to what extent interventions are affecting mortality. However, establishing accurate estimates of infant and child mortality levels is very difficult in South Africa because the data available is nearly a decade out of date. Demographic modelling techniques and extrapolations from out of date data provide the closest estimates but are less than ideal in the middle of an HIV epidemic. What is needed is a surveillance method that can provide rapid, up to date information on infant and child mortality, within an environment of high HIV prevalence that can inform health policy for South Africa's youngest citizens.

This study utilized routinely collected national vital events data to describe trends in infant and child mortality from 1990 to 2006. Mortality was examined by age of death in months, a finer age resolution than has been previously published. Data used in this study consisted of unpublished mortality statistics collected by Statistics South Africa from 1990 to 2002, and data extracted from the Population Register database maintained by the Department of Home Affairs for the years 1998 to 2006. The Population Register database was investigated for use as a potential mortality surveillance tool to measure current trends in infant and child mortality and to measure any effects by HIV/AIDS interventions at a population level.

Several new and unique findings were revealed in this study. First, a new and increasing all-cause peak in mortality was discovered centring at 3 months of age – a new, previously unpublished, demographic phenomenon. Second, a coding error was found in causes of death of infants under 1 year of age in the data recorded by Statistics South Africa (Stats SA) resulting in the incorrect coding of the majority of deaths in this age group. Despite the problems with coding of cause of death, the peak in mortality at 3 months was shown to be due to HIV/AIDS mortality and was the third finding in this study. The fourth finding was that the Population Register data could further be used with the 3 month peak in mortality as a rapid surveillance tool to measure trends in infant mortality. By utilizing the up to date data from the Population Register database and monitoring the peak in mortality at 3 months, this study was able to show that HIV/AIDS interventions such as the ARV rollout and PMTCT programs are beginning to have a positive effect at a population level. This method of surveillance was able to examine changes in mortality at 3 months at both a national and provincial level.

## **Glossary of abbreviations and terms**

<b>AIDS</b>	<b>Acquired Immunodeficiency Syndrome</b>
<b>AIDS sick</b>	<b>Number of people estimated to be living with AIDS defining conditions.</b>
<b>ART</b>	<b>Antiretroviral Therapy</b>
<b>ARV</b>	<b>Antiretroviral</b>
<b>ASSA</b>	<b>Actuarial Society of South Africa</b>
<b>DHA</b>	<b>South Africa Department of Home Affairs</b>
<b>DOH</b>	<b>South Africa Department of Health</b>
<b>External cause</b>	<b>Cause of death due to unintentional and intentional injuries, also called non-natural cause</b>
<b>HIV</b>	<b>Human Immunodeficiency Virus</b>
<b>HSRC</b>	<b>South Africa Human Sciences Research Council</b>
<b>ICD-10</b>	<b>International Classification of Diseases</b>
<b>IMR</b>	<b>Infant mortality rate – the probability of infants dying before reaching 1 year of age</b>
<b>MRC</b>	<b>South Africa Medical Research Council</b>
<b>MSF</b>	<b>Médecins Sans Frontières (Doctors without Borders)</b>
<b>MTCT</b>	<b>Mother-to-Child Transmission</b>
<b>Natural cause</b>	<b>Cause of death as a result of a naturally occurring process</b>
<b>Neonate</b>	<b>Infants aged from birth to 28 days</b>
<b>Neonatal mortality rate</b>	<b>The probability of infants dying between birth and 28 days</b>
<b>NIMSS</b>	<b>National Injury Mortality Surveillance System</b>
<b>Non-natural cause</b>	<b>Cause of death due to unintentional and intentional injuries, also called external cause</b>
<b>PMTCT</b>	<b>Prevention of Mother-to-Child Transmission</b>
<b>Post-neonate</b>	<b>Infants aged 29 days to 11 months</b>
<b>PPIP</b>	<b>The Perinatal Problem Identification Program</b>
<b>SA</b>	<b>South Africa</b>
<b>SADHS</b>	<b>South Africa Demographic and Health Survey</b>
<b>Stats SA</b>	<b>Statistics South Africa</b>
<b>TB</b>	<b>Tuberculosis</b>
<b>U5MR</b>	<b>Under 5 mortality rate - the probability of a children dying before 5 years of age</b>
<b>UNICEF</b>	<b>The United Nations Children's Fund</b>
<b>USA</b>	<b>United States of America</b>
<b>WHO</b>	<b>World Health Organization</b>

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# 1 Introduction

Infant and child mortality levels are extremely high in sub-Saharan Africa, especially when compared to developed countries. HIV/AIDS prevalence is also very high in sub-Saharan Africa, and has had a particularly devastating effect on mortality. By 2004 there were an estimated 1700 infants per day infected with HIV through mother to child transmission (MTCT), most of which occurred in Africa. This is compared to 1 infection per day in Europe and the USA *combined* (McIntyre 2005). It is estimated that 60% of children who become infected with the virus will die before their 5<sup>th</sup> birthday from HIV/AIDS (UNAIDS 2002). South Africa has not been spared, having close to the highest levels of HIV prevalence in the world. Furthermore, estimated levels of infant and child mortality are high. Within this context it is imperative to have a clear understanding of how the epidemic is affecting infants and children in the population, and to what extent interventions are affecting mortality. Accurate estimates of infant mortality rate (the probability of infants dying before reaching 1 year of age) and under 5 mortality rate (the probability of a children dying before 5 years of age) cannot be made in South Africa because the data available is nearly a decade out of date. Demographic modelling techniques and extrapolations from data that is 10 years out of date data provide the closest estimates but are less than ideal in the middle of a rapidly changing HIV epidemic.

This study utilizes routinely collected national vital events data to describe trends in infant and child mortality at a finer age resolution than has been previously published. Data extracted from the Population Register database maintained by the Department of Home Affairs was used to describe the most current mortality trends up to 2006. This data was examined here as a potential data source for a rapid surveillance tool to monitor trends in infant and child mortality, monitor effects of HIV interventions and to offer rapid and up to date information for informing health policy.

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## **Aim and objectives**

### **Aim**

The aims of this research were twofold: *a)* to utilize national vital events data to describe patterns of mortality in infants and children in South Africa from 1990 to 2006, a period of ever increasing HIV prevalence, and *b)* to determine if these data can be accurately and effectively used as a rapid surveillance tool for identifying changes in mortality trends overtime.

### **Objectives**

Arising from the stated aims, four distinct objectives guide the project:

1. Describe the trends in the number of infant and child deaths from 1990 to 2002 by age in months using Statistics South Africa data.
2. Describe the trends in the leading cause of death in infants and children from 1997 to 2002 using Statistics South Africa data by both examining cause of death by age in years, and examining cause of death by age in months.
3. Explore the association of the increased mortality in infants with the prevalence of AIDS sick in the population using Statistics South Africa data.
4. Assess the utility of the Population Register database as a rapid surveillance tool for trends in infant mortality, and determine if it can be used to measure any effects by HIV/AIDS interventions on trends in mortality among infants. This will be done by describing both the current trends in the number of infant deaths from 2002 to 2006, and the trends in the number of infant deaths from 2002 to 2006 by province.

## **2 Literature review**

A dramatic trend that saw great reductions in child mortality occurred during the mid-1980s and throughout the 1990s in most middle and lower income countries. However, this trend has since slowed in many countries and child mortality is once again on the rise (Ahmad, *et al.* 2000). This is particularly obvious in sub-Saharan Africa, and is due largely to the spread of HIV/AIDS (Ahmad, *et al.* 2000). In 2000 it was estimated that close to 99% of the world's 10.9 million children who died under the age of 5 years were children from middle and lower income countries (WHO 2002).

On the 8<sup>th</sup> of September 2000, South Africa joined the world in signing the United Nations Millennium Declaration, a commitment to improving the lives of the world's poorest citizens by 2015 (United Nations 2000). Number four of the Millennium Development Goals set by the declaration calls for a two thirds reduction in the under 5 mortality rate (U5MR) from 1990 levels by 2015 (United Nations 2007). In 2004, as part of this international effort to meet this goal, the World Health Organisation (WHO) and The United Nations Children's Fund (UNICEF) held a joint meeting resulting in the interagency agreement determining minimum key indicators required for monitoring child survival (UNICEF 2004).

These indicators include under 5 mortality rate (U5MR) defined as the probability of dying under the age of 5 years per 1000 live births, infant mortality rate (IMR) defined as the probability of dying under the age of 1 year per 1000 live births, and

neonatal mortality rate defined as the probability of dying after birth to age 28 days per 1000 live births. The indicators chosen were based on the prevention and treatment interventions outlined in the Lancet series on child survival published in 2003.

The latest UNICEF estimates of U5MR, IMR and neonatal mortality rate for selected countries are shown in Table 1 (UNICEF 2007). In 2005 South Africa, a middle income country, and had an estimated U5MR of 68 deaths per 1000 live births and an estimated IMR of 55 per 1000 live births. This is considerably lower than the U5MR in lower income countries such as Mozambique with a reported U5MR of 145 and Uganda with 136. Infant mortality rates and neonatal mortality rates in Mozambique and Uganda were also very high. IMR in Mozambique was 100 and in Uganda, 79. Neonatal mortality rate in Mozambique was 48 and in Uganda, 32. In comparison, the U5MR in Japan was 4 deaths per 1000 live births in 2005, IMR was 3 and neonatal mortality rate was 2 deaths per 1000 live births. Brazil, similar to South Africa in its level of economy activity, had an U5MR in 2005 approximately half that of South Africa (33 deaths per 1000 live births). Infant mortality in Brazil was 31 (South Africa's IMR was 55) and neonatal mortality was 15 (South Africa's was 21).

**Table 1. Under-five mortality rates, infant mortality rates and neonatal mortality rates.**  
 Source: *The State of the World's Children 2007*, UNICEF 2007.

	<b>U5MR</b> (per 1000 live births)	<b>IMR</b> (per 1000 live births)	<b>Neonatal mortality rate</b> (per 1000 live births)
<b>Mozambique</b>	145	100	48
<b>Uganda</b>	136	79	32
<b>South Africa</b>	68	55	21
<b>Brazil</b>	33	31	15
<b>United States</b>	7	6	5
<b>United Kingdom</b>	6	5	4
<b>Japan</b>	4	3	2

South Africa is ranked among the top third of countries for the highest under 5 mortality rate (UNICEF 2007). While South Africa has previously seen a decline in the mortality rate in the 1980s and 1990s, the trends have since reversed and infant and child mortality is now increasing (Nannan, *et al.* 2006). It is estimated that currently 1 infant under 1 year dies every 10 minutes in South Africa, many from preventable conditions including HIV/AIDS (Jacobs, *et al.* 2005; Bradshaw, *et al.* 2003a). Furthermore, 59% of child deaths in South African hospitals were due to HIV/AIDS in 2004 (Krug and Pattinson 2005).

## **2.1 HIV/AIDS in South Africa**

The first cases of AIDS were reported in the United States in 1981 (CDC 1981; Friedman-Kien 1981; Gottlieb, *et al.* 1981; Masur, *et al.* 1981; Safai and Good 1981). Approximately 1 year later the first AIDS cases in South Africa appeared (Ras, *et al.* 1983). Although initially a disease seen in the population of

homosexual men, it eventually spread to the heterosexual population. By 1988 the number of HIV infected women in South Africa had begun to increase (Kustner 1994; Moodie 1994).

Several key factors, including poverty and government responses have resulted in the acceleration of the epidemic in South Africa. It has been shown that poverty and poor nutrition drive the pandemic throughout the world and the poor are the worst affected by HIV/AIDS (Coovadia and Hadingham 2005). When South Africa was ruled by the Apartheid government prior to 1994, migrant labour laws were in place which prevented black males from moving their families with them to the cities where they worked. This, and the sub-Saharan trucking routes, have also contributed to the spread of HIV/AIDS (Lurie 2000). The epidemic was further allowed to proceed by the Apartheid government's inaction to a disease it considered a homosexual or black disease, while the immediate concern of the anti-Apartheid movement was for the liberation of the country (Karim and Karim 2002). It was within this political and social context that the disease took hold in South Africa. By 1990, data collected from national sentinel surveys of public sector antenatal clinic attendees conducted by the South African Department of Health estimated that HIV sero-prevalence among woman attending antenatal clinics was 0.7% (DOH 2007). By 1994 it was 7.6% and four years later in 1998 it had risen as high as 22.8%. The latest National HIV and Syphilis Antenatal Sero-Prevalence Survey in South Africa estimates that HIV prevalence rates among antenatal clinic attendees in South Africa had risen to 30.2% by 2005. HIV prevalence appears to have stabilized, with the 2006 figure at 29.1% (DOH 2007). On a provincial level, surveys indicate that some provinces in South Africa now

have close to the highest HIV prevalence rates in the world. For example, HIV prevalence in KwaZulu-Natal was as high as 39.1% in 2005, but appears to have stabilized at that rate in 2006 (DOH 2007).

For an infant, the greatest risk of becoming infected with HIV is through vertical transmission of the virus from the mother. Mother to child transmission (MTCT) can occur during pregnancy, during labour and delivery, or through transmission of the virus through breast milk. MTCT occurs at a rate of between 25% and 45% in the absence of prevention measures (The Working Group on MTCT of HIV 1995). Recent studies in South Africa have also shown that, depending on whether a child was breastfed or not, MTCT rates ranged from 19% to 36% without intervention (Coutsoudis, *et al.* 2001). In addition, it is estimated that 60% of children who do become infected with the virus will die before their 5<sup>th</sup> birthday from HIV/AIDS in the absence of treatment (UNAIDS 2002).

The number of deaths due to HIV/AIDS are vastly under reported in South Africa, and many deaths are misclassified to the immediate cause of death rather than death due to HIV/AIDS (Groenewald, *et al.* 2005). Groenewald and colleagues investigated 22 specific causes of death for an underlying cause of death of HIV/AIDS in adults and found 9 causes that were likely misclassified HIV/AIDS deaths. In addition, they estimated that 64.3% of lower respiratory infections were attributed to HIV/AIDS in children under 5. In a study carried out in 2000 at a paediatric teaching hospital in Cape Town, South Africa, it was found that 11.4% of HIV-related deaths were under reported and an additional 29.5% of HIV-related deaths were not classified as such, but were described using non-specific terms

(Westwood 2000). Concerns by doctors regarding confidentiality of details written on deaths notification forms and their reluctance to state HIV/AIDS as the cause of death, also contribute to the under reporting and misclassification of HIV/AIDS deaths (Dhai, *et al.* 2000).

## **2.2 Mortality data on infants and children in South Africa**

Data on population mortality is typically collected through vital registration data systems, census data or household surveys. Prior to 1994 the main sources of data on infant and child mortality in South Africa were surveys carried out by the Human Sciences Research Council (HSRC) (Roussouw and Hofmeyr 1990). These surveys suggested a decline in child mortality during the 1980s, but estimating trends in infant and child mortality based on this data is difficult (Nannan 1988). The first nationally representative sources of quality data on infant and child mortality, with the support of the new, post-Apartheid government, were the 1998 South Africa Demographic and Health Survey (SADHS) and the 1996 Census (DOH 2002). Nannan and colleagues (2006) utilised these data sources and identified a reversal of neonatal (refers to infants aged from birth to 28 days) and post-neonatal (refers to infants aged 29 days to 11 months) mortality occurring around 1993. Unfortunately the 1998 SADHS and the 1996 Census are *still* the most current population data sources available on infant and child mortality in South Africa. They are still the most commonly quoted by international organizations (UNICEF 2007; UNDP 2006; WHO 2006; The World Bank 2007), including the estimates reported by UNICEF shown earlier in Table 1. In short it is not possible to make accurate estimates on current infant or child mortality in

South Africa based on data that is a decade old, especially when the HIV/AIDS epidemic can change the demographics of a population so dramatically. In 2003, the next scheduled SADHS survey was conducted but reported implausible levels of child mortality (Dorrington, *et al.* 2004). The survey has been published in summary only, and includes a release note acknowledging the problems with the results (DOH 2003). The next survey is scheduled for 2008. The next scheduled national census was carried out in 2001 but was found to be unusable for childhood mortality estimates (Dorrington, *et al.* 2004). The next census is planned for 2011.

Recognising the lack of timely reporting of mortality statistics in light of an increasing HIV/AIDS epidemic, the national statistics board of South Africa, Statistics South Africa (Stats SA) published two short reports based on small subsets of mortality data gained from vital registration records for the years 1997 to 2001 (Stats SA 2001; Stats SA 2002a). Subsequent reports by Stats SA provide mortality statistics from all available death notification forms, including information on cause of death for the years 1997 to 2004 (Stats SA 2005; Stats SA 2006). A recently published report contains mortality and cause of death data up to 2005 and, for the first time, province of registration of death is included (Stats SA 2007). Exact dates of births and deaths, or ages of death under 1 year, are not provided in any of these reports or the data sets provided with these reports. Infants and children were typically reported in age groups of 0 to 14 years, or further disaggregated to infants under 1 year and children from 1 to 4 years. Information on the leading causes of death among neonates (infants from 0 to 28 days old) and post-neonates (infants from 29 days to 11 months old) was added for 2003

onwards. It is expected that these broader groupings may have been used because data on children is typically scarce.

Based upon these reports, a limited amount of cause of death information is available on infants and children. As reported by Statistics South Africa (Stats SA), the most common cause of death of infants under 1 year of age for the years 1997 to 2005 was *respiratory and cardiovascular disorders originating in the perinatal period*. The leading cause among children in the 1 to 4 year age group during this period was *intestinal infectious diseases*. In 2005, the top cause of death among neonates and post-neonates was *respiratory and cardiovascular disorders originating in the perinatal period*.

Although the data in these reports were published two years after many of the data were collected, the reports are still remiss in giving detailed consideration to the mortality trends of infants and children. Furthermore, because of the lag between the occurrence of events and the time of publication of the data, the Stats SA reports are not suitable for rapid mortality surveillance.

What empirical data remains on infant and child mortality in South Africa are small studies usually conducted on hospital populations. For example, The Perinatal Problem Identification Program (PPIP) of the South African Medical Research Council originating in 1999, now collects data on births from over 164 public health facilities (Pattinson 2000). Between 2003 and 2006 it collected data on approximately 20% of all births occurring in South Africa over that time period. The data collected provides insight into current trends in perinatal and neonatal

mortality in public health facilities. The program has been extended to include children up to age 5 years of age and older (Krug and Pattinson 2005). Yet while the data from these efforts are extremely valuable, they are clinic based samples and are not designed for calculating population estimates.

In the midst of an HIV/AIDS epidemic, and with the paucity of reliable empirical data available on mortality, a modelling approach was used in the South Africa National Burden of Disease Study of 2000 in an attempt to make reliable estimates of mortality (Bradshaw, *et al.* 2004). The study used the ASSA2000 AIDS and Demographic model of the Actuarial Society of South Africa calibrated to available empirical data (ASSA 2000). Estimates of U5MR in 2000 was 95 deaths per 1000 live births and IMR was 59 per 1000 live births (Bradshaw, *et al.* 2003a). Other models have been used in other studies and have produced varying results (Rehle and Shisana 2003; UNDP 2007). Deriving estimates of infant and child mortality from these models is difficult. The problem exists because, while the adult mortality component of the models can be reliably calibrated with empirical data, the data for children is slim and not reliable. (Bradshaw and Dorrington 2007). Therefore current models can not provide accurate estimates on infants and children.

Although the exact levels of infant and child mortality in South Africa are uncertain, it is clear that HIV prevalence is very high in South Africa and public health interventions are needed. The national government of South Africa began providing antiretroviral therapy (ART) in public health facilities at late as 2004, after a constitutional court ruling mandating that they provide antiretroviral drugs (ARVs) to pregnant women for the prevention of mother to child transmission (PMTCT)

(Friedman and Mottiar 2005; TAC 2003). Implementations of services of ART and PMTCT have been very slow. Estimates of coverage of ART in South Africa in 2005 was between 7% and 14% (WHO 2005a; WHO 2005b). Furthermore, only 14% of women who need PMTCT services currently are estimated to be receiving them (Shisana 2007).

The very high HIV prevalence rates in South Africa, the high risk of mother to child transmission (MTCT) and the high mortality estimates due to HIV/AIDS in infants and children creates an urgent need for an accurate measurement tool to evaluate the effect of the epidemic on infants and children in the population. A unique surveillance method for rapidly monitoring adult mortality using vital events data from the Department of Home Affairs has been proposed by Dorrington and colleagues (2001). This method utilised existing population mortality statistics available just 2 months after the deaths occurred. No rapid surveillance method exists, however, to monitor changes in infant and child mortality. Such a method, possessing the ability to monitor infant and child mortality, would be of vital importance in South Africa in the context of a very high HIV prevalence and high infant and child mortality.

### **3 Methods**

This study utilises routinely collected national vital events data to describe trends in infant and child mortality in South Africa from 1990 to 2006. This is an ecological study, examining trends in mortality on a population level. Mortality patterns for males and females were similar at the ages covered in this study, therefore differences between males and females are not part of this study and the data for males and females were combined.

Part 1 of the results section of this paper utilised special tabulations of official mortality statistics acquired through the South Africa Medical Research Council (MRC) from Statistics South Africa (Stats SA), to describe trends in infant and child mortality from 1990 to 2002. Part 2 of the results section utilised data from the Population Register database maintained by the Department of Home Affairs. This data was used to describe current infant and child mortality from 1998 to 2006 and the potential use of this source as a rapid surveillance tool was explored. This data was also acquired through the MRC. The following description of the death registration process and the generation of mortality data is required to understand what part of the South African population is represented in each data source utilized in this study.

### **3.1 Registration of deaths and collection of vital events data in South Africa**

Mortality data used in this study are based upon notification of death forms collected by the Department of Home Affairs. In terms of the Birth and Death Registration Act number 51 of 1992, each death in South Africa must be recorded on a notification of death form provided by the Department of Home Affairs. In 1998 a new form, number BI-1663, (Figure A-1a and A-1b in Appendix A) was introduced replacing the BI-7 and BI-12 forms. It is required that notification of death forms are filled out by a medical practitioner or professional nurse. In rural areas, where a medical practitioner may not be available, an alternate form (number BI-1680) may be completed by a traditional headman (Figure A-1c in Appendix A). In the case where a medical professional is unable to certify that a death was the result of natural causes, a post-mortem is required by law to establish the cause of death (a natural cause of death is a cause of death as a result of a naturally occurring process). After a post-mortem, a district surgeon or forensic pathologist completes the notification of death form. Despite these guidelines, some medical officials still describe the non-natural cause of death on death notification forms (a non-natural cause of death, also called an external cause, is a cause of death due to unintentional and intentional injuries).

Four lines on the death notification form allow for recording of the immediate cause of death, the multiple conditions leading up to the immediate cause of death, and the underlying cause of death. The underlying cause of death is the cause for which were it not present, death would not have occurred. The underlying cause of death is the cause that should be targeted for public health intervention. All

completed notification of death forms are sent to the appropriate regional office of Home Affairs and then on to the national office of Home Affairs where the forms are processed and archived. Processing involves the creation of an official death certificate (Figure A-1d in Appendix A) from the information recorded on the notification of death form. There is only one line available for cause of death on the death certificate. As a result, from the four lines describing the cause of death on the notification of death form, clerks at the Department of Home Affairs typically select the top line on the death notification form, which usually corresponds to the immediate cause of death, and transfers this information to the death certificate. There is no attempt by the clerks to record or determine the underlying cause of death (Bourne 2007). The next step in the process of death registration involves the transfer of information onto a computerised database for purposes of maintaining and updating the South African Population Register. Information from completed death certificates is recorded onto the Population Register database for *only* those individuals for whom the birth was registered with sufficient information for an ID number to be issued, in addition to the death being registered with an ID number. Data from the Population Register database was provided to the Medical Research Council and a de-identified data set was made available for this study. A description of this data set follows this section.

Simultaneously, copies of death notification forms are sent from the national office of the Department of Home Affairs to Statistics South Africa (Stats SA) for statistical analysis and the creation of reports on death as is customary for a national statistics office. At Stats SA, notification of death forms are processed and the underlying cause of death is determined. Processing involves a coder at Stats

SA assigning a code to each cause of death that has been recorded on the four cause of death lines on the forms using the International Classification of Diseases (ICD-10) developed by the World Health Organisation (WHO 1992). Coders follow guidelines contained in the Statistics South Africa (Stats SA) manual, *Guidelines for coders using ICD-10* (Stats SA 2002b). Underlying cause of death is then derived using the Automated Classification of Medical Entities (ACME) software programme developed by the United States National Center for Health Statistics (NCHS 2007). Stats SA records deaths and determines underlying cause of death for both those individuals who possessed a South Africa ID number *and* those individuals who do not. Data from the Stats SA was provided to the Medical Research Council and a de-identified data set was made available for this study. A description of this data set follows.

### **3.2 Vital events data sets analysed in this study**

The vital events data sets used in this study were obtained from the results of the death registration process described previously. The three specific data sets used are described below. The difficulty in obtaining the data, along with confidentiality issues and the completeness of the data contained in the data sets are discussed.

#### **3.2.1 Availability of data sets and confidentiality**

Availability of data for this study was problematic, both in timeliness and with regard to issues around confidentiality. While all data made available for this study was de-identified data acquired through the South African Medical Research

Council (MRC), major constraints hampered access of data from Statistics South Africa in particular. Stats SA had in the past (up to and including the 1996 mortality records) supplied full de-identified unit records for scientific study, but a change in policy meant that Stats SA felt that release of mortality data containing exact date of birth and death might compromise the confidentiality it was obliged to maintain under the Statistics Act of 1999 section 17 (1)(a). The result was that Stats SA was not able to provide data by age of death in days; rather data was limited to a special data tabulation of mortality statistics consisting of an extensive set of tables where age of death was calculated in months of 30.5 average days. The fact that data in this study was not available by age of death in days created a slight artefact when calculating age in months, slightly affecting comparisons between Stats SA data and data from the Population Register. This did not affect the final results and is further explored in section 4.2.1 of the results.

### **3.2.2 Description of data sets analysed in this study**

The data sets used in this study are listed in Table 2. They are described in detail in the sections below.

**Table 2. Data sets used in this study.**

<b>Code</b>	<b>Source of data</b>	<b>Dates</b>	<b>Details</b>
1	Stats SA	1990 to 1996	Total number of deaths of infants under 5 years of age
2	Stats SA	1997 to 2002	Total number of deaths of infants under 5 year of age Underlying cause of death by ICD-10 chapter
3	Population Register from DHA	1998 to 2006	Total number of deaths of infants under 1 year of age by province Cause of death by natural/non-natural cause

### **3.2.2.1 Data from Statistics South Africa**

The first data set used in this study was a special request tabulation of de-identified unit records produced by Statistics South Africa for registered deaths occurring between 1997 and 2002 for which an exact date of birth and date of death was recorded. This data set included deaths of both those individuals *with* a South African ID number and those *without* an ID number. Data was presented in the form of multiple tables containing deaths of infants and children who died under 5 years of age. Data was tabulated by age of death in months of 30.5 days, by sex, and by underlying cause of death coded to ICD-10 chapter category (WHO 1992). Stillbirths were not included in this data set.

The second data set used in this study was an additional tabulation prepared by the MRC from data acquired from Statistics South Africa for deaths occurring

between 1990 and 1996. It also contained deaths of those individuals *with* a registered South African ID number and those *without* an ID number where an exact date of birth and date of death were recorded. It included total numbers of deaths under 5 years of age tabulated by age of death in months of 30.5 days, but contained no cause of death information. Stillbirths were not included in this data set.

### **3.2.2.2 Data from the Population Register of Department of Home Affairs**

In order to obtain more up to date data for this study, a de-identified mortality data set from the Department of Home Affairs containing deaths occurring between 1998 and 2006 was supplied by the MRC. This data set was the third data set used in this study and was based on a computerised database maintained by the Department of Home Affairs for the purposes of updating the South African Population Register. This database contained registered deaths of *only* those individuals for whom the birth was registered with sufficient information for an ID number to be issued, in addition to the death being registered with an ID number. It does not include deaths of those individuals without a South Africa ID number. From the Population Register database, the MRC produced a secondary de-identified data set for use in this study. The data set supplied contained deaths of infants and children who died before the age of 12 months tabulated by age of death in weeks and by the province where the death was registered. In addition, cause of death was separated into the two categories of natural and non-natural deaths. Stillbirths were not included in this data set. Mortality data extracted from the Population Register of the Department of Home Affairs was received by the

MRC in terms of section 29 of the birth and deaths registration act of 1992, which gives discretionary powers to the director general of Home Affairs. As a result the Department of Home Affairs is under much less rigid constraints as far as making population data available for scientific study than is the case for Statistics South Africa. Furthermore, this data is available from the Department of Home Affairs just two months after the deaths were registered.

### **3.3 Completeness of data sets**

The completeness of death registration has an effect on both the Stats SA data sets and the Population Register data set. The completeness of birth registration and the assignment of South Africa ID numbers have an additional effect on the Population Register data set.

#### **3.3.1 Completeness of death registration**

Completeness of death registration affects the quality of both the Stats SA data sets and the Population Register data set. Registration of deaths in South Africa has improved, particularly with the introduction of the new death notification forms in 1998. South Africa has made extensive efforts to improve vital registration (Bradshaw, *et al.* 1998; Bradshaw, *et al.* 2004). The completeness of adult registration in 1990 was estimated at 54%, increasing to 89% in 2000 (Dorrington, *et al.* 2001). Completeness of death registration of infants and children remains a limitation of the mortality data in this study because the completeness of registration of these younger age groups is very poor and difficult to estimate

(Dorrington, *et al.* 2001; Timaeus, *et al.* 2002). One recent study in a rural area outside of the city of Johannesburg showed that completeness of registration of child deaths was increasing but was still currently below 30% (Kahn 2006).

### **3.3.2 Completeness of birth registration and assignment of ID number**

The Population Register data set is a subset of the Stats SA data set containing only those deaths where both the birth and the death are registered and linked by an ID number. The completeness of birth registration and the assignment of a South Africa ID number affect the quality of the Population Register data set, in addition to the completeness of death registration. The completeness of birth registration increased from less than 25% in 1998 to 72% in 2005 (Dobbie, *et al.* 2007). The age specific completeness of ID registration was investigated by Laubscher and colleagues (2007). The study found that the percent completeness of IDs for children under 1 year of age in 1998 was only 9%, but had increased to 36.2% by 2004.

In the Population Register data set deaths of infants under the age of 1 month are grossly under reported. If a child is born alive but dies before the birth is registered, the death is not registered on the Population Register (Dobbie, *et al.* 2007). Furthermore, both a first name and a surname are required before a birth can be registered. Therefore this age group of children is largely underrepresented in the Population Register data set.

### **3.4 Statistical methods**

This is an ecological population study based on routinely collected vital events data consisting of total numbers of deaths and cause of death information. A large part of the work here is an exploratory examination of empirical data using graphical techniques to describe trends in infant and child mortality. Where appropriate in selected sections, statistical analysis was conducted. Total numbers of deaths and age specific mortality are examined on a national and provincial level. Causes of death are examined by calculating the leading underlying causes among selected age groups under 5 years of age on a national level. Causes of death are also presented by age of death in months.

This study is based on numerator data only, describing trends rather than attempting to calculate rates. Although it would be ideal to be able to determine infant mortality rates and under 5 mortality rates, there is great uncertainty around finding an accurate denominator, or the population at risk. Questions regarding completeness of birth registration and the inability of the latest national census, and latest demographic and health survey to provide accurate data on births, make the calculation of a denominator problematic. The issues around the determination a reliable denominator are complex in themselves, and beyond the scope of this study. This does not distract from the main issue of examining trends in mortality. Births were estimated to be fairly stable from 1997 to 2005 at around 1.1 million per annum (Moultrie and Timaeus 2003; Moultrie and Dorrington 2004; Moultrie 2006). It follows that variations among births are much less than variations among deaths over the period studied here. Conversely, as shown in this study, mortality

is changing rapidly, so numerator data (death counts) is an appropriate proxy for mortality rates.

The entire data contained in the data sets acquired for this study were used in the analysis and no form of sampling was required, therefore the study samples are the populations of registered deaths represented by the recorded deaths contained in the data sets described previously in section 3.2.2.

### 3.4.1 Correlations using the area of the peak

Correlations between the increasing peak in mortality at 2 to 3 months and the HIV epidemic were made using an approximation of the excess deaths at 2 to 3 months. The total number of deaths was plotted by age of death in months for 1990 to 2002. Excess deaths were approximated by calculating the area of the peak at 2 to 3 months for each calendar year. The area of the peak at 2 to 3 months represents the excess deaths at the age of 2 to 3 months beyond the approximate, classical exponentially decreasing curve of mortality (Figure 1). The area of the peak was defined for each calendar year plotted as the polygonal approximation at the scale of 1 month of age using the following formula:

$$(D(1)+0.5*(D(2)-D(1))+D(2)+0.5*(D(3)-D(2))+D(3)+0.5*(D(4)-D(3))+D(4)+0.5*(D(5)-D(4)) - 4*D(1)+(0.5*(D(1)-D(5))*4), \text{ where } D(n) \text{ is the number of deaths at month } n \text{ exactly.}$$

This formula gives a numerical value for the area of the peak at 2 to 3 months for each calendar year which was then regressed against the proportion of AIDS sick

in the population for the same calendar years. AIDS sick is defined as the number of people living with AIDS defining conditions in a given calendar year estimated by the ASSA2003 model, the AIDS and Demographic model of the Actuarial Society of South Africa (ASSA 2003).

### Calculating area of the Peak (AOP)

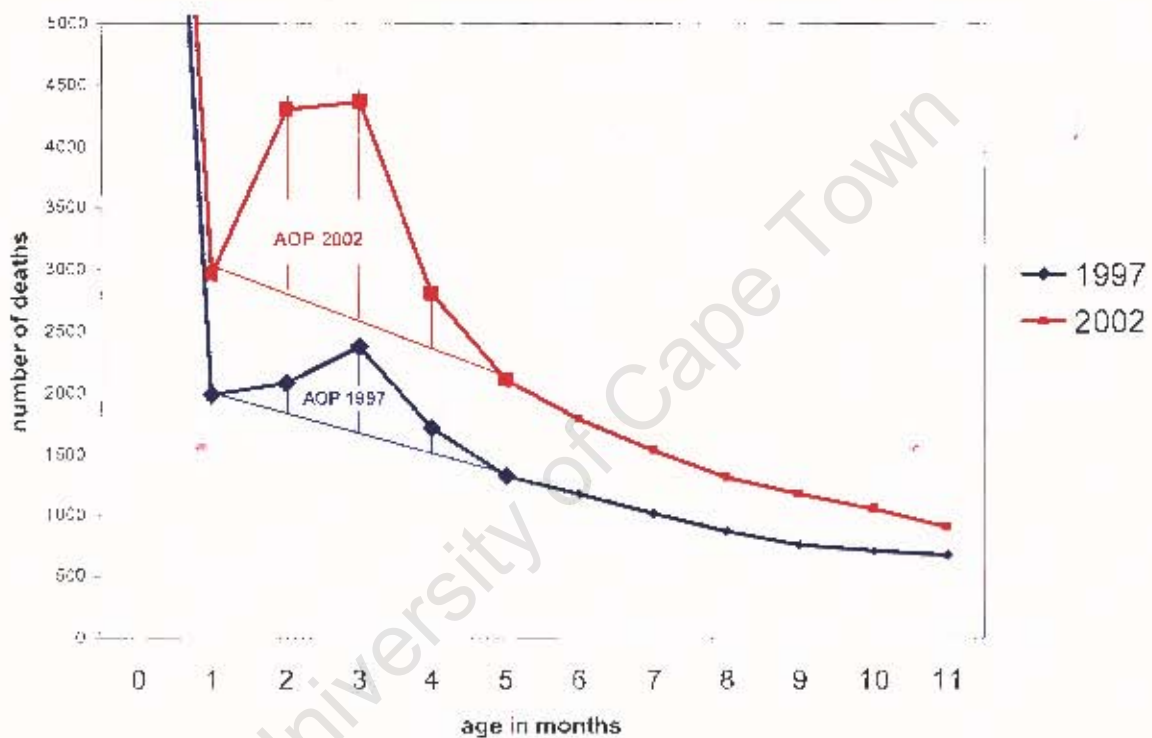


Figure 1. Calculation of excess deaths at 2 to 3 months using the area of the peak (AOP).

#### 3.4.2 Adjustments for combined registration effects in the Population Register data

The Population Register data set is affected by a combination of efficacy of birth registration and ID number assignment, and the efficacy of death registration in addition to efforts aimed at improving these processes. Changes in registration

completeness can make comparisons of death over time difficult, therefore it is necessary to find a method to accommodate these changes. The results from this study suggest that deaths due to non-natural (external) causes was flat or decreasing slightly in infants and children under the age of 5 years from 1997 to 2006 as shown in the results section of this paper in Figure 7 and Figure 9. Another independent study conducted by the National Injury Mortality Surveillance System (NIMSS) (Matzopoulos 2004) found that the number of non-natural (external) deaths in children under 1 year of age did not change in the Cape Metropole region of the Western Cape from 2001 to 2004. The data in this study was collected from participating mortuaries and the population is fairly representative of the Western Cape as a whole (Matzopoulos 2007). Based on this evidence and the results found in this study, it is a reasonable assumption that the true rate of non-natural (external) deaths in South Africa is constant over the period under study and that the underlying force of mortality of non-natural deaths is constant over the period. Assuming also that the efficacy of registration of deaths from natural causes and non-natural (external) causes is the same, the total number of non-natural deaths can be used as a reasonable adjustment factor for potential unmeasured changes in natural deaths. The number of natural deaths was adjusted by dividing the number of natural deaths at each month from 0 to 11 months, by the total number of non-natural deaths from 0 through 11 months for the corresponding year and province. This then expresses the mortality data as the risk of dying from natural causes relative to that of dying from non-natural causes in a given calendar year. This method was considered the best form of standardisation or correction that could be applied with the data that was available.

### **3.4.3 Logistic regression analysis**

Logistic modelling techniques were used to confirm changes in mortality seen over time when plotting the ratio of natural deaths to non-natural deaths (Thompson 2007). Details of this analysis can be found in Appendix D.

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## 4 Results

The results section of this paper is presented in two parts. Part one of the results section presents the analysis of data from Statistics South Africa (Stats SA) for deaths of infants and children up to 5 years of age occurring from 1990 to 2002. Trends in mortality and cause of death were analysed, and an association with increased mortality and the HIV epidemic was explored.

In order to examine current trends in mortality, data extracted from the Population Register database maintained by the Department of Home Affairs was used to allow analysis up to 2006. Part two of the results section presents the analysis of this data set, exploring mortality trends in infants up to 1 year of age on a national and a provincial level. The Population Register data set was also examined as a potential data source for use as a rapid mortality surveillance tool to monitor trends in infant mortality and to measure any effects by HIV/AIDS interventions on infant mortality from 1998 to 2006.

## **Results Part 1**

### **4.1 Mortality trends using Statistics South Africa data, 1990-2002**

Part 1 of the results utilized the data sets from Statistics South Africa (Stats SA) to describe mortality trends of infants and children under age 5 from 1990 to 2002. Age distribution of deaths by age of death in months is explored, as well as trends in cause of death. The association with increases in mortality and the HIV epidemic were also investigated.

#### **4.1.1 Numbers of infant and child deaths, 1990-2002**

The total number of registered deaths of infants under 1 year of age and children aged from 1 to 4 years recorded by Statistics South Africa (Stats SA) from 1990 to 2002 is shown in Table 3 and Figure 2. In 1990 the number of infants in South Africa dying before their 1st birthday was 15,844. The number increased steadily to 31,060 deaths in 1999, remained fairly flat through 2001, increasing to 36,476 deaths by 2002. Deaths of children aged 1 year to 4 years was much lower but increased steadily from 4490 in 1990 to 11,917 deaths in 2002.

Table 3. Total number of deaths of infants under 1 year and children aged 1 to 4 years, 1990-2002, Statistics South Africa data.

	Age <1 year	Age 1-4 years
1990	15844	4490
1991	17384	5959
1992	18346	4961
1993	17343	5015
1994	19784	1683
1995	21707	8420
1996	22525	7707
1997	26156	7322
1998	31060	9047
1999	30051	9600
2000	30276	10251
2001	30544	11092
2002	36476	11917

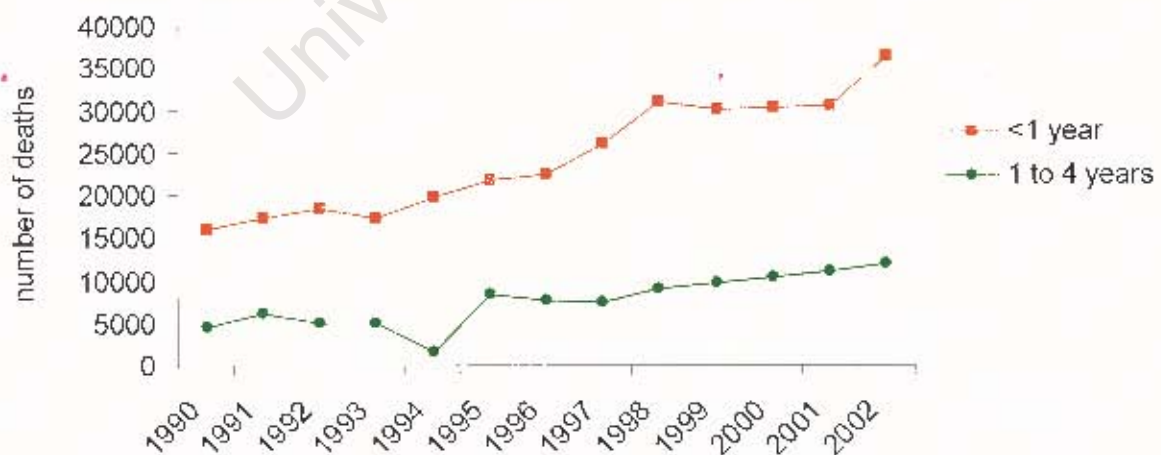
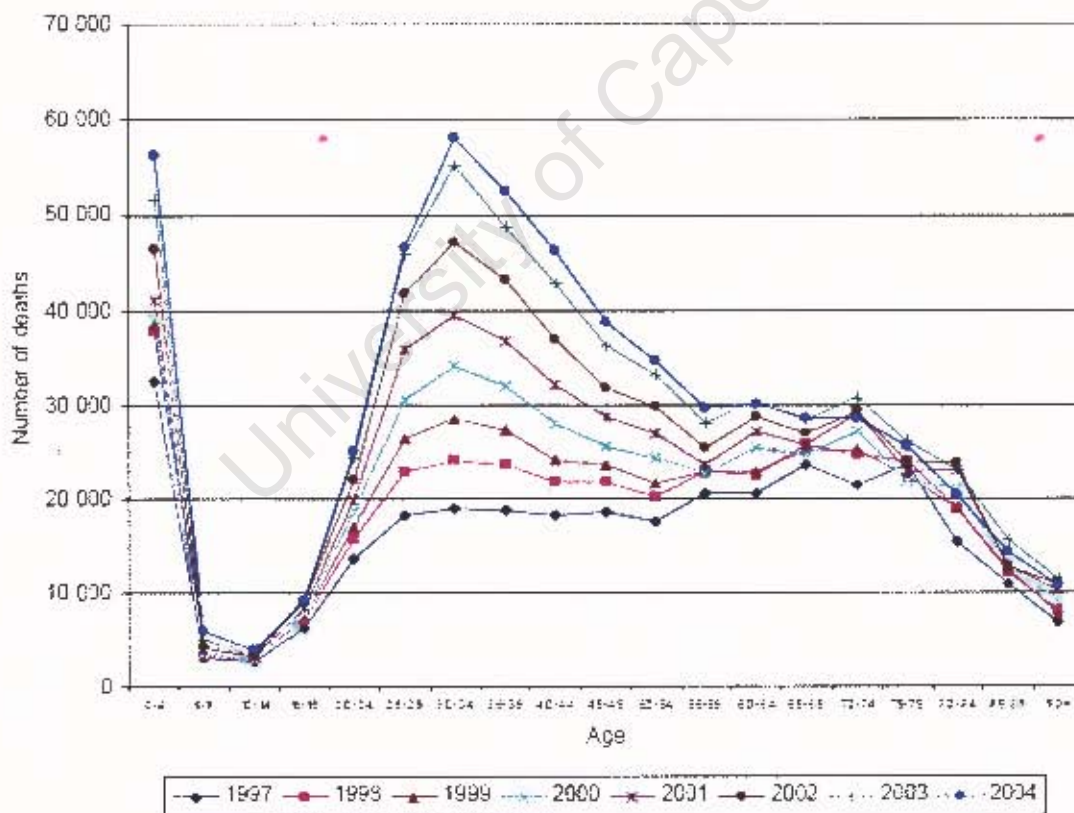


Figure 2. Total number of deaths of infants under 1 year and children aged 1 to 4 years, Statistics South Africa data.

#### 4.1.2 Age distribution of deaths from Statistics South Africa report, 1997-2004

In order to put in perspective the results obtained in this study, the latest *published* results on the age distribution of all-cause deaths by Statistics South Africa (Stats SA) are given here for comparison (Figure 3). The classic age specific pattern of mortality due to a high HIV prevalence and high HIV/AIDS mortality is evident with an increasing peak in mortality at its highest among the 25 to 34 year age groups (Dorrington, *et al.* 2001). Although it appears that during the same time period of 1997 to 2004, mortality in infants and children aged 0 to 4 years increased, the age grouping makes it impossible to assess mortality patterns within this group at a finer age detail.



**Figure 3. Age specific all causes mortality in South Africa, all ages, 1997-2004, Statistics South Africa.**

Courtesy of Statistics South Africa report: *Mortality and causes of death in South Africa, 2003 and 2004 Findings from death notification, 2006.*

In this study infant and child mortality was examined at a finer age resolution than is typically reported in the official reports on mortality statistics. Rather than age groups or age at death in years, deaths of infants and children are examined by age at death in months.

#### **4.1.3 Age distribution in months of infant and child deaths, 1990-2002**

The Stats SA data set (data set number 1) provided for this study was used here to show the distribution of total deaths of infants and children who died between the ages of 0 to 59 months in 1997 to 2002 (Figure 4). Examination at this fine age resolution revealed a striking mortality pattern not previously described. When the distribution of deaths is examined by age of death in months, a very sharp local peak in mortality is evident. This peak, centring around the ages of 2 to 3 months, increases in magnitude each year from 1997 to 2002. The numbers of deaths at 1 month are high, but no other peak in mortality is evident through the age of 59 months, or 5 years. In order to determine at what year the peak at 2 to 3 months began to emerge, data set number two, the Stats SA data set containing total deaths from 1990 to 1996, was used. The total number of deaths by age of death in months for the years 1990 to 2002 up to the age of 11 months is shown in Figure 4. From 1990 to 1993 there appears to be no peak in mortality at 2 or 3 months. By approximately 1994, however, the peak in mortality at 2 to 3 months begins to emerge, and increases steadily through 2002.

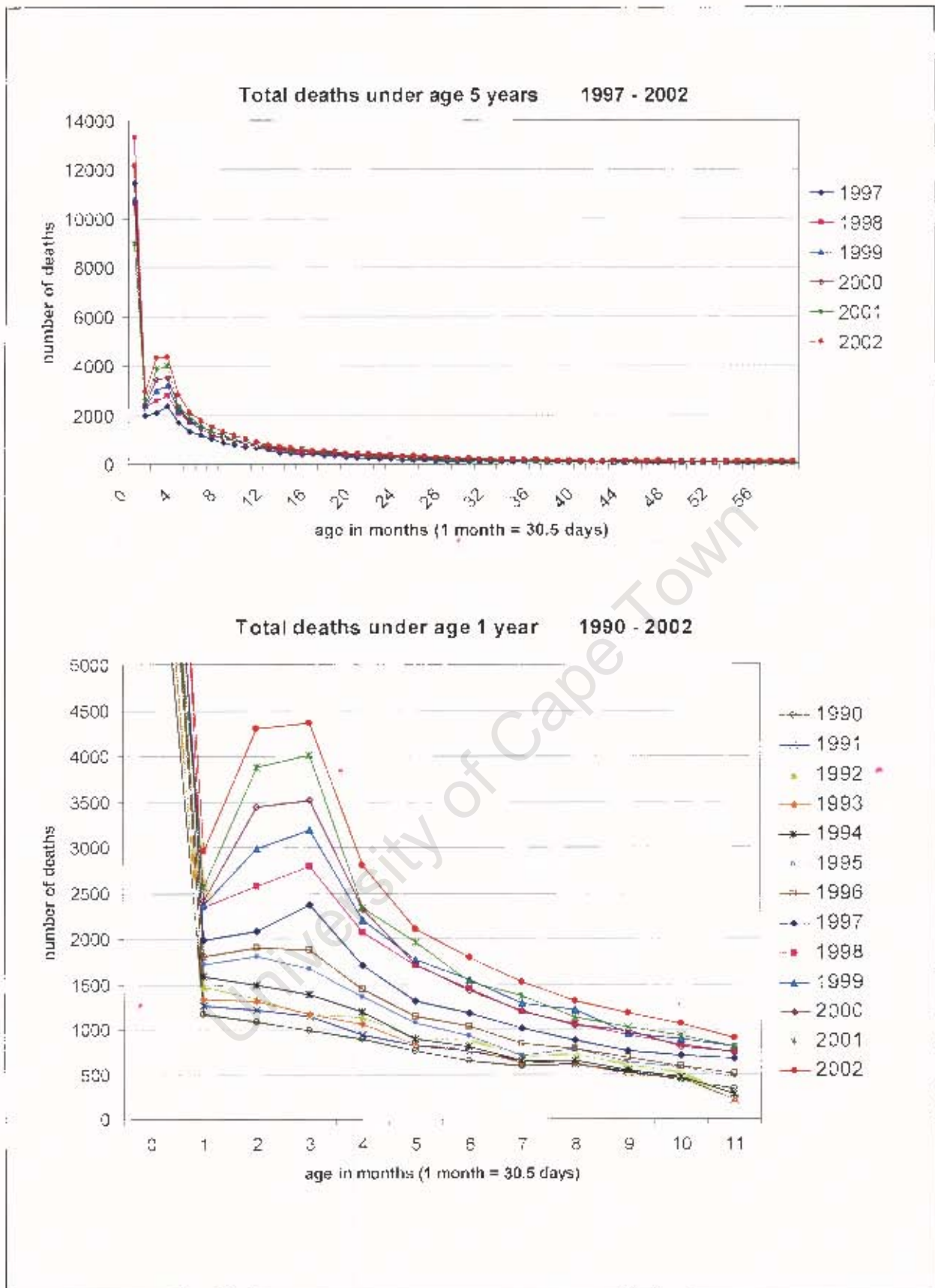


Figure 4. Age distribution of deaths of infants and children under 5 years, 1997-2002 (top) and infants under 1 year, 1990-2002, Statistics South Africa data (bottom).

To estimate the number of deaths contained in the peak at 2 to 3 months, a polygonal approximation was calculated at the scale of 1 month of age for each calendar year. The area of the peak at 2 to 3 months represents the excess deaths at the age of 2 to 3 months beyond the approximate, classical exponentially decreasing curve of mortality for each year (Figure 5). In 1990 the excess deaths at 2 to 3 months contributed just 0.9% to post-neonatal mortality (age 1 to 11 months). By 1994 it had contributed 3.4% and by 2002, 16% of death in the post-neonatal period was due to the excess deaths at 2 to 3 months. Compared to all deaths under 1 year, the excess deaths, or peak at 2 to 3 months contributes less than 1% to total mortality due to the large number of deaths in the neonatal period (birth to 28 days). However, the number of deaths in the age group of 2 to 3 months increased 16 fold from 1990 to 2002 and is a sharp local phenomenon. Age specific mortality patterns of infants and children under 5 years of age were similar for males and females (Figure B-1 in Appendix B) therefore the data were combined throughout this study.

## Calculating area of the Peak (AOP)

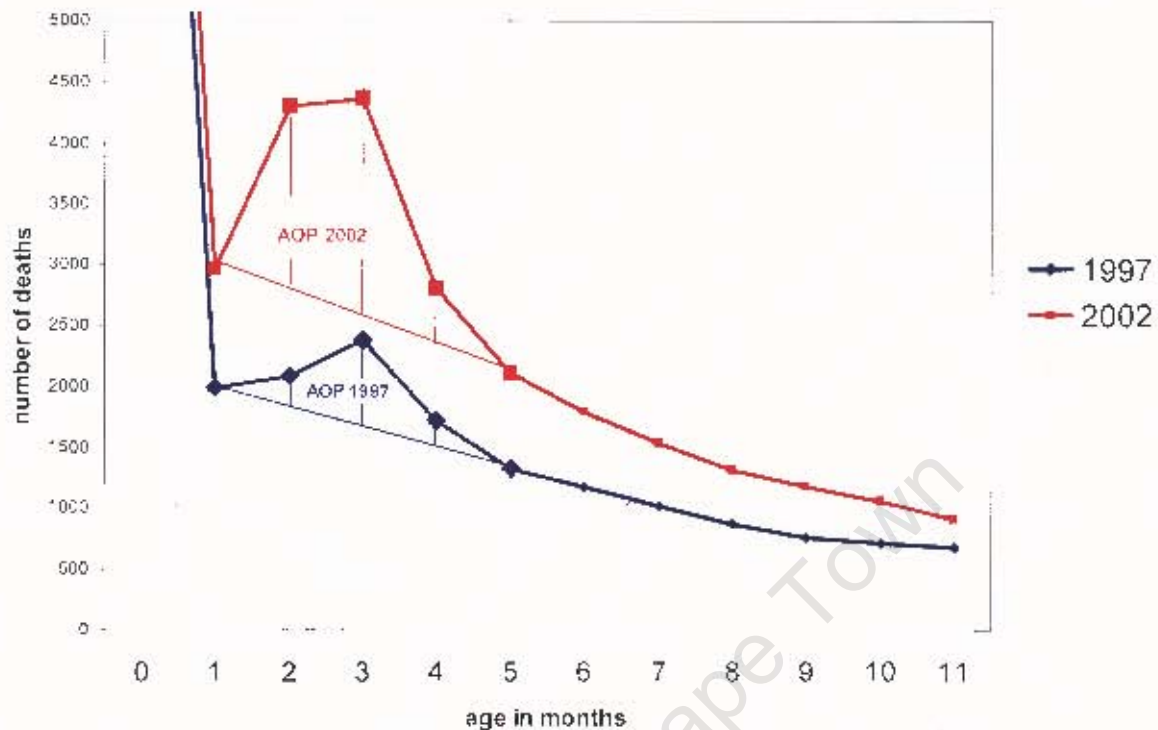


Figure 5. Calculation of excess deaths at 2 to 3 months using the area of the peak (AOP).

### 4.1.4 Comparison of trends in cause of death among infants and children in 1997 and 2002

To determine which causes of death might be contributing to the 2 to 3 month increasing peak in mortality, trends in the leading underlying causes of death in 1997 were compared to those in 2002. Infants and children were grouped here by age of death in years. Cause of death was recorded by Stats SA in data set one as the single underlying cause of death by ICD-10 chapter category. Figure 6 shows the comparison between the leading causes of death among infants and children for 1997 and 2002.

During the process of analysing this data it was discovered that an incorrect algorithm had been used by Stats SA when causes of death were coded for infants under the age of 1 year. The result is an under reporting of the correct cause of deaths among infants under 1 year and an inflation of the numbers coded into perinatal codes, especially the category called *certain conditions originating in the perinatal period*. This error is limited to infants under 1 year of age and has little, if any, effect on other age groups. However, this error must be considered when examining the leading causes of death in this age group. The coding error is examined in detail in section 4.1.6 of the results section.

#### ***Infants aged under 1 year (0 to 11 months)***

The cause of death category called *certain conditions originating in the perinatal period* was the leading cause of death in infants under 1 year of age in 1997 and in 2002 (Figure 6). This category consists of such conditions as neonatal infections, other perinatal infections, cot death and low birth weight. In 1997, 75% of the total number of deaths in under ones, and 76.1% of the deaths in 2002, was due to deaths from conditions within this cause of death category.

The 2nd leading cause of death among infants under 1 year was deaths described as *symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified*. Deaths due to the category called *certain infectious and parasitic diseases* moved up the ranking to the 3rd leading cause of death in 2002 from the 5th leading cause in 1997. This category includes tuberculosis, HIV/AIDS, diarrhoeal diseases and malaria. Deaths due to *diseases of blood and blood-forming organs and certain disorders involving the immune mechanisms* also

moved up in ranking from 7th in 1997 to 5th in 2002. This category contains conditions such as immunodeficiencies and anaemias. The cause of death category called *external causes of morbidity and mortality* (or non-natural causes), defined as all unintentional and intentional injuries were ranked among the leading ten causes of death but did not increase in ranking. Deaths due to the category called *endocrine, nutritional and metabolic diseases and congenital conditions* also did not increase from 1997 to 2002.

#### ***Children aged 1 year (12 to 23 months)***

The leading cause of death at 1 year of age in both 1997 and in 2002 was *certain infectious and parasitic diseases*. This category accounted for 35.7% of the total deaths among this age group in 1997 and 38.8% in 2002. Deaths due to *diseases of the respiratory system* increased from a ranking of 5th in 1997 and 11.3% of the total deaths to 2nd in 2002 with 17.5% of the total deaths. This category contains conditions such as influenza and pneumonia. Blood/immune diseases also increased from a ranking of 8th to 6th which is an increase from 2.0% to 4.8% of the total number of deaths in this age group.

#### ***Children aged 2 years (24 to 35 months)***

The leading cause of death in children aged 2 years in 1997 and in 2002 was *certain infectious and parasitic diseases*. The proportions increased from 26.8% to 34.7%. The category, *diseases of the respiratory system* increased from the 4th to the 2nd leading cause of death among children aged 24 to 35 months of age by 2002. Blood/immune diseases increased from a ranking of 8th to 6th in this age group.

### ***Children age 3 years (36 to 47 months) and 4 years (48 to 59 months)***

Deaths due to *certain infectious and parasitic diseases* increased from the second, to the leading cause of death in children aged 3 years with proportions increasing from 18.5% in 1997 to 30.1% in 2002. Deaths due to *diseases of the respiratory system* increased from 9.7% to 16.2%, and blood/immune diseases increased from 2% to 4.2% in this age group.

Among children ages 4 years of age, the patterns and levels of deaths due to *certain infectious and parasitic diseases, diseases of the respiratory system, and diseases of blood and blood-forming organs and certain disorders involving the immune mechanisms* were similar to those of children aged 3 years.

### ***External causes and trends***

*External causes of morbidity and mortality* (or non-natural causes), contribute a large proportion to the total number of deaths in children especially at ages over 11 months. External causes include accidental injuries, homicides, automobile accidents, deaths from burns and other accidental or intentional deaths. Among children in 1997 at age 3 years, external causes contributed 34.8%, and 37.1% to the 4 year age group. The category, external causes was the leading cause of death in 1997 for both age groups. By 2002 external causes was the 2nd leading cause of death (replaced by infectious/parasitic) in both age groups and the proportions had decreased. But this relative decrease was more than likely a result of the increase in other causes.

Overall, deaths due to three cause of death categories increased from 1997 to 2002 in every age group examined. These categories were:

- *certain infectious and parasitic diseases*
- *diseases of the respiratory system*
- *diseases of blood and blood-forming organs and certain disorders involving the immune mechanisms*

The three cause of death categories listed above ranked among the leading ten causes of death in every age group under 5 years of age. These three categories also increased from 1997 to 2002.

It must be noted that the ranking of causes of death should be interpreted with caution and in combination with other evidence. Ranking is dependent upon the aggregation used. For example death due to Streptococcal septicaemia would rank much lower than the category, *certain infectious and parasitic diseases*. Nevertheless, ranking cause of death is a valuable tool for describing a mortality profile and comparison between different time periods and ages.

# 1997

rank	0-11 months	12-23 months	24-35 months	36-47 months	48-59 months
1	perinatal 75%	infect/parasit 25.7%	infect/parasit 20.0%	external 24.9%	external 37.1%
2	not class 8.4%	not class 14.3%	external 2%	infect/parasit 16.5%	infect/parasit 17.3%
3	congenital 4.7%	external 13.8%	not class 14.3%	not class 14.3%	not class 14.5%
4	external 34%	endocrine 12.6%	respiratory 12.8%	respiratory 5.7%	respiratory 8.3%
5	infect/parasit 2.7%	respiratory 11.2%	endocrine 9.4%	nervous 5.7%	nervous 5.3%
6	endocrine 1.6%	circulatory 2.4%	nervous 4.1%	endocrine 4.5%	circulatory 3.7%
7	blood/immune 1.5%	nervous 2.2%	circulatory 2.6%	neoplasms 3.1%	endocrine 1.4%
8	nervous 1%	blood/immune 2%	blood/immune 2.6%	circulatory 2.3%	neoplasms 3%
9	respiratory 0.7%	congenital 1.7%	congenital 2%	congenital 2.1%	digestive 2%
10	circulatory 0.2%	digestive 1.5%	digestive 1.4%	blood/immune 2%	congenital 1.6%

# 2002

rank	0-11 months	12-23 months	24-35 months	36-47 months	48-59 months
1	perinatal 76.1%	infect/parasit 28.6%	infect/parasit 34.7%	infect/parasit 28.1%	infect/parasit 24.4%
2	not class 7.6%	respiratory 12.5%	respiratory 17.2%	external 16.5%	external 21.4%
3	infect/parasit 1.5%	not class 12.8%	not class 12.6%	respiratory 16.2%	respiratory 13.5%
4	congenital 1.4%	endocrine 11.9%	external 11.6%	not class 12.2%	not class 13.1%
5	blood/immune 2.9%	external 3.9%	endocrine 10.2%	endocrine 6.5%	nervous 5.7%
6	external 1.3%	blood/immune 4.3%	blood/immune 4%	blood/immune 4.2%	endocrine 5.4%
7	endocrine 1.2%	nervous 2%	nervous 3.5%	nervous 4%	blood/immune 2.6%
8	nervous 1%	digestive 1.6%	circulatory 1.9%	circulatory 2.6%	circulatory 2.6%
9	respiratory 0.4%	circulatory 1.3%	digestive 1.2%	digestive 1.2%	neoplasms 2.4%
10	circulatory 0.2%	congenital 1%	neoplasms 1.1%	congenital 1.1%	digestive 2%

Figure 6. Leading causes of death of infants and children under 5 years in 1997 and in 2002, Statistics South Africa data.

#### 4.1.5 Trends in the causes of death among infants and children from 1997 to 2002

In the previous section, trends in the leading causes of death in infants and children were compared between 1997 and 2002. In this section trends were examined *throughout* the period between 1997 to 2002. This is graphically represented in Figure 7.

Total numbers of deaths are shown on a log scale where an equal proportional change translates to an equal separation between the lines in the graphs. As described previously, deaths among infants under 1 year are dominated by the ICD-10 cause of death category called *certain conditions origination in the perinatal period*. The number of deaths in this category increased from 19,606 deaths in 1997 to 27,754 deaths in 2002. However, the number of deaths from *certain infectious and parasitic diseases* more than doubled in this age group, from 714 deaths in 1997 to 1658 in 2002. Deaths due to the category called *diseases of blood and blood-forming organs and certain disorders involving the immune mechanisms* also increased during this time period from 381 to 1067. Deaths from *diseases of the respiratory system* increased slightly, while deaths from *endocrine, nutritional and metabolic diseases and congenital conditions* remained stable during the time period. The number of deaths due to *external causes of morbidity and mortality* (or non-natural causes) decreased from a total of 989 in 1997 to 654 in 2002 among infants under 1 year of age.

Among children aged 1 year (12 to 23 months) deaths due to *certain infectious and parasitic diseases* contributed the largest numbers, increasing from 1491 deaths in

1997 to 2403 deaths in 2002. Deaths due to *diseases of the respiratory system* also increased from 470 deaths to 1086. Deaths from blood/immune diseases increased from 69 deaths in 1997 to 299 in 2002. Deaths due to endocrine conditions increased slightly during the time period and deaths from external causes decreased. Trends among children aged 2 years (24 to 35 months) were similar to those at aged 1. Total numbers of deaths were much lower in children aged 3 and 4 years and interpretation becomes more difficult. Nonetheless, the trends are similar, with deaths increasing due to the three cause of death categories highlighted previously: *certain infectious and parasitic diseases*, *diseases of the respiratory system*, and *diseases of blood and blood-forming organs and certain disorders involving the immune mechanisms*. Deaths due to external causes were flat during the time period among children aged 3 and 4 years.

The fact that deaths increased in every age group examined due to the three disease categories, *certain infectious and parasitic diseases*, *diseases of the respiratory system*, and *diseases of blood and blood-forming organs and certain disorders involving the immune mechanisms* between 1997 and 2002 is quite an important observation. Each of these three cause of death categories includes specific causes that are considered AIDS-related conditions (Groenewald, *et al.* 2005). Cause of death data in South Africa is plagued by the misclassification of HIV/AIDS deaths. This is due in part by the associated stigma surrounding the disease. Deaths due to HIV/AIDS are also misclassified because the opportunistic condition that is typically the final cause of death is very often recorded rather than the *underlying* cause of death, HIV/AIDS. An increase in the cause of death

categories mentioned above suggests an increase in deaths due to HIV/AIDS because they each include specific causes considered to be AIDS-related. Similar findings were reported in a recent report on mortality in the Western Cape, where cause of death categories that included specific AIDS-related conditions increased from 1997 to 2002, while causes that did not include those conditions did not increase over the period (Brody, *et al.* 2007).

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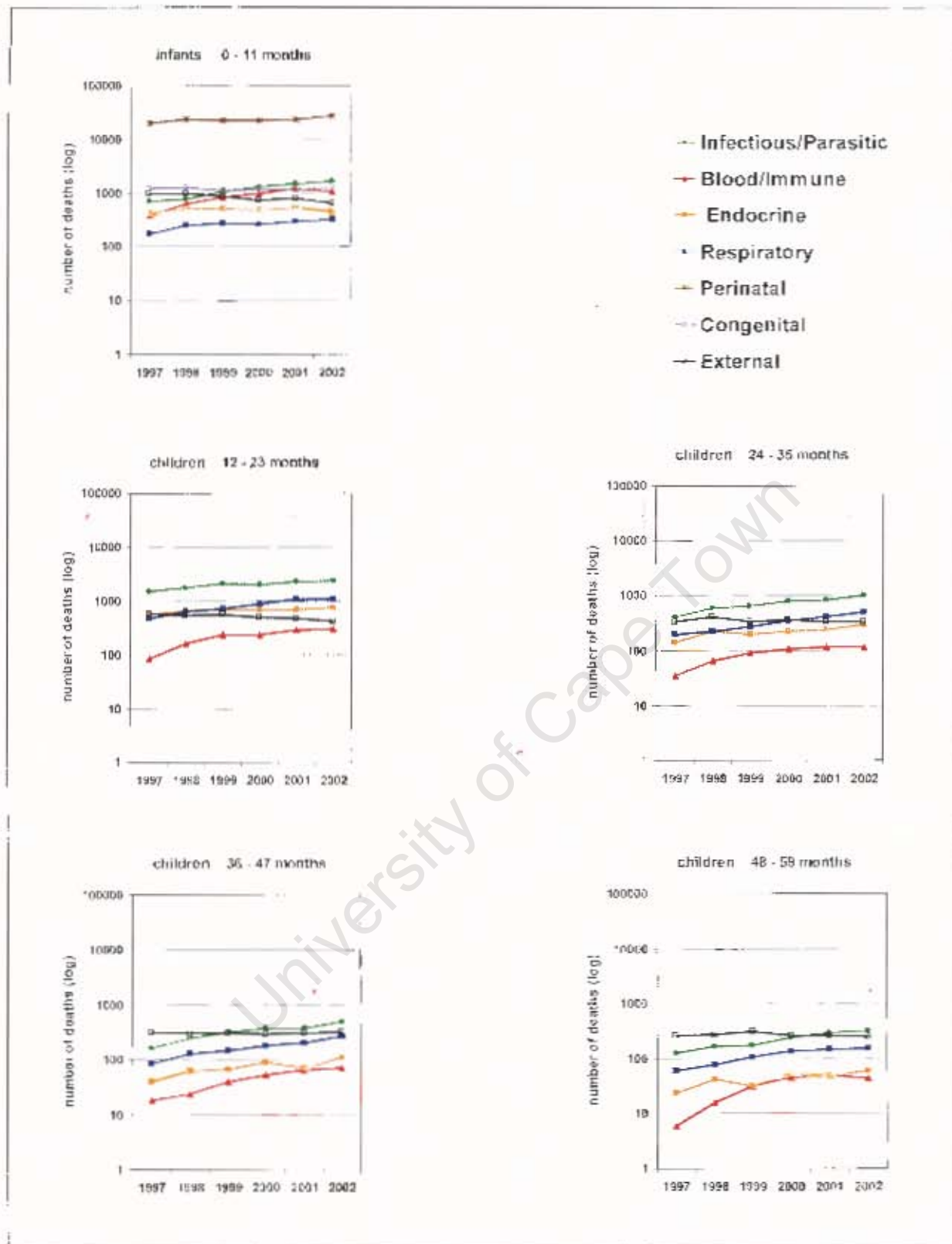


Figure 7. Selected leading causes of death of infants and children under 5 years from 1997 through 2002, Statistics South Africa data.

#### 4.1.6 Causes by age of death in months

Selected leading causes of death of infants and children were then investigated at the fine age resolution of age of death in months (Figures 8a, b and c). This level of age detail for population data in South Africa has not been published before this study, and would not be possible without the data sets acquired for this study. At the age resolution of 1 month and the disaggregation of data by ICD-10 cause of death chapter category, an artefact at 12 months of age was revealed. This artefact of miscoding of cause of death by Statistics South Africa (Stats SA) is the second major finding in this study.

A discontinuity in the data consisting of an unnaturally sharp increase at the age of 12 months became evident when deaths due to *diseases of the respiratory system*, and deaths due to *certain infectious and parasitic diseases* were plotted (Figure 8a). The graph of *endocrine, nutritional and metabolic diseases and congenital conditions* showed a slight discontinuity at 12 months (Figure 8a). A slight discontinuity at 12 months can also be seen in graphs of *diseases of the digestive system*, in *diseases of the circulatory system*, and in the category of *symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified*, or unclassified conditions (Figure 8b). However, the numbers in these categories are very low. The artefact does not exist in the graph of *diseases of blood and blood-forming organs and certain disorders involving the immune mechanisms* (Figure 8c). This artefact is also not seen in the graph of external causes (Figure 8c). When deaths due to *certain conditions originating in the perinatal period* was plotted the artefact at 12 months consisting of a sharp decrease, rather than increase at 12 months, and this is where the problem lies (Figure 8c). Discussions

with Stats SA revealed that underlying causes of death were preferentially given perinatal codes if the death occurred before an infant's first birthday, and that these codes were not restricted to causes *originating in the first week of life* in accordance with the ICD definitions. This coding practice has resulted in a substantial inflation of perinatal conditions and a corresponding under representation of the actual underlying causes of death for infants who died prior to 12 months of age. This makes a literal acceptance of the numbers of deaths in any cause category erroneous for infants under 12 months. In spite of the incorrect coding practice, some causes of death appear to be correctly coded, leading to non-zero (but highly under reported) numbers in the other cause of death categories for infants under 12 months.

Another important finding was revealed when cause of death categories were plotted at the age resolution of 1 month. The increasing peak in mortality at 2 to 3 months which was observed previously in all-cause mortality (Figure 4) was replicated in some cause of death categories and not in others. Of the three cause of death categories shown to increase from 1997 to 2000 in infants and children under 5 years of age in this study, *certain infectious and parasitic diseases* (Figure 8a) and *diseases of blood and blood-forming organs and certain disorders involving the immune mechanisms* (Figure 8c), showed a clear peak in mortality at 2 to 3 months. *Diseases of the respiratory system* showed a small peak at 2 to 3 months (Figure 8a). In addition, *endocrine, nutritional and metabolic diseases and congenital conditions* showed a small peak (Figure 8a).

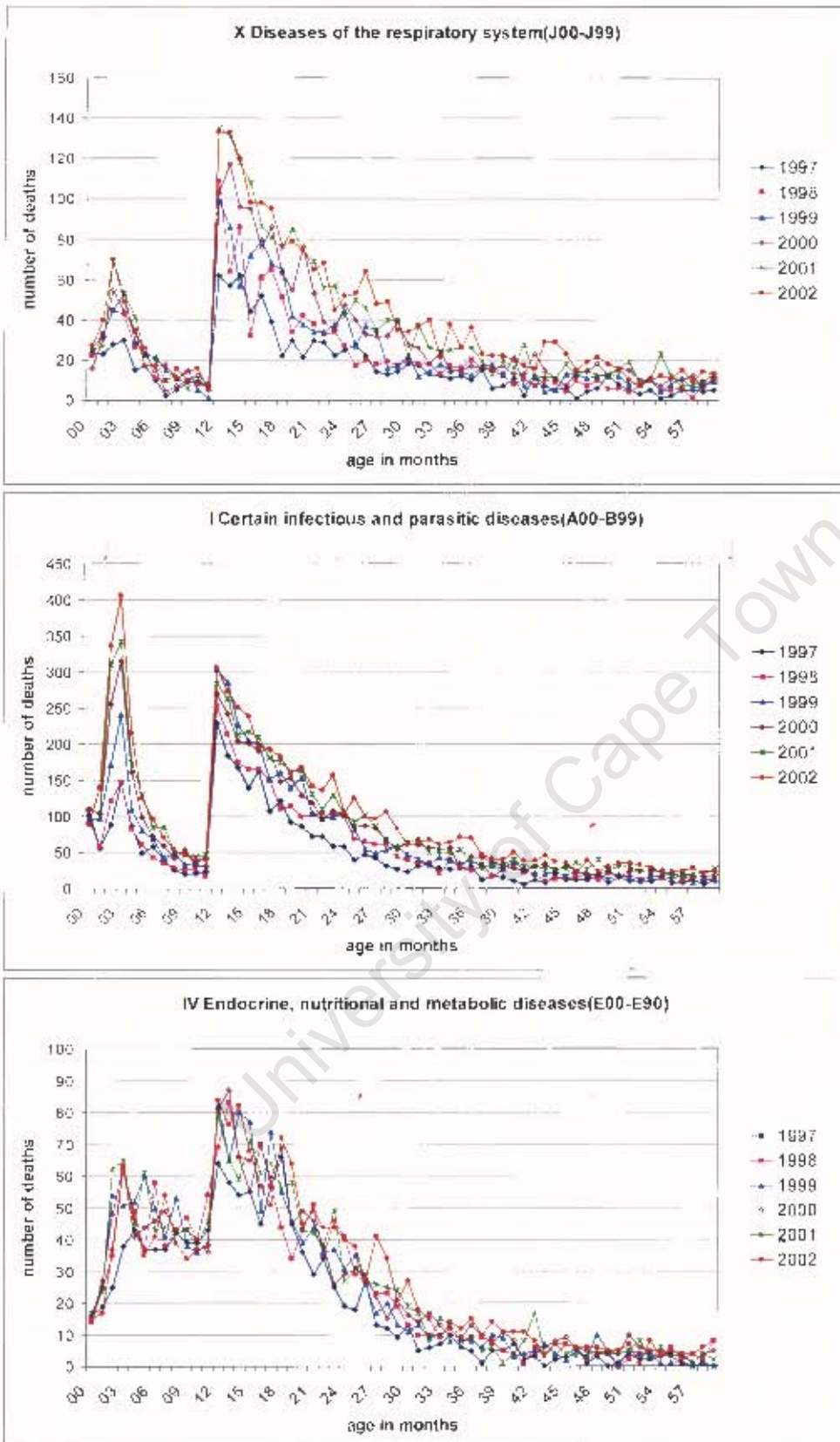


Figure 8a. Age distribution of deaths by cause of death of infants and children under 5 years, Statistics South Africa data.

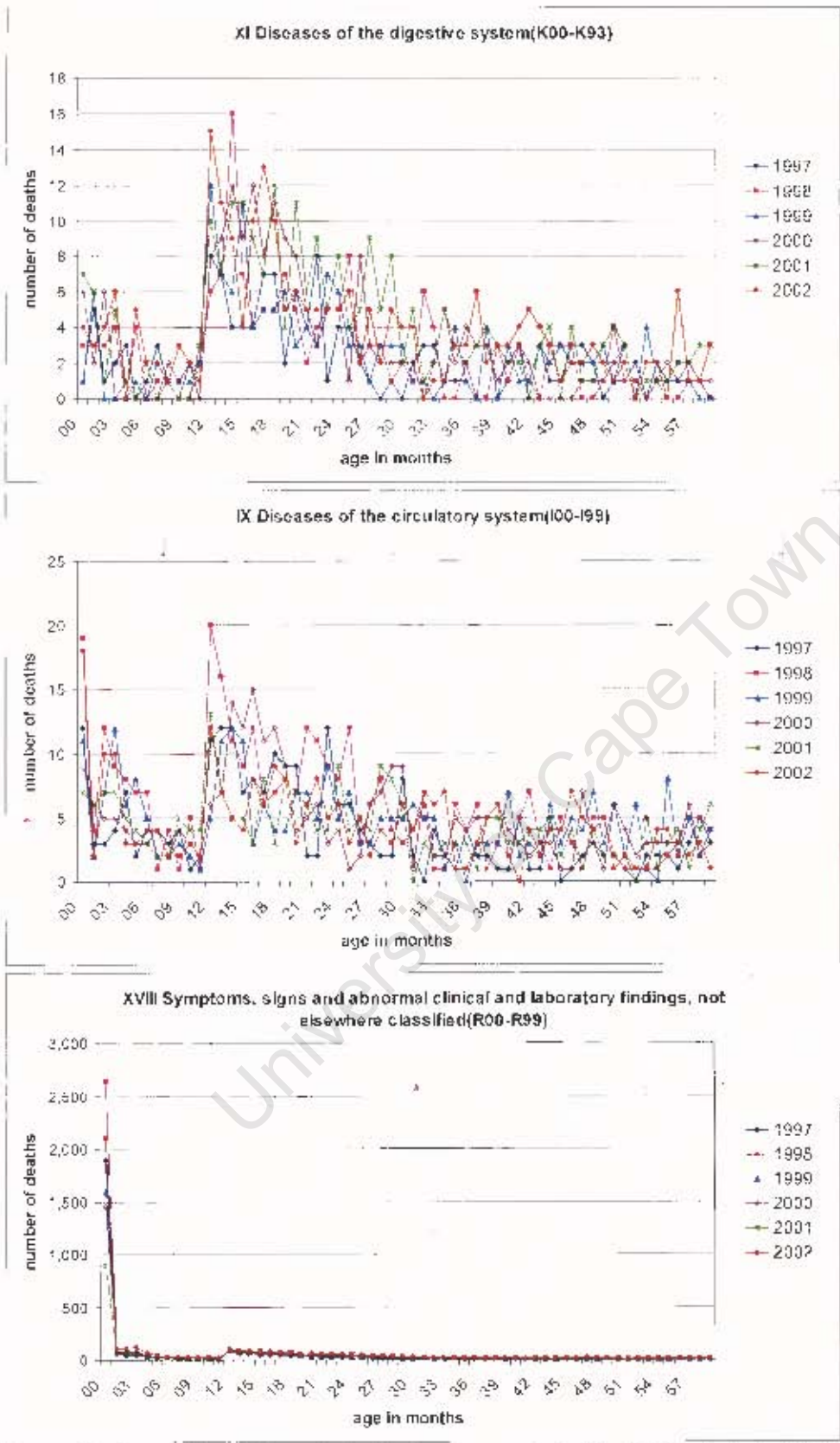


Figure 8b. Age distribution of deaths by cause of death of infants and children under 5 years, Statistics South Africa data.

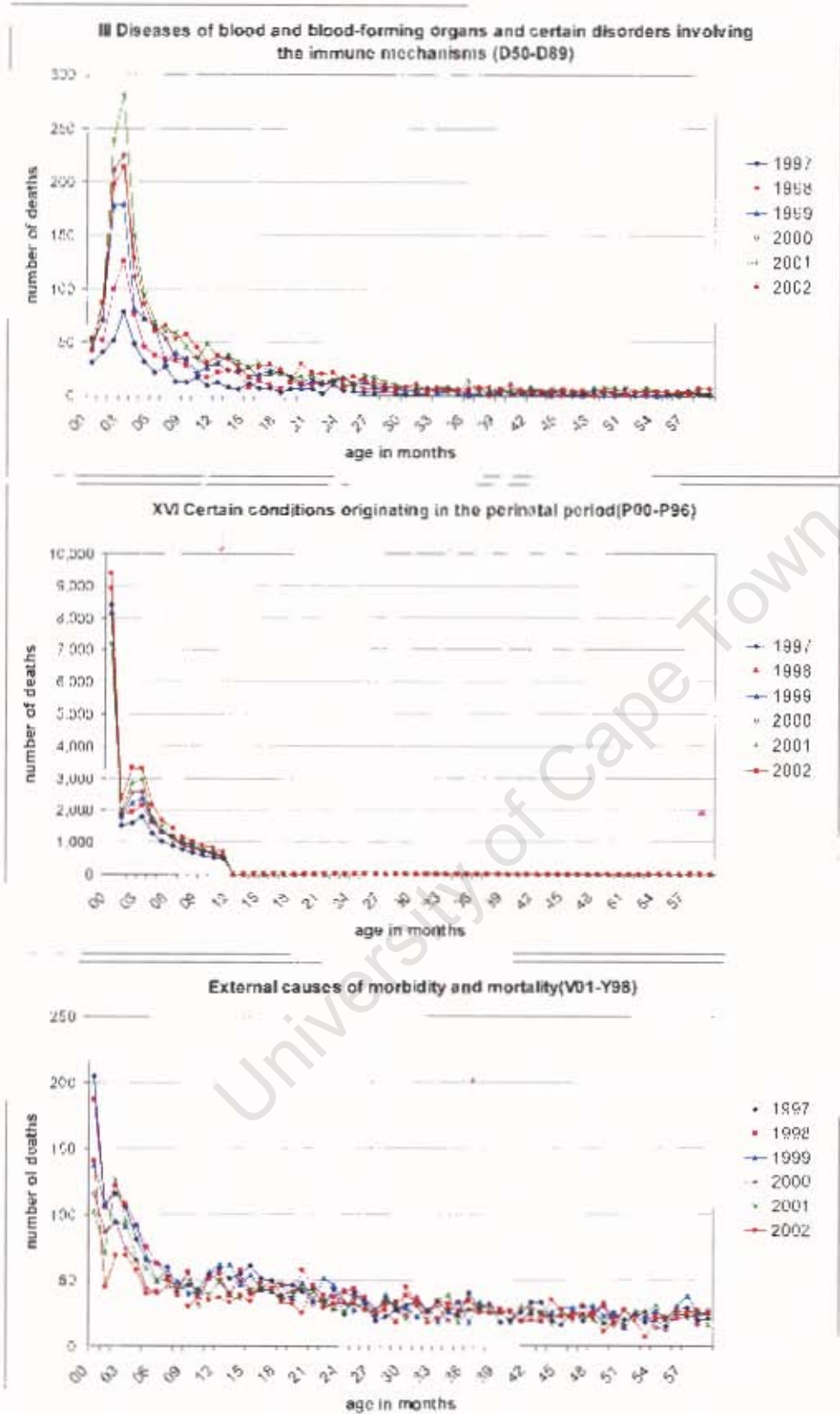


Figure 8c. Age distribution of deaths by cause of death of infants and children under 5 years, Statistics South Africa data.

For reasons of further analysis of the increasing peak at 2 to 3 months, and to confirm that the numbers of non-natural (external) deaths did not vary from year to year, deaths due to all non-natural causes, and deaths due to all natural causes were plotted for infants up to 1 year by age in months for 1998 to 2002 (Figure 9). Poisson Confidence intervals were calculated for each point. The annual data revealed a lack of temporal coherence for non-natural deaths, and also, a peak which may be perceived by eye, is well within Poisson noise. Poisson Confidence intervals calculated for deaths due to natural causes shows that the emerging peak in deaths due to natural causes is unlikely due to chance during the period under study.

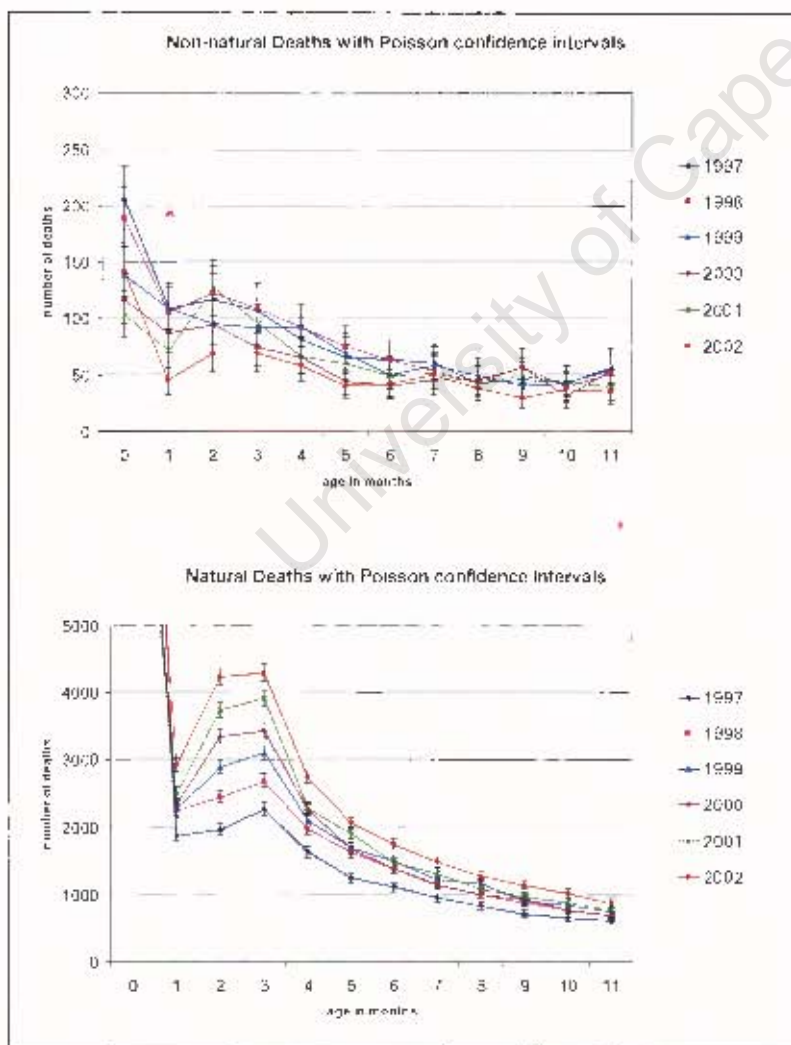


Figure 9. Poisson confidence intervals for non-natural and natural deaths of infants and children under 5 years, 1997-2002, Statistics South Africa data.

#### 4.1.7 The association between the increased mortality in infants and the prevalence of AIDS sick, 1990-2002

As mentioned previously, HIV/AIDS as a cause of death is largely under reported in South Africa. The result is a vast majority of deaths due to HIV/AIDS are recorded as deaths due to other causes. In order to explore an association between the increase in all-cause mortality of infants at 2 to 3 months and the HIV/AIDS epidemic, the excess deaths at the age of 2 to 3 months beyond the approximate, classical exponentially decreasing curve of mortality was estimated and compared to the proportion of AIDS sick in the population. The proportion of AIDS sick in the population is an estimate of the prevalence of people who are living with AIDS defining conditions in a given year derived from the ASSA2003 AIDS and demographic model. The estimation of the excess deaths at 2 to 3 months was determined by calculating the area of the peak at 2 to 3 months for each calendar year from 1990 to 2002 (Figure 5). The value for the area of the peak for each calendar year was then regressed against the proportion of AIDS sick in the population for those same years (Figure 10). A strong association was shown ( $R^2 = 0.9923$ ) between the excess number of all-cause deaths at the age of 2 to 3 months and the proportion of AIDS sick in the population.

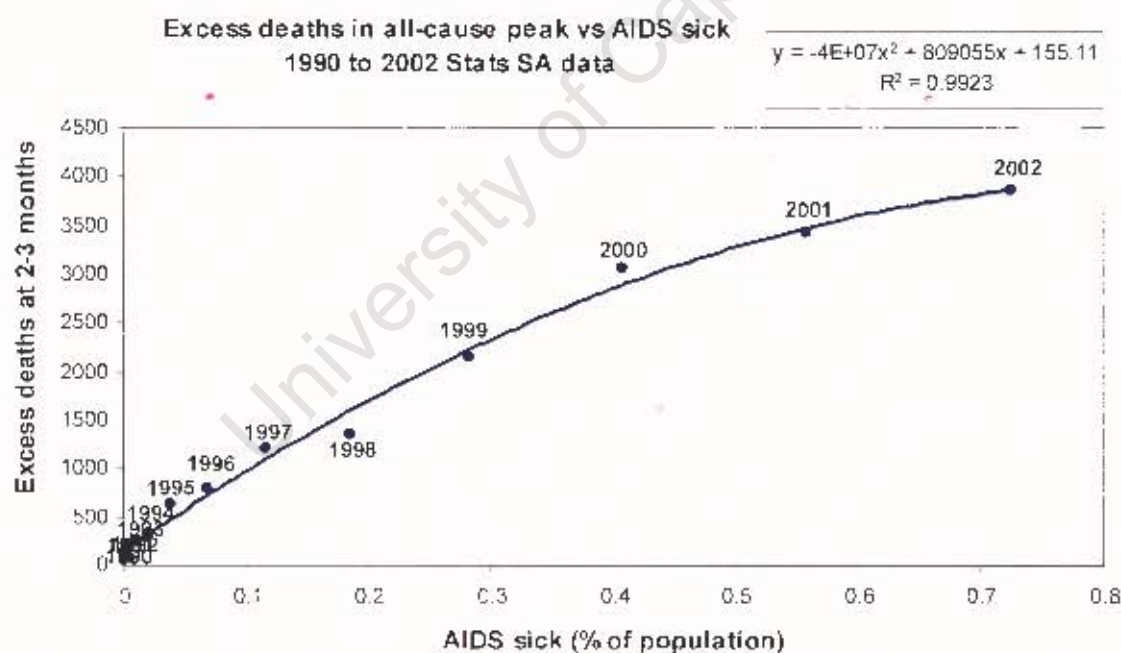
Causes of death categories were then separated into two groups and each was regressed against the estimated AIDS sick in the population. The first group, called "AIDS-related", contained those deaths coded to cause of death categories that were likely to contain deaths related to HIV/AIDS. The second group called the "Non AIDS-related" group, contained those categories that were *not* likely to contain deaths related to HIV/AIDS. The cause of death categories in each group are shown in Table 4.

**Table 4. "AIDS-related" and "Non AIDS-related" causes of death.**  
 Causes in this table are ICD-10 chapter categories.

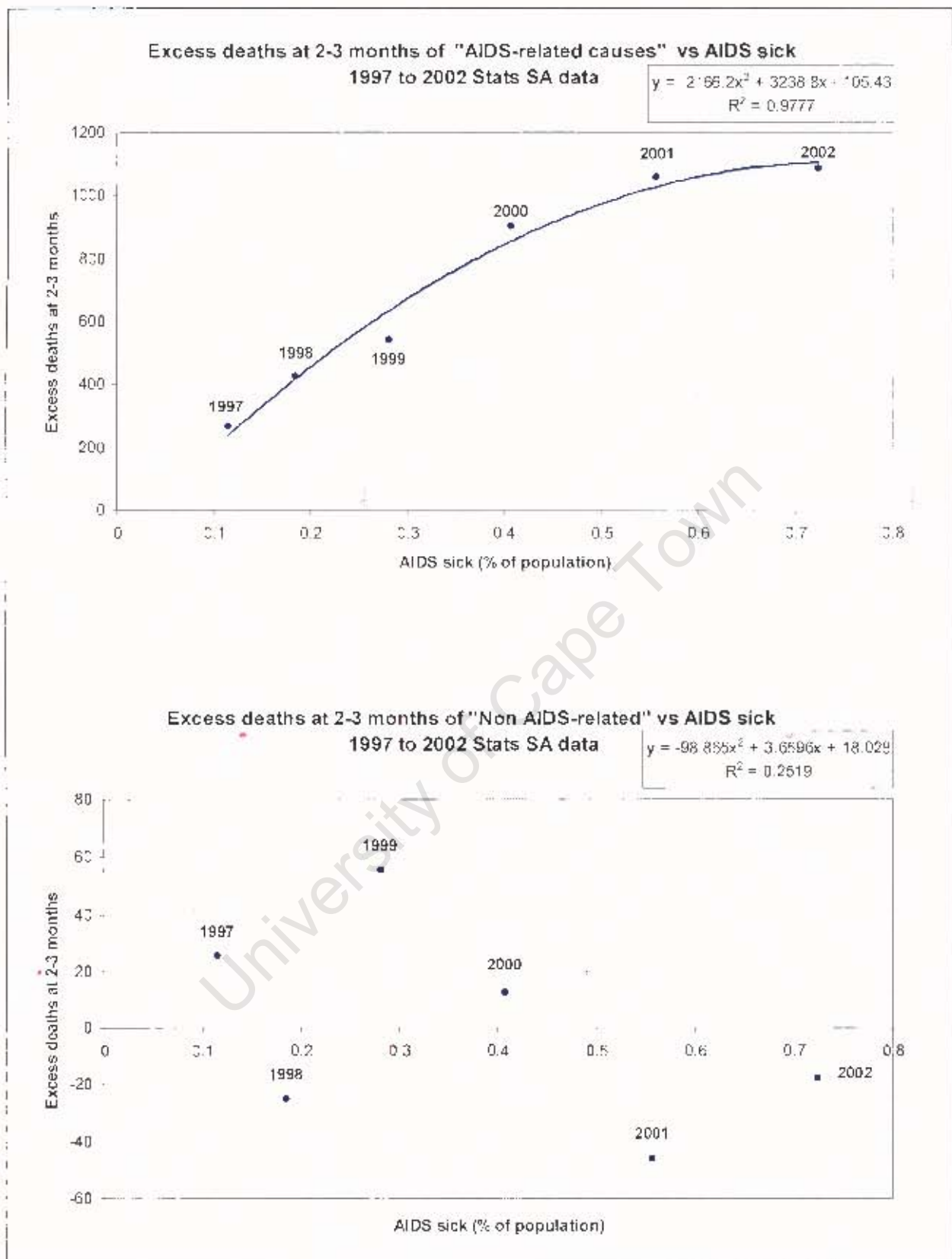
"AIDS-related" causes	"Non AIDS-related" causes
infectious/parasitic	neoplasms
blood/immune	external causes (non-natural)
endocrine/nutritional/metabolic	congenital
circulatory	genitourinary
respiratory	skin
digestive	musculo/connective
perinatal conditions	mental
nonclassified	nervous
	ear

The total number of deaths in the "AIDS-related" group was plotted by age of death by month for 1997 to 2002. This was also carried out for the "Non AIDS-related" group (data not shown). The estimation of the excess deaths at 2 to 3 months for each group was created by calculating the area of the peak at 2 to 3 months for each calendar year from 1990 to 2002. The values for the excess deaths at 2 to 3 months of the "AIDS-related" group for 1997 to 2002 were regressed against the proportion of AIDS sick in the population for those same years (Figure 11). The values for the excess deaths at 2 to 3 months of the "Non AIDS-related" group were also regressed against the proportion of AIDS sick in the population.

A very strong correlation was found between the excess deaths at 2 to 3 months in the "AIDS-related" group and the proportion of AIDS sick in for 1997 to 2002 ( $R^2 = 0.9774$ ). No correlation was found between the "Non AIDS-related" group and the proportion of AIDS sick ( $R^2 = 0.2527$ ). Correlations were fitted to the polynomial model which was found to be the best fit. In addition to the high correlations, it should be noted that the correlations were not constrained to go through the origin. However, both the correlations between the all-cause peak versus AIDS sick, and the "AIDS-related" peak versus AIDS sick pass very close to the origin, within the expected error of the data. This infers that when there is no AIDS, there is no peak in mortality.



**Figure 10. Correlation between the excess deaths in the all-cause peak and proportion of AIDS sick in the population, 1990 to 2002.**



**Figure 11. Correlations: "AIDS-related causes" and AIDS sick, 1997 to 2002 (top) and "non AIDS-related" causes and AIDS sick, 1997 to 2002.**

Correlation between the excess deaths at 2-3 months of the "AIDS-related causes" and proportion of AIDS sick, 1997 to 2002 and the correlation between the excess deaths at 2-3 months of the "non AIDS-related" causes and proportion of AIDS sick, 1997 to 2002.

This study has shown that the increasing mortality in infants and children is characterised by the emergence of an all-cause peak in mortality at 2 to 3 months which was shown to increase from 1990 to 2002. Despite the finding here of a major coding error in cause of death data for infants under 1 year, examination of cause of death data revealed that the increase in mortality is likely due to the HIV/AIDS epidemic. This is strongly supported by the fact that the all-cause peak in mortality highly correlates with the HIV/AIDS epidemic. This makes the all-cause peak a potentially valuable and useful surveillance tool to monitor infant mortality. However, using this peak in conjunction with the data from Statistics South Africa (Stats SA) will not work for rapid surveillance, as this data is not up to date. In part 2 of the results, the more up to date data set from the Population Register of the Department of Home Affairs was examined as a potential data source for rapid mortality surveillance to measure current trends in infant and child mortality. This data source was also used to extend this study beyond 2002 to more recent years.

## Results Part 2

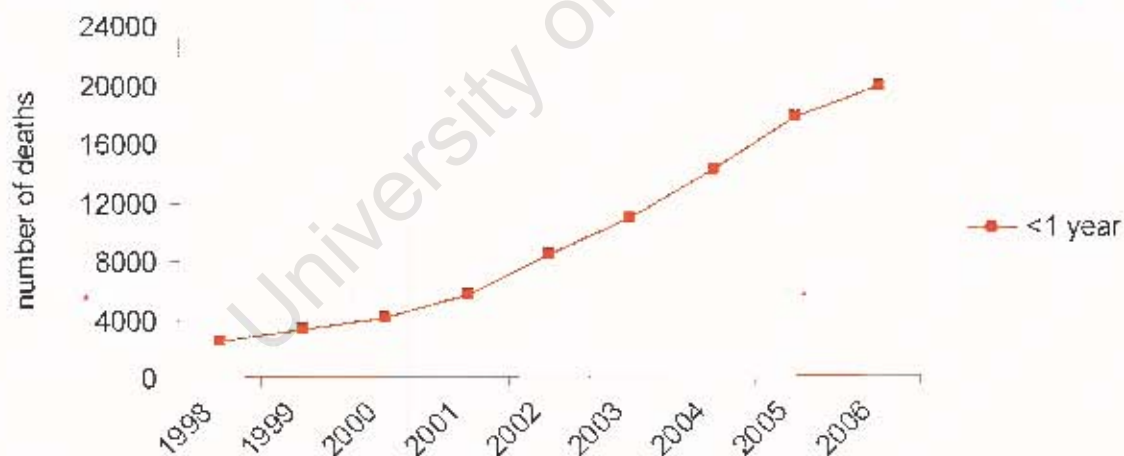
### 4.2 Mortality trends using the Population Register data, 1998-2006

In the midst of an HIV/AIDS pandemic it is necessary to extend the results obtained so far in this study beyond 2002 to more recent years. To date, the only current data available is the population data extracted from the Population Register of the Department of Home Affairs. However this data set, while up to date and available at just a two month delay, has its own set of biases and limitations which will be considered in the following sections. In addition, the Population Register data set will be examined as a potential rapid surveillance source for measuring current trends in infant mortality during a period of high HIV prevalence and any effects HIV/AIDS interventions may have on infant mortality in the population.

The Population Register data set provided for this study covers 1998 to 2006 and was provided by age at death in weeks. Causes of death were separated by natural and non-natural causes. The data was also provided by province, a variable not available in the Statistics South Africa (Stats SA) data sets. The total number of registered deaths recorded in the Population Register data set are shown in Table 5 and Figure 12. The total number of infants who died under 1 year of age recorded in this database was 2469 in 1998. Recorded deaths increased steadily to 19,748 in 2006.

**Table 5. Total number of deaths of infants under 1 year, Population Register data**

	Age <1 year
1998	2469
1999	3295
2000	4071
2001	5646
2002	8454
2003	10875
2004	14119
2005	17673
2006	19748



**Figure 12. Total number of deaths of infants under 1 year, 1998-2006, Population Register data.**

#### 4.2.1 Age distribution in months of infant deaths, 1998-2006

The age distribution of deaths in months for infants under 12 months from the Population Register data set is compared graphically to the data contained in the Stats SA data sets (Figure 13). The increasing all-cause peak in mortality in infants which was observed in the Stats SA data is replicated clearly in the Population Register data. The peak in the Population Register data is centred more around three months, rather than encompassing 2 and 3 months as in the Stats SA data due to the different methods used to calculate months. Because of the difficulty in obtaining the data for this study and the fact that the data was not available by age of death in days, Stats SA data was provided by age of death in months which had been calculated as 1 month corresponding to an average of 30.5 days. Population Register data was provided by age of death in weeks. To calculate age of death in months from the Population Register data required using a 28 day month, or a 4 week period for 1 month. Therefore when comparing the two data sources, the increasing peak in mortality is spread over 2 and 3 months in data from Stats SA. In order to define the exact shape of the peak without the artefact introduced using the different discreet time periods for months, a special tabulation of the national data for the year 2005 was prepared by the MRC from Population Register database from the DHA where age of death was given in days. This data is plotted in Figure 14 and the peak is confirmed with its highest point at approximately 90 days, or 3 months.

Although the peak is replicated in the Population Register data set and this data set may be suitable for rapid surveillance, it has some deficiencies. Deaths of infants under the age of 1 month are very poorly recorded in the Population

Register, making this data unreliable for this age group (Dobbie, *et al.* 2007). Furthermore, the Population Register data set contains fewer deaths per year than the data sets provided by Stats SA. The Stats SA data contains deaths of individuals with a South Africa ID number *and* those individuals without an ID. An individual must have an ID to be included on the Population Register data set. Improvements in birth registration and the assignment of ID numbers, in addition to improvements in death registration have an effect on the Population Register data set. The combined improvements in registration efficacy are evident when comparing the two data sources. The total number of deaths recorded in the Population Register was 8% of those deaths recorded by Stats SA in 1998, increasing to 23.2% in 2002.

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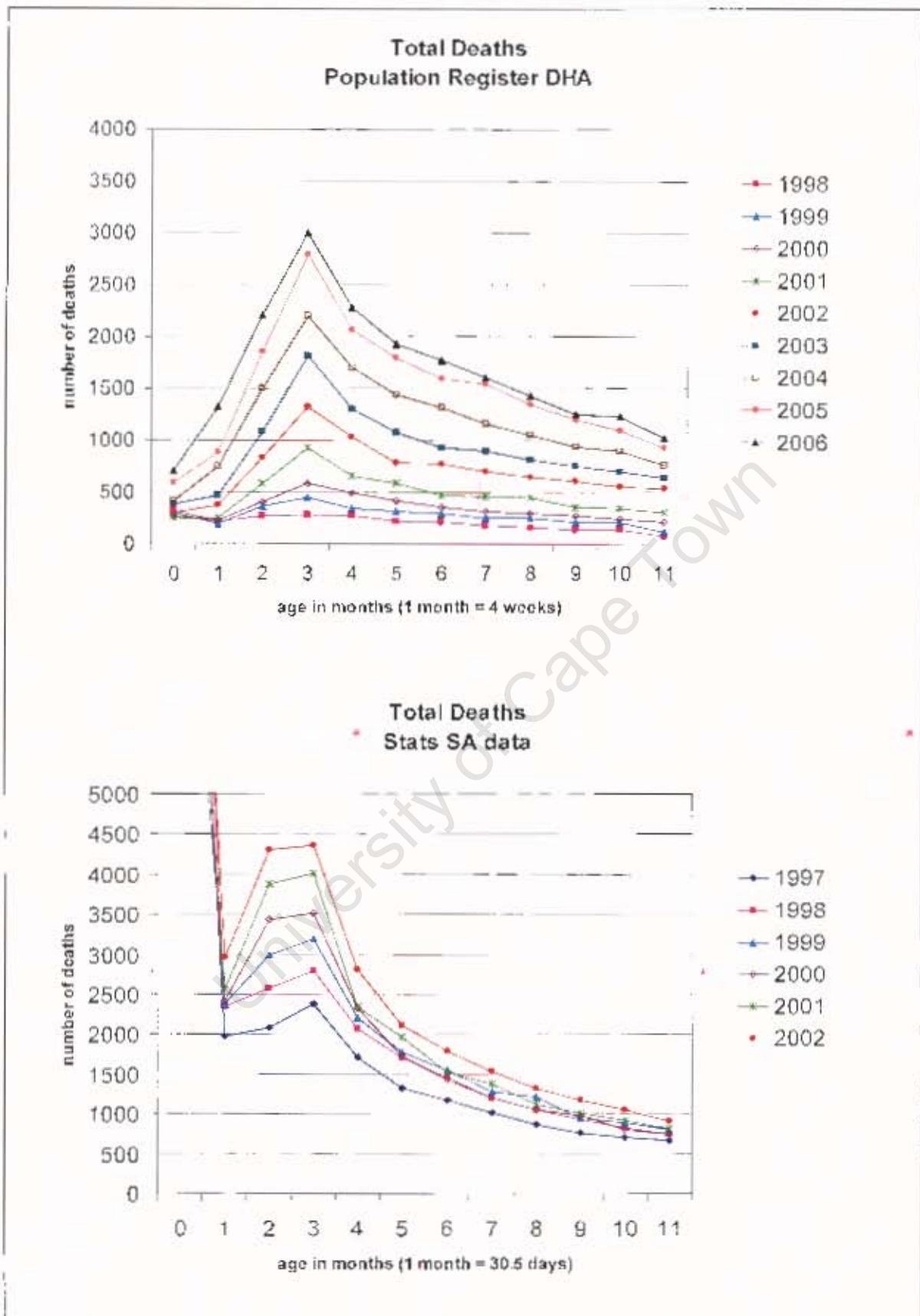


Figure 13. Age distribution of deaths of infants under 1 year, Population Register data (top) and age distribution of deaths of infants under 1 year, Statistics South Africa data (bottom).

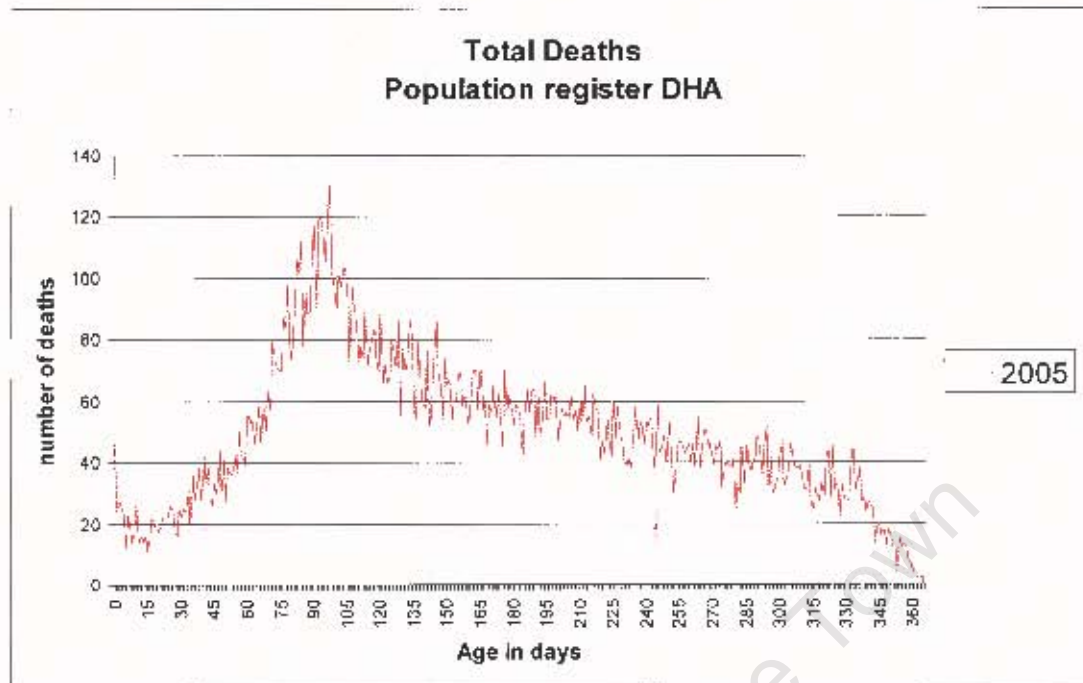


Figure 14. Age distribution of deaths of infants under 1 year by age of death in days in 2005, Population Register data.

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#### 4.2.2 Age distribution in months of infant deaths by province, 1998-2006

The Population Register data set was provided by natural and non-natural (external) causes of death, and by province. Deaths due to natural causes are plotted for each province by death by age in months in Figures 15 a, b and c. A map of the provinces in South Africa is provided in Figure C-1 of Appendix C. Although the number of deaths in the Western Cape and the Northern Cape are much lower than in other provinces, all provinces show an increase in mortality around 3 months of age which is consistent with the national data from Statistics South Africa. All provinces show an increase around 3 months of age during the period of 1998 to 2006, although the mortality patterns vary slightly between provinces.

In most provinces the peak in mortality at 3 months is not visible in 1998 but may be visible in 1999. In the Free State Province a peak is evident in 1998. In Gauteng, KwaZulu-Natal and the North West Province there is a suggestion of the very beginning of a peak in 1998. By 1999 there is a sharp increase in deaths at age 3 months in the Free State, Gauteng, KwaZulu-Natal and the North West Province. In the Eastern Cape, a peak is suggested by 1999 and evident at 2000. In Mpumalanga the peak may begin in 1999 or 2000. In the Western Cape a peak there may be an increase in mortality by 1999 or 2000 but there is a prominent peak by 2001. After the emergence of the peak, mortality increases every year up to 2006 in the Eastern Cape, the Northern Cape, KwaZulu-Natal and in the Limpopo Province. The increase appears to have slowed down after 2005 in the Free State, Gauteng, the Northwest Province and in Mpumalanga.

Natural deaths for South Africa as a whole are plotted in Figure 15d showing an increase over time around 3 months of age during the period of 1998 to 2006.

The interpretations here must be viewed with caution as the numbers of deaths are low in many provinces, especially during the earlier years. Furthermore, as the Population Register data are affected by changes in both birth and death registration, it is not possible to separate out what proportion of the increases in mortality seen in this data set are due to real increases in mortality or increases in birth or death registration. However, it is very promising to note that the age specific pattern of mortality and the peak at 3 months is replicated down to the provincial level.

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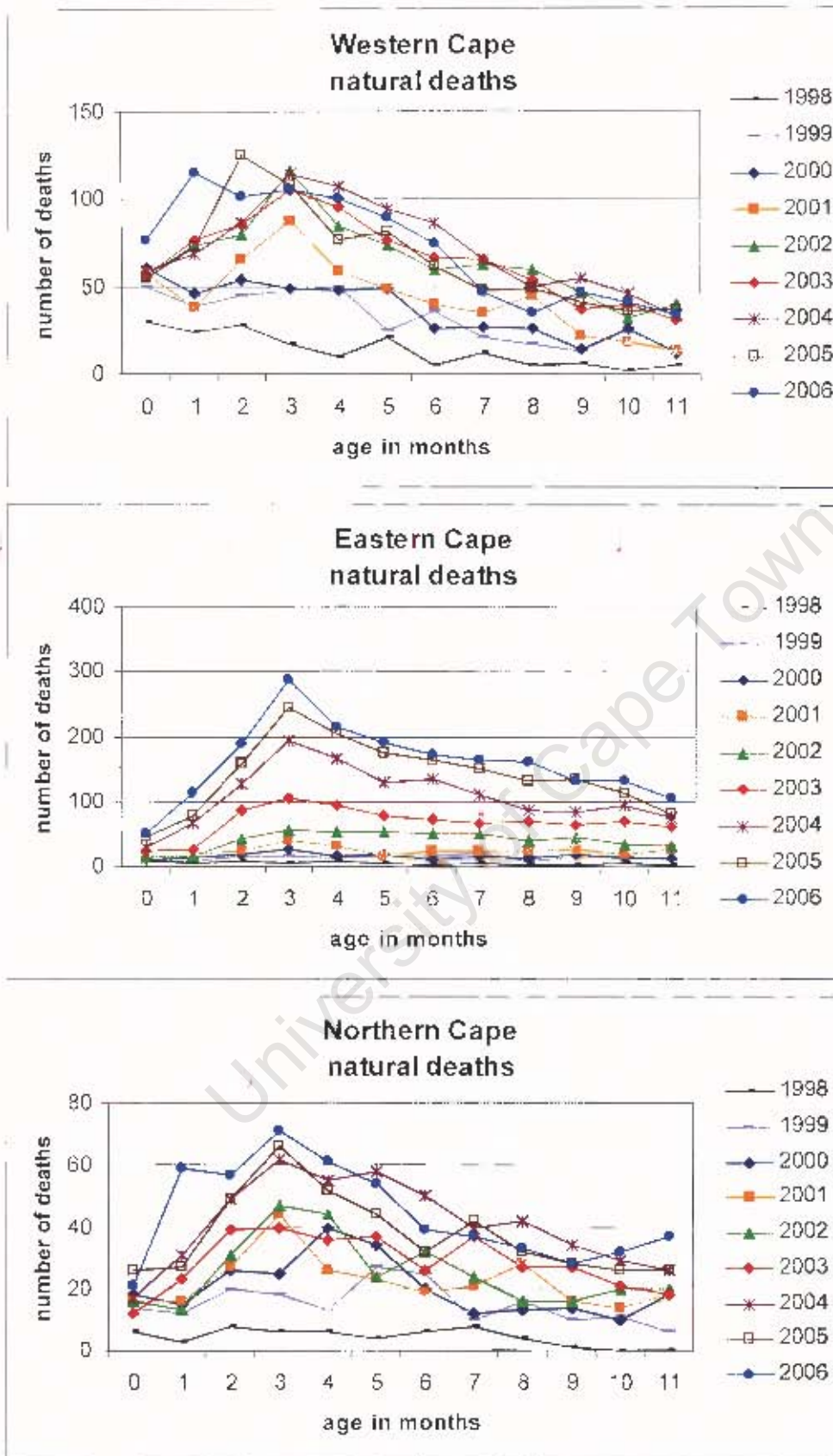


Figure 15a. Age distribution of natural deaths in the Western Cape, Eastern Cape and Northern Cape, 1998-2006, Population Register data.

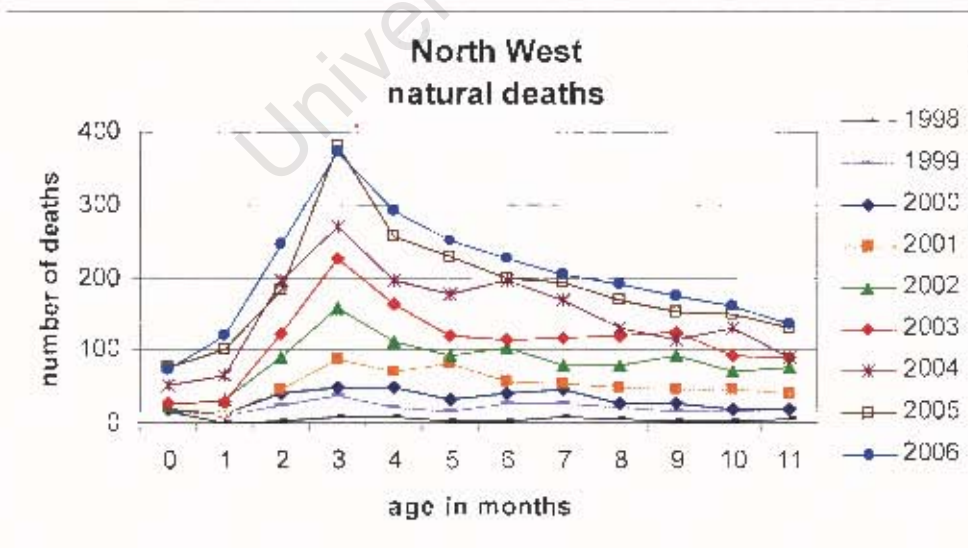
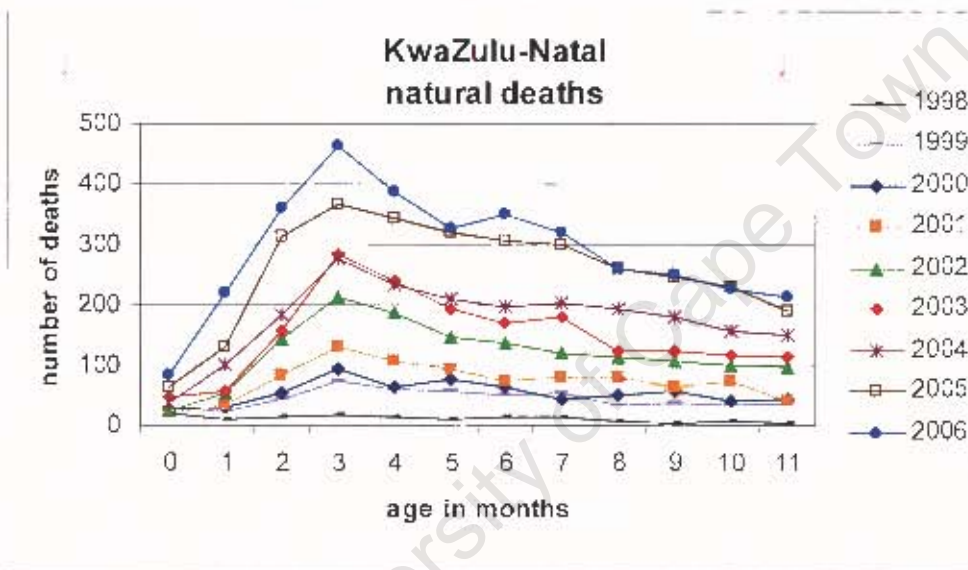
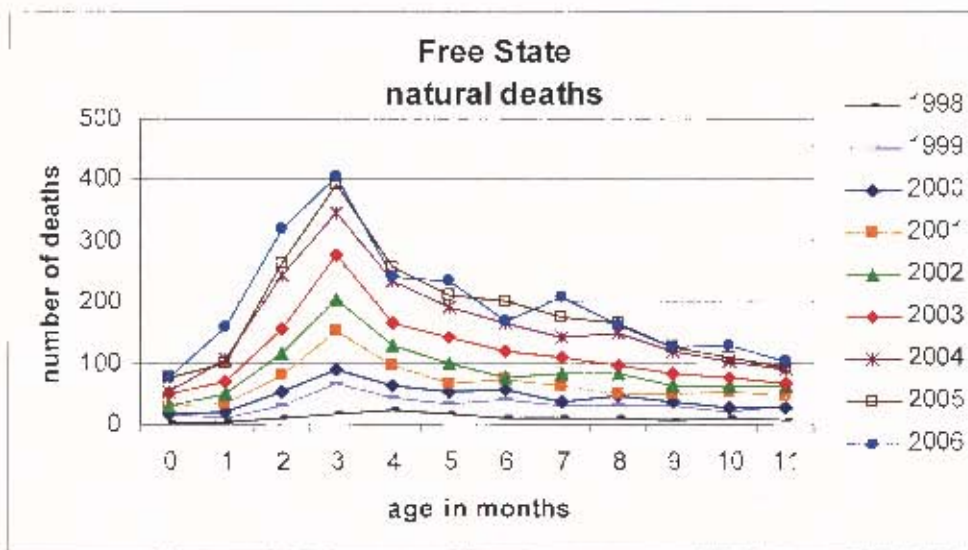


Figure 15b. Age distribution of natural deaths in the Free State, KwaZulu-Natal and the North West, 1998-2006, Population Register data.

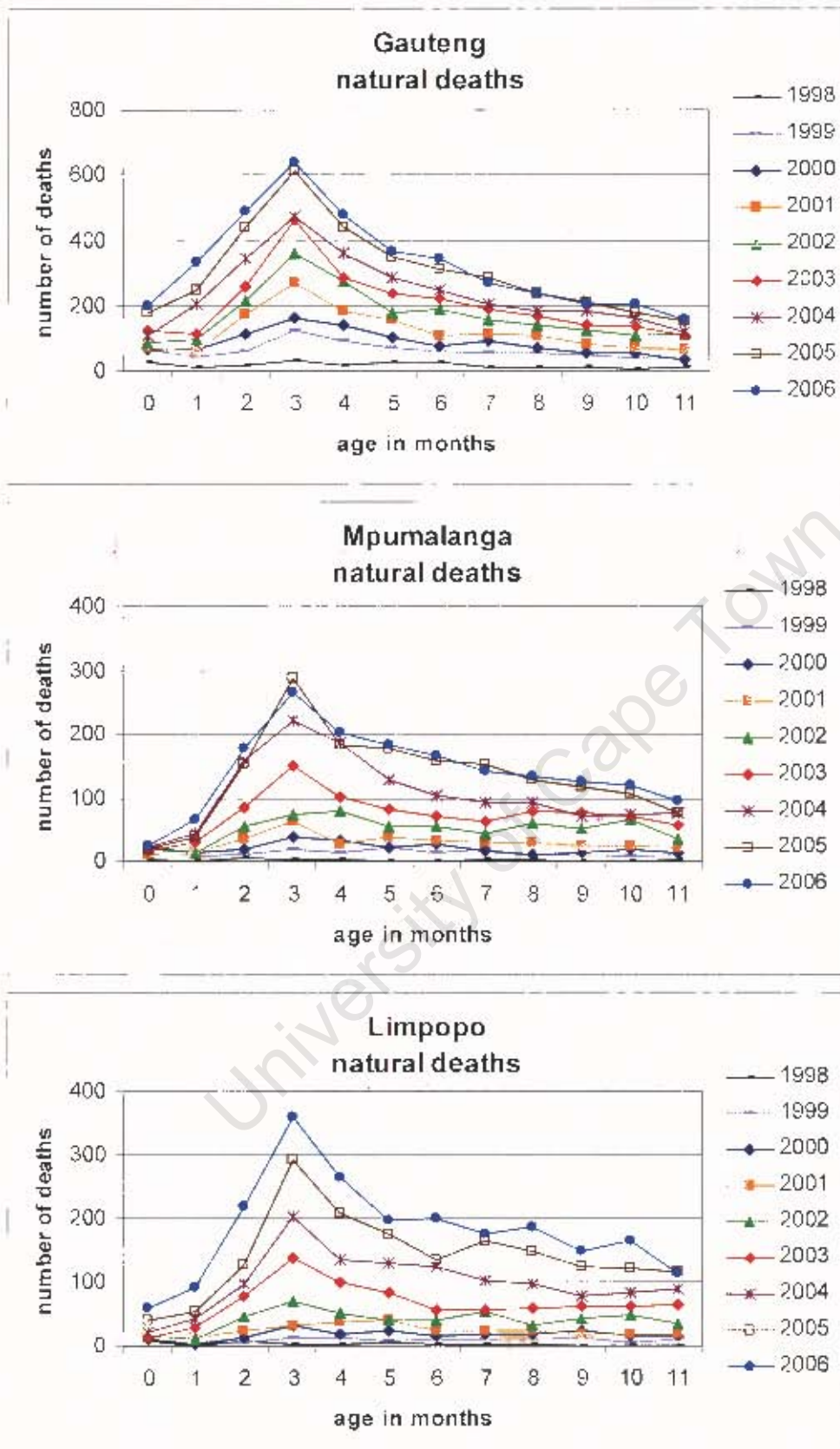


Figure 15c. Age distribution of natural deaths in Gauteng, Mpumalanga and Limpopo, 1998-2006, Population Register data.

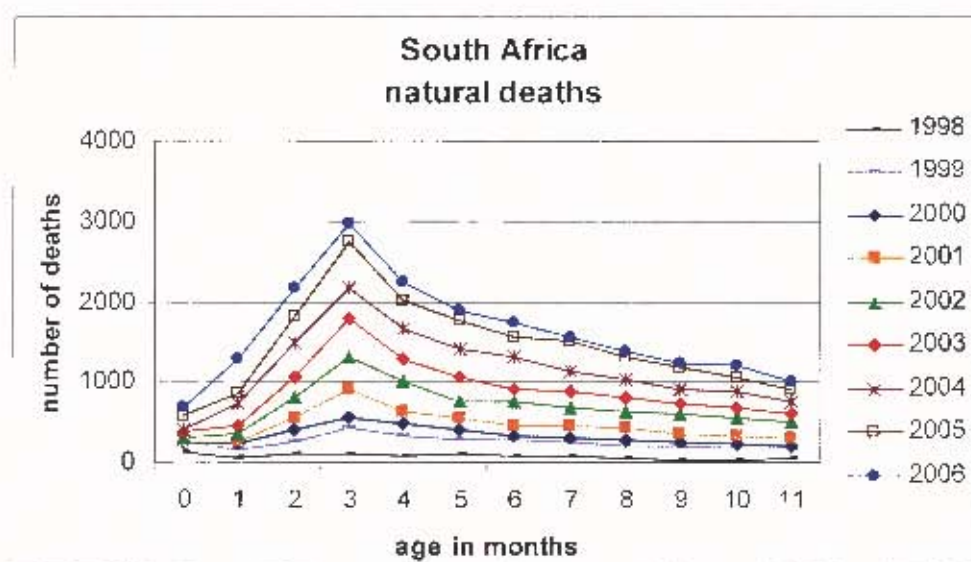


Figure 15d. Age distribution of natural deaths in South Africa, 1998-2006, Population Register data.

In an attempt to adjust for the changes in birth and death registration affecting the Population Register data, an adjustment factor was introduced. As this study (see Figure 7) and others have suggested, deaths due to non-natural (external) causes in South Africa have remained fairly flat from 1997 to 2006. Therefore, the number of natural deaths at each month for infants from 0 to 11 months was divided by the total number of non-natural deaths from age 0 to 11 months for the corresponding year and province. These death ratios are plotted in Figures 16a, b and c. What is evident in all provinces is that after the adjustment using the death ratios, the mortality patterns, including the 3 month peak, are still robust.

The mortality pattern in the Western Cape is different from all other provinces. It appears that mortality at 3 months in the Western Cape turned around after 2003, decreasing to the point where levels in 2006 were below 1998 levels. It should be

noted here that the HIV prevalence in the Western Cape is lower and has always been lower than in other provinces. In contrast, mortality at 3 months increased steadily each year from 1998 to 2006 in the Free State. No turnaround in mortality levels was observed. Other provinces appear to show promising signs of a turnaround or slow down in mortality. In Mpumalanga deaths around 3 months increased from 1998 up to 2004. Thereafter, in 2005 and 2006, levels remained at 2004 levels. In Limpopo the turnaround appears to be in 2005 with 2006 levels remaining at 2005 levels. In the Eastern Cape, KwaZulu-Natal, the North West province and in Gauteng the peak in mortality at 3 months appears to have decreased to 2003 levels. However, each of these provinces shows a slightly different pattern of turnaround. In the Eastern Cape the peak increased from 1998 to 2005, only turning around in 2006. In KwaZulu-Natal the increase in mortality at 3 months appears to have slowed in 2004 and 2005, turning around in 2006. In the North West province this slow down appears to have begun in 2003, while in Gauteng the turnaround may have occurred in 2004.

Natural deaths for South Africa as a whole, adjusted for registration effects by using the ratio of natural deaths to non-natural deaths are plotted in Figure 16d.

On a national level, it appears that mortality at 3 months may have begun to turn after 2003, and that the HIV epidemic may be slowing.

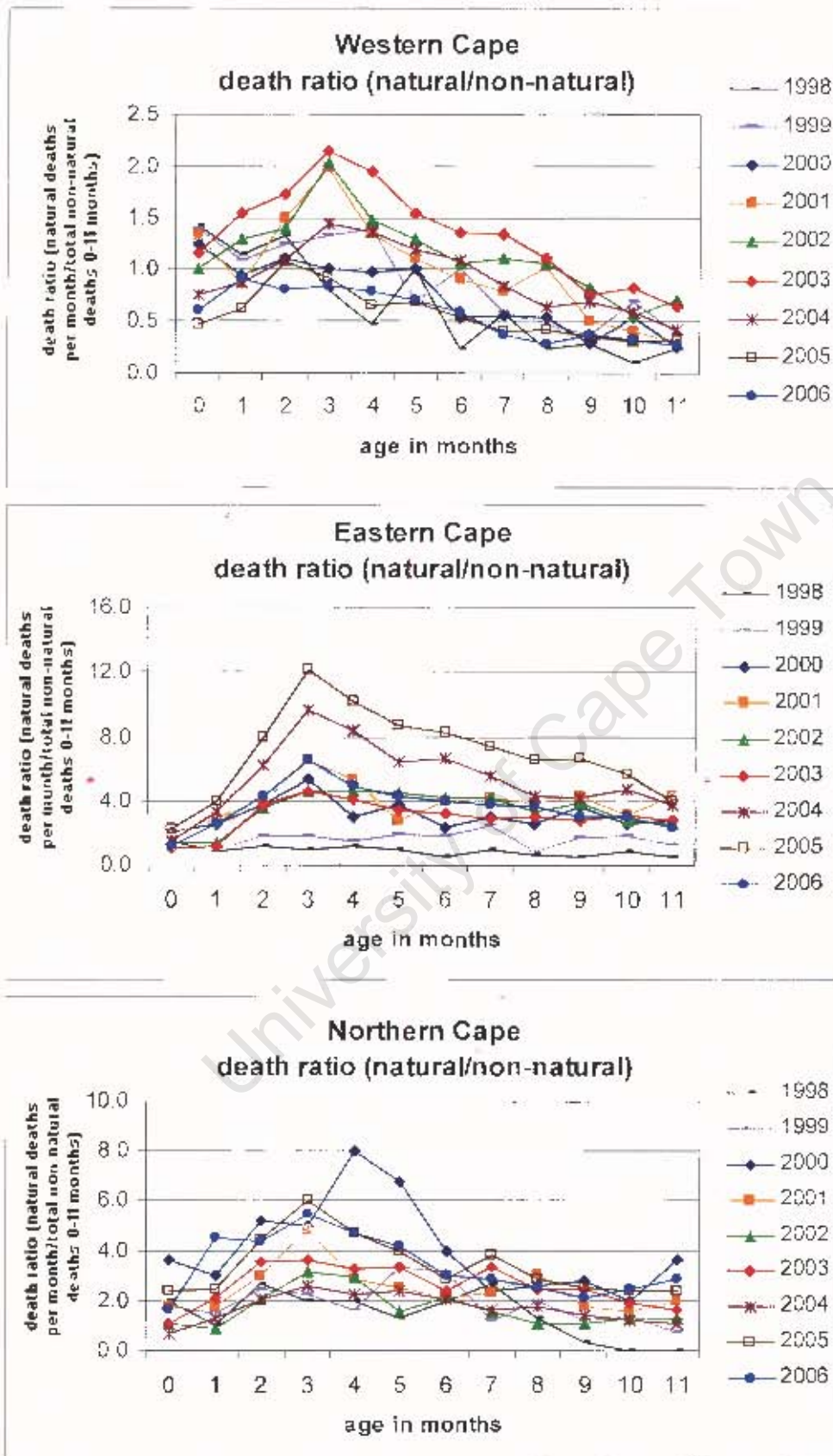
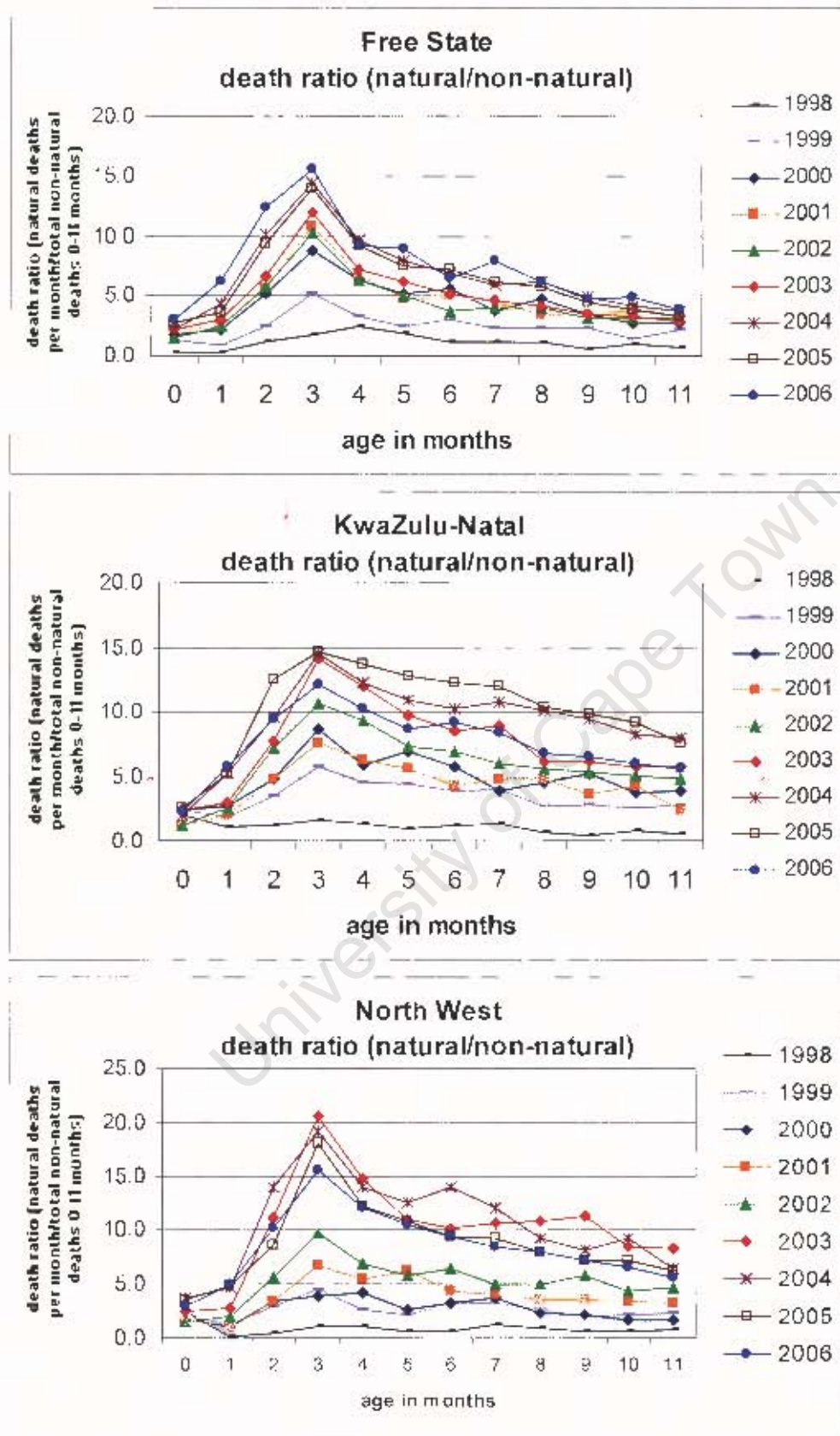


Figure 16a. Death ratios in the Western Cape, Eastern Cape and Northern Cape, 1998-2006, Population Register data.

The death ratio is the number of natural deaths at a specific month divided by the total non-natural deaths at ages 0-11 months for the same year.



**Figure 16b. Death ratios in the Free State, KwaZulu-Natal and the North West, 1998-2006, Population Register data.**

The death ratio is the number of natural deaths at a specific month divided by the total non-natural deaths at ages 0-11 months for the same year.

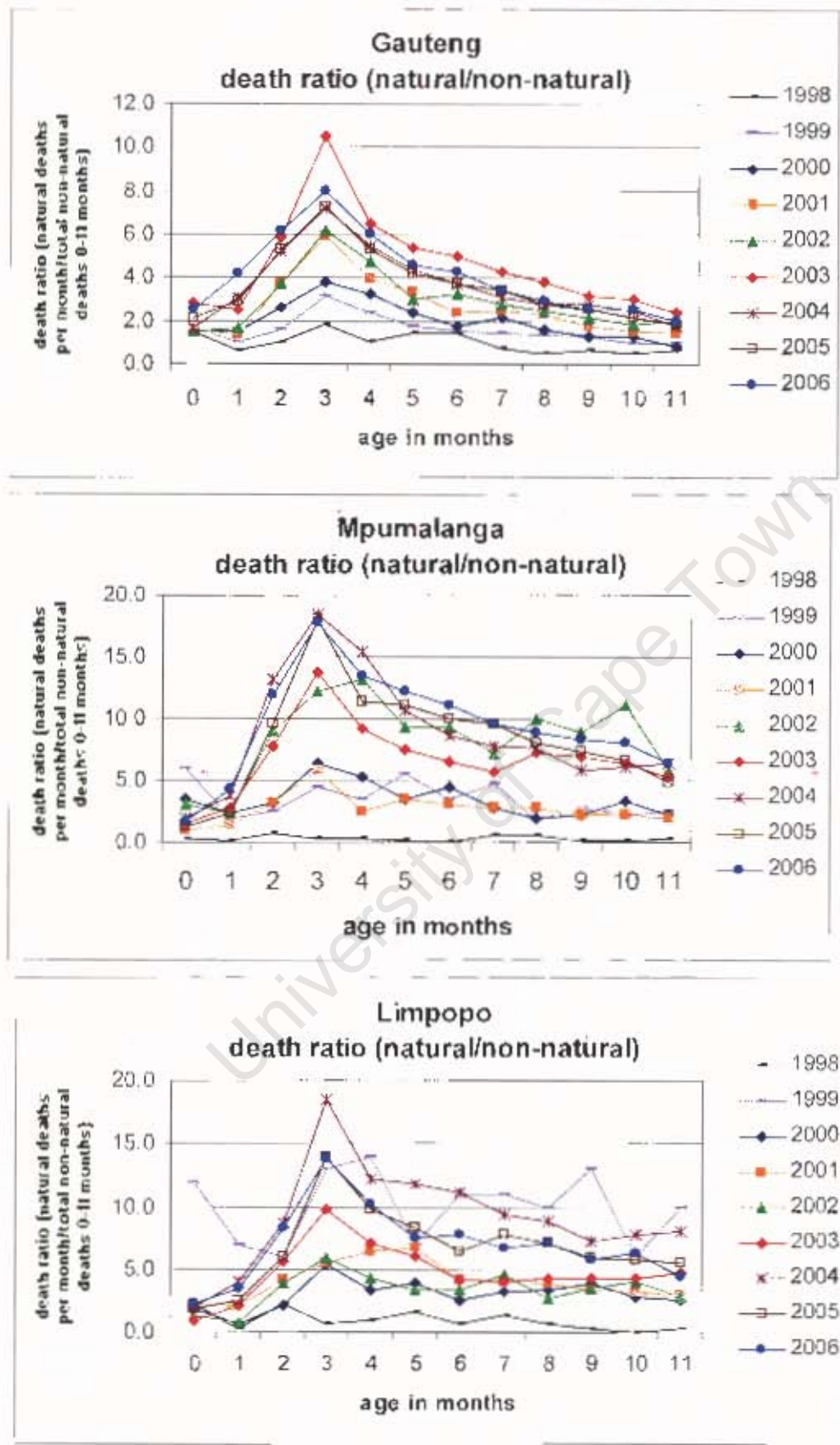
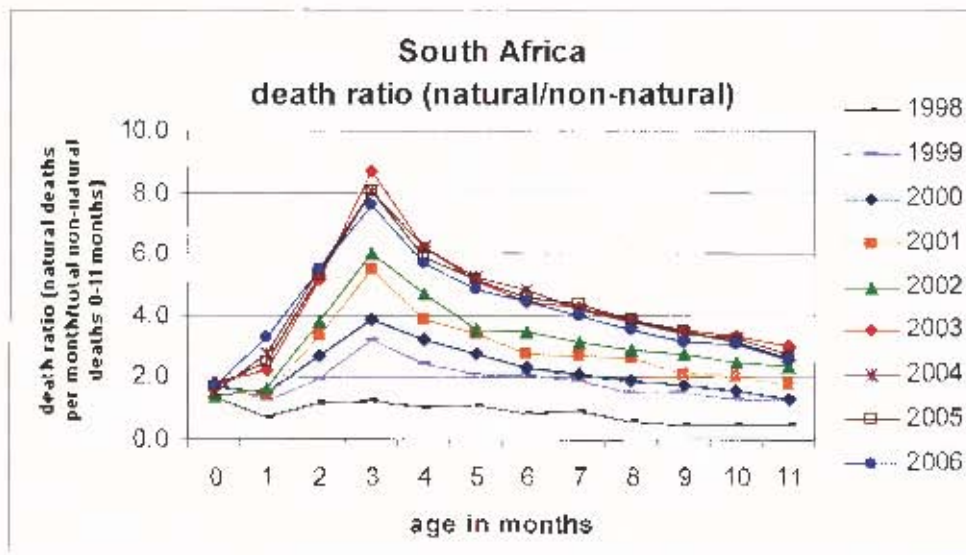


Figure 16c. Death ratios in Gauteng, Mpumalanga and Limpopo, 1998-2006, Population Register data.

The death ratio is the number of natural deaths at a specific month divided by the total non-natural deaths at ages 0-11 months for the same year.



**Figure 16d. Death ratios in South Africa, 1998-2006, Population Register data.**  
 The death ratio in the number of natural deaths at a specific month divided by the total non-natural deaths at ages 0-11 months for the same year.

Logistic modelling techniques were used to confirm the decrease in mortality seen over time when plotting the ratio of natural deaths to non-natural deaths (Thompson 2007). These results are shown in Appendix D. Age at death was grouped into 5 categories: 0 to 1 month; 2 to 4 months; 5 to 7 months; 8 to 10 months; 11 to 12 months. In the Western Cape the risk in death at all ages (relative to non-natural deaths) dropped from 2003 to 2004, and dropped from 2004 to 2005 (Figure D-1 in Appendix D). The drop in both years was statistically significant at most age groups. At the 2 to 4 month age group the ratio from 2004 compared to 2003 was 0.71 (p-value = 0.08, although the confidence interval included 1) and for 2005 compared to 2004 the ratio was 0.67 (p-value = 0.01).

A logistic model was fitted to the data in the Population Register data set, ignoring age at death. This estimates the odds of a natural death (relative to a non-natural

death), see Figure D-2 in Appendix D. The odds ratio for 2004 compared to 2003 was 0.7 with confidence intervals of 0.48 and 1.04 (p-value = 0.09) and for 2005 compared to 2004 the odds ratio was 0.60 (p-value = 0.001). Both regression methods did not show a drop when 2005 was compared to 2006. In addition, no drop was shown during the earlier years. Both regression modelling techniques were applied to the data for the Gauteng province and no drop was shown in any year at any age (Figure D-3 and D-4 in Appendix D).

These results support the observation that in the Western Cape, the increasing mortality in infants around the age of 90 days began to turn around in 2004. In Gauteng no turnaround was seen in the years from 1998 to 2006.

## **5 Discussion**

Here for the first time, a critical analysis of national vital events data examined trends in infant and child mortality at a finer age resolution than has been previously reported. This study utilized unpublished data from Statistics South Africa (Stats SA) and data extracted from the Population Register database maintained by the Department of Home Affairs. Several new and unique findings with respect to infant and child mortality in South Africa were revealed in the course of this study.

The first and most striking new finding was the discovery of an age specific peak in mortality centred at 3 months of age that increased over the time of the study. This is a new demographic phenomenon that has never been published before. The second finding was a major coding error in the coding of underlying cause of death of infants dying before the age of 1 year in the data recorded by Stats SA. However, despite the miscoding of cause of death in infants under one year of age, a third key finding was that this study was able to show that the peak in mortality at 3 months was strongly correlated with measures of the HIV/AIDS epidemic. Correct coding of cause of death was not required to show this correlation. The fourth finding in this study was that this all-cause peak, in conjunction with current Population Register data, was shown to be an effective and rapid surveillance method to measure infant mortality and the effects HIV/AIDS interventions have on infant mortality both nationally and on a provincial level.

## 5.1 Causes of death of infants and children – a coding error

One new finding in this study was the incorrect coding procedures used when Statistics South Africa (Stats SA) coded the underlying cause of death of infants who died under 1 year of age. This was clearly obvious when the leading causes of death of infants and children under 5 years were plotted separately by age of death in months, revealing a considerable discontinuity at the age of 12 months. The error was the result of Stats SA preferentially giving perinatal cause of death codes to infants who died before 1 year of age rather than restricting perinatal codes to causes of death *originating in the first week of life* in accordance with the ICD definitions. The result is an inflation of perinatal causes and an under reporting of the true cause of death in infants under 1 year, and care must be taken when examining cause of death of infants under 1 in this data. As a result of this finding, Statistics South Africa has agreed to change this practice from the next processing phase covering 2006 deaths. In addition to the coding error in infants, it has been well established that HIV/AIDS deaths are vastly under reported in South Africa and often misclassified to other causes. Despite the numerous problems with misclassification of HIV/AIDS deaths and miscoding of deaths of infants under 1 year, this study was able to show that the mortality pattern of infants under 1 year, consisting of an increasing peak in mortality centred at 90 days of age, is consistent with the massive HIV epidemic occurring in South Africa. Furthermore, this study has shown that the leading causes of death in infants under 1 year is consistent with being largely due to HIV/AIDS. This result is in line with current studies of leading causes of death in children in South Africa (Bradshaw, *et al.* 2003b; Krug and Pattinson 2005).

In light of the coding error in infants under 1 year and the considerable misclassification of HIV/AIDS deaths coupled with the extremely high prevalence rates of HIV infection in this country, it is imperative that a technique be developed to monitor paediatric AIDS in the population *without* the need for accurate cause of death information. A surveillance method, which does not rely on an accurate recording of underlying cause of death, is developed here in the following section. This method utilizes an all-cause indicator, the peak in infant mortality at 90 days, similar to the young adult peak used to monitor the HIV/AIDS epidemic in adults (see Figure 3).

## **5.2 Age specific peak in mortality – and HIV/AIDS**

This study examined all-cause mortality data at a fine age resolution and found a new age specific pattern of mortality among infants under 1 year of age. This pattern consists of a peak in mortality centred at an age of death of 90 days, emerging approximately in 1994 and steadily increasing through 2003 on a national level. This is a new demographic phenomenon, revealed because South Africa is one of very few countries with a high HIV prevalence *in addition to* statistics on population mortality of relatively high quality. This peak in mortality at 90 days has not been shown explicitly before, although Newell and colleagues reported that the cumulative probability of dying from birth to 2.5 years showed a sharp rise at an age of approximately 90 days (Newell, *et al.* 2004). A recalculation of this cohort data into age specific mortality rates gives a corresponding peak in mortality at approximately 90 days (data not shown).

This study showed that the leading causes of death of infants under 1 year and children under 5 years of age during the period under study were causes related to HIV/AIDS. This study also showed that the excess deaths represented by the area of the peak in mortality at 90 days strongly correlated with the prevalence of AIDS sick in the population. In addition, the polynomial model which was found to be the best fit when the all-cause peak was regressed against the prevalence of AIDS sick in the population passed very close to the origin. This implies that when there is no AIDS sick in the population, there is no peak in mortality at 90 days. Conversely, the "non AIDS-related" causes at the same age showed no correlation with the prevalence of AIDS sick in the population.

### **5.3 Clinical mechanisms for the peak in mortality**

This study has thus far shown an empirical relationship between HIV/AIDS and the peak in mortality in infants at age 90 days. A number of clinical studies on the immunological status of both mother and infant support this relationship.

A healthy mother provides maternal immunity to her infant through placental transfer and through breast milk. At approximately 3 months after birth an infant's maternally acquired immunity naturally begins to decline while the infant's own immunity, which begins development in the womb, is still very immature (Zinkernagel 2001). Studies have shown that infants born to mothers who are HIV positive receive deficient maternal immunity as a result of deficient placental transfer of maternal antibodies or because an HIV positive mother may simply have levels of antibodies too low for sufficient transfer (de Moraes-Pinto, *et al.*

1993; de Moraes-Pinto, *et al.* 1996; Kuhn, *et al.* 2005). Two studies suggest that an HIV-induced deficient maternal immune system fails to adequately support the development of a competent immune system in infants (Choughnet, *et al.* 2000; Clerici, *et al.* 2000). In addition, one study showed an increase in mortality in infants born to HIV positive mothers *without* vertical transmission to the infant (Graham and Gibb 2002). Infants at 3 months are naturally losing maternal immunity and their own immunity is just beginning to develop. However, when an infant is infected with HIV through vertical transmission or simply born to an HIV positive mother, this age is a particularly vulnerable period. Further evidence for immunological vulnerability leading to death from HIV/AIDS at an early age is provided in studies of the bimodal expression of clinical symptoms due to AIDS in children HIV infected infants in a study by Blanche and colleagues (1990) presented with early and severe disease with a poor rate of survival at 3 years, while the majority of infants had less severe disease and a high probability of surviving at 3 years. The earlier group are thought to have become infected in the womb or during delivery, while the latter are thought to become infected through breastfeeding (Spira, *et al.* 1999). However, the earlier group may also present severe disease as a result of a deficient immune system causing rapid progression to death due to HIV infection at this early age.

The increase in mortality seen at 3 months in this study may be a result of the particular immunological vulnerability at this young age and exposure to the HIV virus. This peak in mortality was shown here to be strongly correlated with the increase in AIDS sick in the population. As interventions aimed at reducing HIV prevalence in the population are implemented, the infection rate in the population

will begin to decline, including the infection rate in mothers. It follows then, that as infection rate in mothers decreases, fewer infants in the population will be exposed to the virus and mortality at 3 months will decrease. This is evident when observing infant mortality in the province of the Western Cape, where the HIV/AIDS interventions of ART and PMTCT were successfully implemented early in the epidemic and HIV prevalence was drastically reduced.

#### **5.4 The Population Register as a data source for using the peak in mortality as a surveillance tool**

In this study a method for surveillance of paediatric AIDS as measured by an increasing peak in mortality at 3 months of age has been presented that does not depend upon accurate cause of death data. The data from Stats SA is several years out of date and not suitable for rapid surveillance. The Population Register database maintained by the Department of Home Affairs has the potential to be used for rapid surveillance. This data can be accessed with just a two month delay and is the most current population based mortality data available. It is also available by province. The data has some limitations, however. The Population Register data consists of data on deaths of individuals where the birth was registered with sufficient information for an ID number to be issued, and the death was registered with an ID number recorded. South Africa has made extensive efforts to improve vital registration and efforts are showing success as registration of both births and deaths is improving. The combination of improvements to vital registration substantially affects the number of deaths recorded on the Population Register.

A form of standardisation was applied to the data in the Population registration data set to adjust for the effects of increased registration. The choice of the ratio of natural to non-natural deaths, denoted here as a death ratio, was based upon a number of assumptions. First, deaths due to non-natural causes (external) were shown to be fairly flat during the time period under study. It is a reasonable assumption that the underlying force of mortality of non-natural deaths is constant over the period under study; no major disasters or wars took place during the period. It is also reasonable to assume that the efficacies of registration of natural and non-natural deaths are similar and also that increases in registration are uniform across all ages from 0 to 1 year of age. It was also assumed that efficacies of registration are similar throughout the provinces, although this may not be so. Based on these assumptions, the total number of non-natural deaths was used as an adjustment factor for potential unmeasured registration changes in natural deaths recorded in the Population Register.

When the number of natural deaths at a specific age in months was divided by the total non-natural deaths at ages 0-11 months for the same year and plotted by age of death in months, all provinces in South Africa showed a peak in mortality at 90 days. Although there are slight differences in the patterns of mortality between provinces, it appears that in general the HIV/AIDS epidemic is turning in South Africa. This is illustrated by the *decrease* in the infant mortality peak centred at 90 days. The Western Cape showed the most dramatic changes in mortality. The peak increased from 1998 to 2003 then turned around in 2004, decreasing to 1998 levels by 2006. The Free State did not show a turn around, with mortality at 90 days increasing steadily from 1998 to 2006. In Gauteng it appears that the

epidemic may be beginning to slow with 2004 and 2005 levels similar, but 2006 levels are higher than these years. In other provinces, and in South Africa as a whole, the HIV epidemic appears to be turning around or slowing around 2004 or 2005.

### **5.5 Monitoring HIV/AIDS interventions**

The surveillance method presented here has shown that the HIV epidemic in the Western Cape has been going through the most dramatic changes as reflected by dramatic decreases in infant mortality. Of all provinces in South Africa the provision of antiretroviral therapy (ART) and the implementation of drug regimens for the prevention for mother to child transmission (PMTCT) programs began earliest in the province of the Western Cape. The Western Cape Provincial Health Department, in partnership with Médecins Sans Frontières (MSF), began a pilot programme offering ART in May of 2001 at three community health centres in Khayelitsha, a township near Cape Town (Coetzee, *et al.* 2004). As late as April of 2004 the South African government, after a constitutional court mandate, began rollout of the antiretroviral treatment program in public health facilities throughout the country. PMTCT services in the Western Cape were first offered by the Provincial Health Department in 1999. By 2003 services were fully in place and included dual therapy for both mothers and their infants (Draper 2006). Rollout of PMTCT services in public health facilities throughout the rest of the country have been extremely slow. Uptake of PMTCT services on a national scale is currently estimated at only 14%

Although HIV/AIDS interventions such as ART and PMTCT services have not reached other provinces to the extent they have in the Western Cape, the slight decreases in mortality at 90 days seen in some provinces suggests that these services actually are having some effect, or possibly the epidemic is reaching natural stabilisation. Provinces with high HIV prevalence such as KwaZulu-Natal are showing a promising decrease in mortality. It may be that one or more of the interventions put in place to stem the tide of the epidemic is having a positive effect on infant mortality.

## **5.5 Limitations**

The major limitation in this study was the accessibility of the data. South Africa has a wealth of existing, potentially available micro data, yet fails to provide timely analysis of this data in detail in its official publications. Data from Statistics South Africa was only available through 2002. Furthermore, as with all vital registration data, these data are a slightly biased subset of the population. Data from Stats SA contains only those deaths that were recorded on official death notifications and contained an exact date of birth and date of death. This might exclude sections of the population who died in remote rural areas and who might be less likely to have the death officially recorded. Also, children living in remote areas may be less likely to have received South African ID numbers. These two facts could bias the data sets so that the very poorest in the population are under represented. This same group might also have less access to health care. Therefore the sicker individuals in the population might be under represented in the data sets analysed here. If this

were the case the extent of the epidemic and its effect on infant mortality would be under estimated in this study.

The Population Register data set contains fewer deaths than the Stats SA data sets, especially in earlier years. In addition, infants who died under the age of 1 month were not recorded on the Population Register data set and this section of the population is grossly under reported as can be seen when compared to the STATS SA data set (Figure 13). The lower numbers in the Population Register data set, especially in earlier years makes estimating the year of the emergence of the 3 month peak difficult. The emergence of the peak corresponds well with the increase in HIV prevalence in South Africa when viewing the data from Statistics South Africa. The peak begins to appear in around 1994 (Figure 13b) and HIV prevalence in South Africa was beginning to increase at the same time. When viewing the emergence of the peak in the Population Register data set, the peak is not evident until 1999 (Figure 13a). Therefore, due to the lower numbers recorded in earlier years and the increasing registration from 1998 to 2006, the Population Register data set is less accurate at monitoring mortality at earlier years.

Other forms of bias that must be considered when viewing the results in this study are the potential biases in efficacy of birth and death registration between provinces and must be considered when any comparisons between provinces are made. In addition, the epidemic is different in different provinces. HIV arrived relatively late in the Western Cape and the province has had a much lower the HIV prevalence rate than other provinces even before interventions began to take effect.

It should also be noted here that the method of adjustment for registration effects in the Population Register is conservative when measuring a decline in rate. Therefore the declines may be larger than observed. It follows that in the case of rising rates over time, this adjustment could exaggerate the increases.

### **5.6 Requirements for a good surveillance system**

This study has shown the increase in mortality due to HIV/AIDS at 3 months can be monitored in an extremely timely fashion by utilising the Population Register data maintained by the Department of Home Affairs. The timeliness in surveillance is described by Klauke and colleagues (1998) as one of the requirements for a good surveillance system. The fact that the surveillance system described in this paper does not require the development of additional data collection methods, and relies entirely on a data collection system that is already in place, makes this surveillance method both simple and sustainable, two major requirements for a good surveillance system. Relying on a data system already in place makes this aspect of the method less flexible in that changes to data collection methods are not very feasible. The system does show some flexibility in application as this surveillance system could be used in other countries with a high HIV prevalence and good vital events data. Botswana is a possible example. The reliability and utility required for a good surveillance system are at the centre of the conclusions made in this study and are evident in the ability of the surveillance system presented here to accurately identify an increasing peak in mortality in infants and show that the peak is due to the HIV epidemic. This, and the fact that no additional

data collection methods need to be implemented, make this method for a rapid surveillance tool for monitoring infant mortality in South Africa extremely valuable in a time of high HIV prevalence and high infant mortality.

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## **6 Conclusion**

This study utilized routinely collected national vital events data to describe trends in infant and child mortality from 1990 to 2006. Increases in mortality were found to be characterized by an HIV/AIDS related peak in mortality among infants – a new demographic phenomenon. The association with the HIV/AIDS epidemic came from a triangulation of analysis by fine age group showing a changing age pattern, the cause of death profiles, the strong correlation with the prevalence of AIDS sick and the biological plausibility based on maternal and infant immune protection. Despite problems with the data in this analysis, including problems with coding of cause of death and changes in birth and death registration, a rapid method of surveillance for infant mortality and the HIV/AIDS signature peak has been presented here. This surveillance method has the advantage of not relying on accurate cause of death coding. By utilizing available vital events data this method can be very current and show the effects of HIV/AIDS intervention methods at a provincial as well as a national level. Results from this rapid surveillance method can be very useful in informing policy on the health issues concerning South Africa's youngest and most vulnerable citizens in an environment of high HIV prevalence.

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# Appendix A Death registration forms



**REPUBLIC OF SOUTH AFRICA  
DEPARTMENT OF HOME AFFAIRS  
NOTIFICATION / REGISTER OF DEATH / STILL BIRTH**

BI - 1463

In terms of the Births and Deaths Registration Act,  
1992 (Act No. 51 of 1992)

Space for Bar Code

\* Must be completed in black ink (please tick  where applicable)

\* Please refer to instructions

SERIAL No:

**A0 1857265**

FILE No:

DATE:

<b>A PARTICULARS OF DECEASED INDIVIDUAL</b> <input type="checkbox"/> / <b>STILLBORN CHILD</b> <input type="checkbox"/>		Date of birth Y Y Y Y M M D D Age at last birthday _____ years Sex _____ If death occurred within 24 hours after birth No. of hours after _____
Identity number of deceased _____ Surname _____ Maiden Name (if female) _____ Postname _____		Log Stamp of Registrar
<b>MARITAL STATUS OF DECEASED</b> Single <input type="checkbox"/> Civil Marriage <input type="checkbox"/> Living as married <input type="checkbox"/> Widowed <input type="checkbox"/> Religious Law Marriage <input type="checkbox"/> Divorced <input type="checkbox"/> Customary Marriage <input type="checkbox"/>		
PLACE OF BIRTH (municipal district or country if abroad) _____ PLACE OF DEATH (City / Town / Village) _____ PLACE OF REGISTRATION OF DEATH _____ CITIZENSHIP OF DECEASED _____		
<b>B PARTICULARS OF INFORMANT</b> Identity number _____ Initials and Surname _____ Relationship to deceased Parent <input type="checkbox"/> Spouse <input type="checkbox"/> Child <input type="checkbox"/> Other (specify) _____ Postal address _____ Postal Code _____ District Code _____ Telephone No. _____ Was the next of kin of the deceased a member* during the past five years? Yes <input type="checkbox"/> No <input type="checkbox"/> Intends to marry <input type="checkbox"/>		Log Stamp of Registrar
Date _____ <b>C PARTICULARS OF FUNERAL UNDERTAKER</b> Initials and Surname _____ Designation No. _____ Place of burial / cremation _____ Date _____ Signature _____		
<b>D CERTIFICATE BY ATTENDING MEDICAL PRACTITIONER / PROFESSIONAL NURSE</b> I, the undersigned, hereby certify that the deceased named in Section A, in the best of my knowledge and belief, died solely and exclusively due to <b>NATURAL CAUSES</b> specified in Section C <input type="checkbox"/> I, the undersigned, am not in the position to certify that the deceased died exclusively due to natural causes <input type="checkbox"/>		Postal Address _____ Postal Code _____ SAMEC / SANC Reg. No. _____ Date signed _____
<b>E CERTIFICATE BY ASSISTANT SURGEON / FORENSIC PATHOLOGIST</b> I, the undersigned, hereby certify that a medical-legal post-mortem examination has been conducted on the body of the person whose particulars are given in Section A and that the body is no longer required for the purposes of the Inquest Act, 1959 (Act No. 58 of 1959) and that the cause of death is: Unnatural <input type="checkbox"/> Under investigation <input type="checkbox"/> Natural (Cause of Death as indicated in Section C) <input type="checkbox"/>		Postal Address _____ Postal Code _____ Date _____ Signature _____ Date signed _____ SAMEC Reg. No. _____
<b>F FOR OFFICIAL USE ONLY</b> Registration of death approved and burial order issued Address _____ Date _____ Signature _____		Initials and Surname of Registrar _____ Page No. / Designation No. _____ Postal No. _____ Office Stamp

\* Persons who smokes tobacco on most days

Figure A-1a. Notification of death form, page one.

**NOTIFICATION / REGISTER OF DEATH / STILL BIRTH**  
**INFORMATION FOR MEDICAL AND HEALTH USE ONLY**  
 (After completion seal to ensure confidentiality)

BH - 1443  
Page 2

FILE No: _____ DATE: _____ SERIAL No: <b>A01857265</b>	Space for Burial																														
<b>F DEMOGRAPHIC DETAILS</b> Initials and Surname of deceased _____ Identity Number _____ Place of death 1. Hospital (Inpatient) <input type="checkbox"/> HH/Outpatient <input type="checkbox"/> DCA <input type="checkbox"/> 2. Nursing Home <input type="checkbox"/> 3. Home <input type="checkbox"/> 4. Other (Specify) <input type="checkbox"/> _____ FACILITY NAME (if an institution, give street and number) _____ Usual residential address of deceased at _____ Suburb _____ Name of Flat, Farm, etc. _____ Census Enumeration Area _____ Street name and number _____ Migrant No. _____ Deceased's Education (Specify) <input checked="" type="checkbox"/> only highest class completed/attended <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <th>None</th> <th>Gr1</th> <th>Gr2</th> <th>Gr3</th> <th>Gr4</th> <th>Gr5</th> <th>Gr6</th> <th>Gr7</th> <th>Gr8 Form 1</th> <th>Gr9 Form 2</th> <th>Gr10 Form 3</th> <th>Gr11 Form 4 NCEC</th> <th>Gr12 Form 5 NCEC</th> <th>Unk Mark</th> <th>CODE</th> </tr> <tr> <td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td> </tr> </table> Postal Code _____ Province _____ Country _____		None	Gr1	Gr2	Gr3	Gr4	Gr5	Gr6	Gr7	Gr8 Form 1	Gr9 Form 2	Gr10 Form 3	Gr11 Form 4 NCEC	Gr12 Form 5 NCEC	Unk Mark	CODE															
None	Gr1	Gr2	Gr3	Gr4	Gr5	Gr6	Gr7	Gr8 Form 1	Gr9 Form 2	Gr10 Form 3	Gr11 Form 4 NCEC	Gr12 Form 5 NCEC	Unk Mark	CODE																	
USUAL OCCUPATION OF DECEASED (give type of work done during most of working life. Do not use suffix) _____ TYPE OF BUSINESS / INDUSTRY (e.g. Mining, Farming) refer to manual _____																															
Was the deceased a smoker* five years ago? ( <input checked="" type="checkbox"/> ) : Yes <input type="checkbox"/> Do not know <input type="checkbox"/> Not applicable (infant) <input type="checkbox"/>																															
<b>G MEDICAL CERTIFICATE OF CAUSE OF DEATH</b> PART 1. Enter the disease, injury or complication that caused death, and enter the mode of dying, such as cardiac or respiratory arrest, shock, or brain failure. List only the most important conditions. IMMEDIATE CAUSE (final disease or condition resulting in death) a. _____ Due to (or as a consequence of) _____ Substantially less conditions, if any, leading to immediate cause. Enter UNDERLYING CAUSE here (disease or injury that initiated events resulting in death) b. _____ Due to (or as a consequence of) _____ c. _____ Due to (or as a consequence of) _____ d. _____ Due to (or as a consequence of) _____ PART 2. Other significant conditions contributing to death but not resulting in the underlying cause given in Part 1. _____ If a female, was she pregnant 42 days prior to death? ( <input checked="" type="checkbox"/> ) : Yes <input type="checkbox"/> No <input type="checkbox"/> If stillborn, please write term in grams _____ Do you consider the deceased to be: African <input type="checkbox"/> White <input type="checkbox"/> Indian <input type="checkbox"/> Coloured <input type="checkbox"/> Other <input type="checkbox"/> (Specify) _____ Method of ascertainment of cause of death: 1. Autopsy <input type="checkbox"/> 2. Opinion of attending medical practitioner <input type="checkbox"/> 3. Opinion of attending medical practitioner on day <input type="checkbox"/> 4. Opinion of registered professional nurse <input type="checkbox"/> 5. Interview of family member <input type="checkbox"/> 6. Other <input type="checkbox"/> (Specify) _____																															
# Where deceased lived on most days * Deceased who smokes tobacco on most days																															

Figure A-1b. Notification of death form, page two.



REPUBLIC OF SOUTH AFRICA  
DEPARTMENT OF HOME AFFAIRS  
FULL DEATH CERTIFICATE  
(Issued in terms of Act 51 of 1920)

Certified a true extract from the death register of:

1. Identity Number

2. Surname .....

3. Forenames in full .....

4. Date of birth: Year     Month   Day   5. Gender .....

6. Occupation..... 7. Marital status.....

8. Country of birth .....

9. Nature of pension .....

10. Residential address .....

PARTICULARS OF DEATH

11. Date of death: Year     Month   Day

12. Place of death .....

13. Cause of death .....

14. Duration of disease or last illness .....

15. Name of medical practitioner .....

16. Intended place of burial .....

INFORMANT

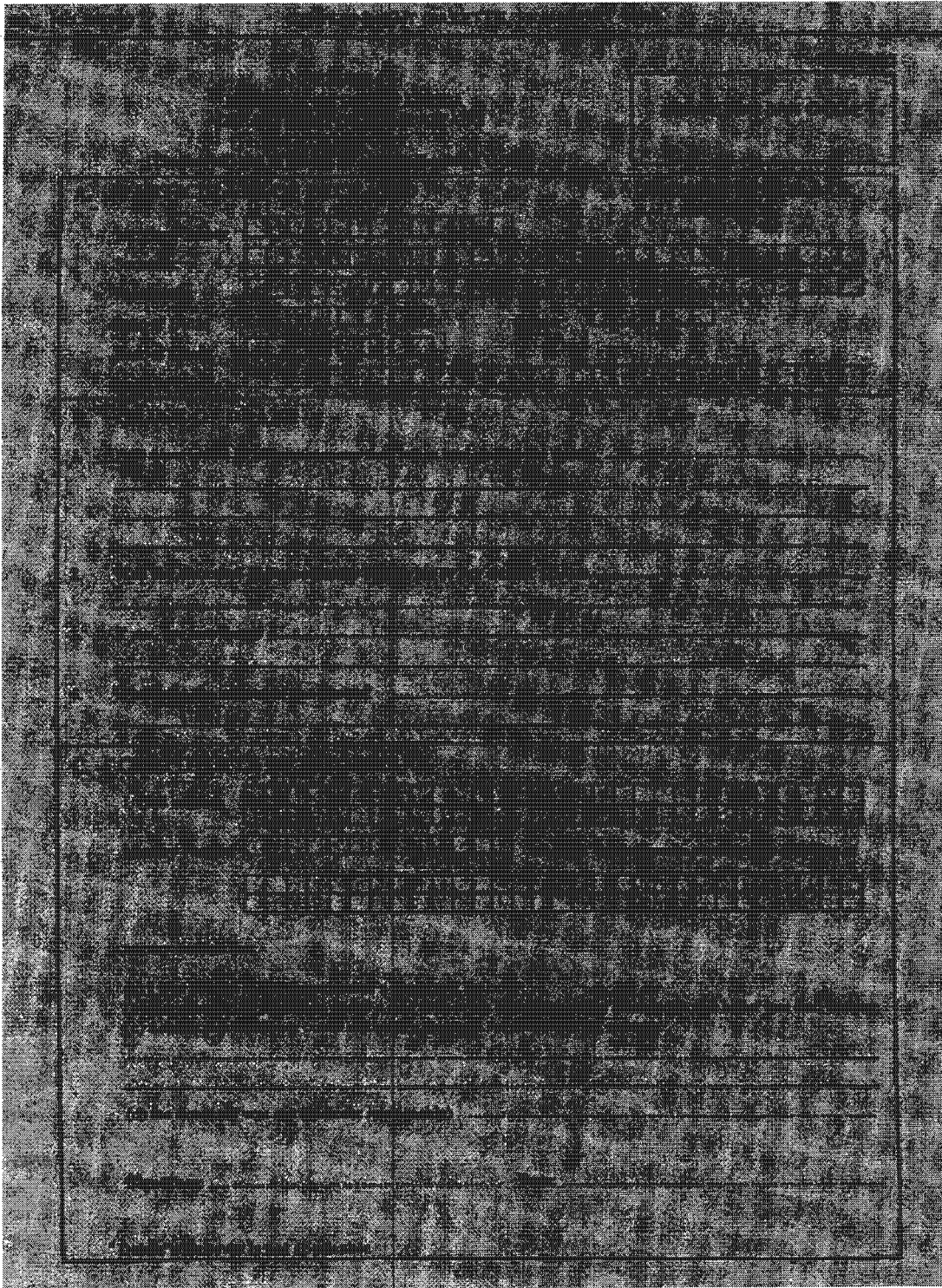
17. Capacity .....

18. Signed by .....

(Official date stamp)

Director-General, Home Affairs

Figure A-2. Death certificate.



**Figure A-3. Death Report.**

## Appendix B Age distribution of deaths, males and females

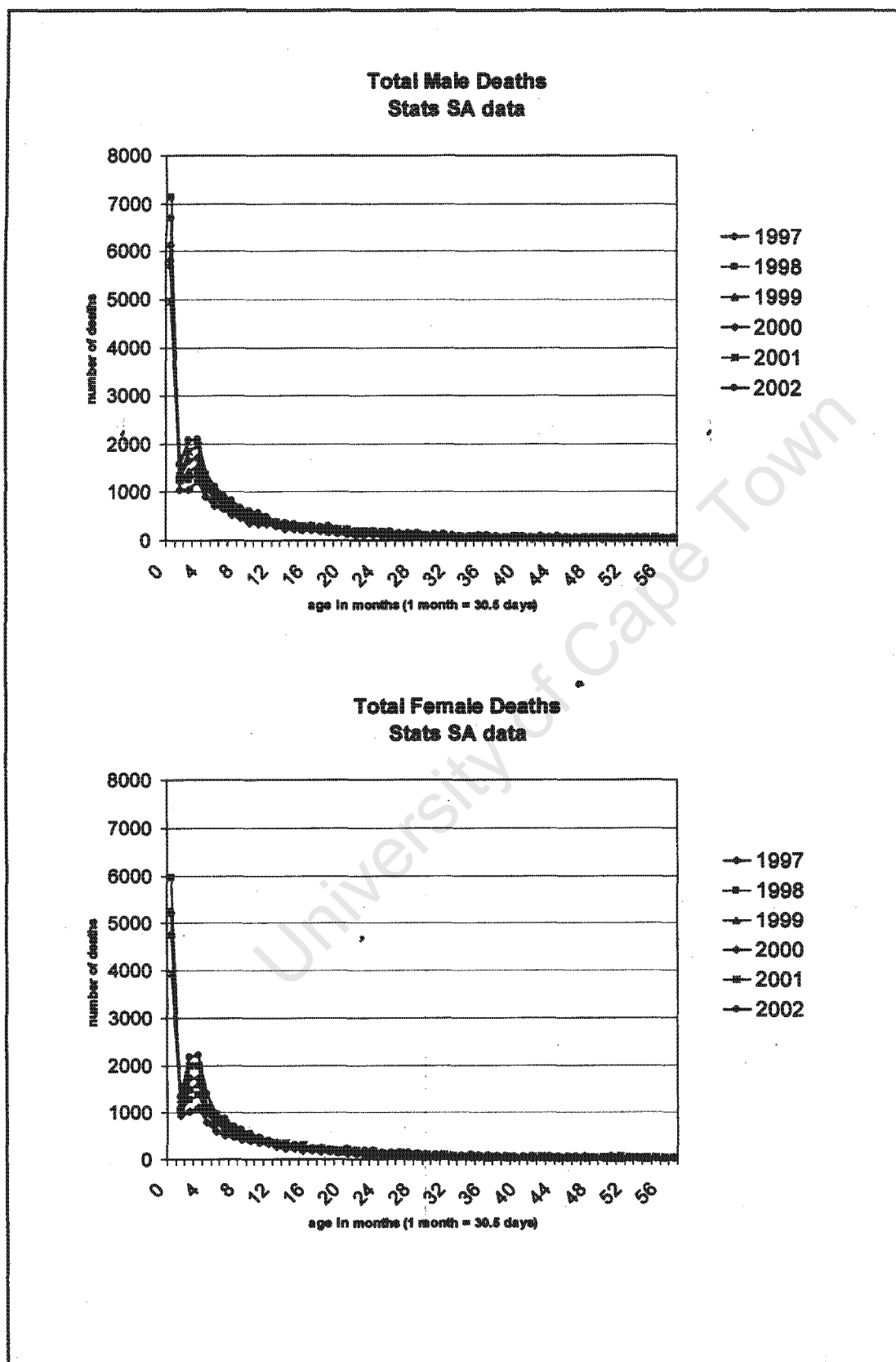


Figure B-1. Age distribution of deaths of male and females infants and children under 5 years, 1997-2002, Statistics South Africa data.

**Appendix C      Map of provinces, South Africa**



**Figure C-1. Map of provinces in South Africa.**

## Appendix D Logistic regression analysis

Logistic modelling techniques were used to confirm changes in mortality seen over time when plotting the ratio of natural deaths to non-natural deaths. Techniques used here were devised and the calculations by were performed by Thompson (2007).

At each age of death in months, a significant reduction in the ratio from 1 calendar year to another suggests a significant decrease in mortality at that age of death. For natural deaths, age at death was grouped into 5 categories: 0-1 month; 2-4 months; 5-7 months; 8-10 months; 11-12 months.

Conditional on a child having died, a logistic multinomial model was fitted to the probability of death, with unnatural death in each year as the reference category for that year, i.e.

$$\text{Log(RR)} = \log\left(\frac{P(\text{child dies natural death at age } i | \text{Year } j)}{P(\text{child dies unnatural death} | \text{Year } j)}\right) = \beta_{0i} + \beta_{1ij}.$$

Hence  $\exp(\beta_{1ij} - \beta_{1ik})$  reflects the ratio of the risk of dying at age  $i$  in year  $j$  (relative to an unnatural death in year  $j$ ) to the risk of dying at age  $i$  in year  $k$  (relative to an unnatural death in year  $k$ ). Comparing these risks from year to year allows one to track trends in the risk of death at that age (relative to unnatural death) over time.

A logistic model was also fitted to this data ignoring age at death which estimated the odds of a natural death (relative to an un-natural death) from year to year.

**Table D-1. Multinomial logistic regression for Western Cape.  
(Thompson 2007).**

<b>Age at death</b>	<b>Year</b>	<b>RRR</b>	<b>SE</b>	<b>p-value</b>	<b>95% CI</b>
<b>0-1 month</b>	1999 vs 1998	.91	.29	.77	(.46,1.71)
	2000 vs 1999	.91	.23	.73	(.55,1.52)
	2001 vs 2000	1.02	.25	.94	(.62,1.66)
	2002 vs 2001	1.05	.25	.83	(.66,1.69)
	2003 vs 2002	1.11	.25	.64	(.71,1.74)
	2004 vs 2003	0.63	.14	.04	(.41,.97)
	2005 vs 2004	0.66	.13	.03	(.46,.97)
	2006 vs 2005	1.40	.24	.05	(1.00,1.96)
<b>2-4 months</b>	1999 vs 1998	1.44	.45	.25	(.78,2.66)
	2000 vs 1999	.80	.20	.37	(.50,1.30)
	2001 vs 2000	1.60	.37	.05	(1.01,2.52)
	2002 vs 2001	1.02	.22	.94	(.66,1.56)
	2003 vs 2002	1.12	.23	.59	(.74,1.69)
	2004 vs 2003	.71	.14	.08	(.48,1.04)
	2005 vs 2004	.67	.11	.01	(.48,.93)
	2006 vs 2005	.93	.14	.62	(.69,1.25)
<b>5-7 months</b>	1999 vs 1998	1.19	.40	.60	(.62,2.30)
	2000 vs 1999	0.95	.25	.83	(.57,1.58)
	2001 vs 2000	1.38	.34	.19	(.85,2.23)
	2002 vs 2001	1.23	.28	.38	(.78,1.93)
	2003 vs 2002	1.16	.25	.49	(.76,1.78)
	2004 vs 2003	.77	.16	.21	(.52,1.15)
	2005 vs 2004	.51	.09	<.0005	(.37,.73)
	2006 vs 2005	1.04	.17	.83	(.75,1.42)
<b>8-10 months</b>	1999 vs 1998	2.33	.96	.04	(1.04,5.23)
	2000 vs 1999	.91	.26	.74	(.52,1.59)
	2001 vs 2000	1.46	.39	.15	(.87,2.45)
	2002 vs 2001	1.26	.31	.34	(.78,2.03)
	2003 vs 2002	1.03	.23	.89	(.66,1.61)
	2004 vs 2003	.76	.16	.20	(.50,1.16)
	2005 vs 2004	.55	.10	.002	(.38,.80)
	2006 vs 2005	.91	.16	.62	(.64,1.30)
<b>11-12 months</b>	1999 vs 1998	2.43	1.38	.12	(.80,7.36)
	2000 vs 1999	.73	.27	.39	(.35,1.51)
	2001 vs 2000	1.30	.47	.47	(.64,2.65)
	2002 vs 2001	1.64	.52	.12	(.88,3.06)
	2003 vs 2002	.95	.27	.84	(.54,1.64)
	2004 vs 2003	.81	.22	.43	(.48,1.37)
	2005 vs 2004	.60	.15	.04	(.37,.97)
	2006 vs 2005	.96	.23	.85	(.60,1.52)

**Table D-2. Logistic regression for Western Cape**  
 All ages (0-11 months) of natural relative to all ages of unnatural death (Thompson 2007).

<b>Year</b>	<b>OR</b>	<b>SE</b>	<b>p-value</b>	<b>95% CI</b>
1999 vs 1998	1.31	.38	.35	(.75,2.30)
2000 vs 1999	.87	.20	.53	(.56,1.35)
2001 vs 2000	1.38	.30	.14	(.90,2.10)
2002 vs 2001	1.14	.24	.54	(.76,1.71)
2003 vs 2002	1.10	.22	.62	(.75,1.63)
2004 vs 2003	.73	.13	.09	(.51,1.05)
2005 vs 2004	.60	.09	.001	(.45,.81)
2006 vs 2005	1.02	.14	.84	(.79,1.34)

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**Table D-3. Multinomial logistic regression for Gauteng.**  
(Thompson 2007).

<b>Age at death</b>	<b>Year</b>	<b>RRR</b>	<b>SE</b>	<b>p-value</b>	<b>95% CI</b>
0-1 month	1999 vs 1998	1.39	.46	.31	(.73,2.65)
	2000 vs 1999	1.14	.29	.61	(.69,1.86)
	2001 vs 2000	.98	.24	.93	(.61,1.58)
	2002 vs 2001	1.09	.25	.72	(.70,1.69)
	2003 vs 2002	1.56	.34	.04	(1.02,2.38)
	2004 vs 2003	.97	.20	.87	(.65,1.45)
	2005 vs 2004	1.03	.18	.88	(.73,1.45)
	2006 vs 2005	1.35	.22	.07	(.98,1.86)
2-4 months	1999 vs 1998	2.01	.60	.02	(1.12,3.61)
	2000 vs 1999	1.39	.32	.15	(.89,2.18)
	2001 vs 2000	1.44	.31	.09	(.94,2.21)
	2002 vs 2001	1.07	.22	.75	(.71,1.58)
	2003 vs 2002	1.42	.28	.08	(.96,2.09)
	2004 vs 2003	.86	.17	.44	(.59,1.26)
	2005 vs 2004	.96	.16	.80	(.69,1.33)
	2006 vs 2005	1.15	.18	.37	(.85,1.56)
5-7 months	1999 vs 1998	1.41	.43	.25	(.78,2.57)
	2000 vs 1999	1.39	.33	.16	(.87,2.20)
	2001 vs 2000	1.33	.30	.20	(.86,2.07)
	2002 vs 2001	1.09	.23	.66	(.73,1.64)
	2003 vs 2002	1.48	.30	.05	(1.0,2.18)
	2004 vs 2003	.84	.16	.37	(.57,1.23)
	2005 vs 2004	.97	.16	.85	(.70,1.35)
	2006 vs 2005	1.11	.18	.51	(.81,1.51)
8-10 months	1999 vs 1998	2.38	.80	.01	(1.23,4.60)
	2000 vs 1999	1.20	.29	.44	(.75,1.94)
	2001 vs 2000	1.36	.31	.18	(.87,2.14)
	2002 vs 2001	1.15	.24	.50	(.76,1.74)
	2003 vs 2002	1.41	.29	.09	(.95,2.11)
	2004 vs 2003	.87	.17	.50	(.59,1.29)
	2005 vs 2004	.90	.15	.54	(.64,1.26)
	2006 vs 2005	1.11	.18	.52	(.81,1.52)
11-12 months	1999 vs 1998	1.58	.60	.23	(.75,3.34)
	2000 vs 1999	.92	.26	.76	(.52,1.60)
	2001 vs 2000	1.73	.46	.04	(1.02,2.91)
	2002 vs 2001	1.19	.28	.46	(.75,1.87)
	2003 vs 2002	1.19	.27	.43	(.77,1.85)
	2004 vs 2003	.82	.18	.35	(.53,1.250)
	2005 vs 2004	1.01	.19	.94	(.70,1.47)
	2006 vs 2005	1.12	.20	.53	(.79,1.59)

**Table D-4. Logistic regression for Gauteng**

All ages (0-11 months) of natural relative to all ages of unnatural death (Thompson 2007).

<b>Year</b>	<b>OR</b>	<b>SE</b>	<b>p-value</b>	<b>95% CI</b>
1999 vs 1998	1.74	.48	.05	(1.01,3.00)
2000 vs 1999	1.29	.28	.25	(.84,1.98)
2001 vs 2000	1.36	.29	.15	(.90,2.06)
2002 vs 2001	1.10	.22	.64	(.75,1.62)
2003 vs 2002	1.43	.28	.07	(.98,2.09)
2004 vs 2003	.87	.16	.45	(.60,1.25)
2005 vs 2004	.96	.16	.81	(.70,1.32)
2006 vs 2005	1.15	.18	.35	(.85,1.56)

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