Expanding the South African Rapid Mortality Surveillance to cover provincial mortality

By

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ABSTRACT

Mortality estimates are useful for evaluating health status for a country. These estimates, especially for a country heavily affected by HIV epidemic and at the sub-national level, are a foundation in formulating health strategies and policies to reduce premature deaths and improve quality of life. However, estimating consistent levels and trends in mortality for a developing country like South Africa with incomplete vital registration and errors in censuses or survey data is difficult. This research examines whether one can combine National Population Register (NPR) data and Vital Registration (VR) data to produce reliable estimates of specific indices of mortality at the provincial level. In addition, the same approach as used in 2015 RMS report is applied to registered maternal deaths, neonatal deaths, and neonatal deaths captured by the District Health Information System (DHIS) to derived reliable estimates of MMR and NMR at the provincial level.

The quality of NPR data and VR data is evaluated and since NPR data does not include the whole population, it is adjusted for incompleteness relative to VR data. It is found that there are some problems in the VR data such as VR death misplacement between the provinces and missing VR deaths in most recent years, which makes extrapolation of past trends in the completeness of NPR relative to VR into the future difficult. Suitable assumptions are made to correct for these anomalies and NPR data together with VR data are further adjusted for the general under-registration. Estimates of child mortality from Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016) and estimates of adult mortality from Dorrington and Timæus (2017) are used to derive the estimates of completeness of death registration.

The estimates of mortality rates produced from combining NPR and VR data appear to be sensible, showing some internal and external consistency. However, the estimates of MMRs produced from VR data as well as NMR from VR and DHIS data shows that there is a great deal of uncertainty around the estimates of these mortality indicators.

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ACRONYMS AND ABREVIATIONS

$_{1}q_{0}$ - probability of a live birth dying before age 1

$_{5}q_{0}$ - probability of a live birth dying before age 5

$_{45}q_{15}$ - conditional probability of a 15-year-old person dying before age 60

AIDS - acquired immune deficiency syndrome

ASSA - Actuarial Society of South Africa

CARe - Center of Actuarial Research

DHA - Department of Home Affairs

DHIS - District Health Information System

DNF - death notification form

e_0 - life expectancy at birth

e_{60} - life expectancy at age 60

HIV - human immunodeficiency virus

HDACC - Health Data Advisory and Coordinating Committee

ID - identity document

IGME - UN Interagency Group for Child Mortality Estimation

IHME – Institute of Health Metrics and Evaluation

IMR - infant mortality rate

MMIEG - Maternal Mortality Interagency Estimation Group

MMR - maternal mortality ratio

NMR - neonatal mortality rate

NPR - National Population Register

RMS - Rapid Mortality Surveillance

SAMRC - South African Medical Research Council

SNBD – Second National Burden of Disease

Stats SA - Statistics South Africa

U5MR - under-5 mortality rate

SDGs – Sustainable Development Goals

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1 INTRODUCTION

1.1 Background

Over the years, several attempts have been made by the government and non-governmental organizations to reduce mortality and disparities in mortality among individuals in South Africa (Harrison 2009). Particular attention has been paid to infant and under-five mortality as these are associated with the quality and access to medical care, public health practices, socio-economic conditions and maternal health, and hence they are important indicators of the health of a country (Olson, Diekema, Elliott *et al.* 2010). The estimates for South Africa provided by United Nations Children's Fund (UNICEF Data 2017) show that recent under-five mortality is still higher than in other countries with the same gross domestic product (GDP) per capita. For example, the under-five mortality in 2016 for South Africa was 43.2 deaths per 1000 live births compared to 15.1 deaths per 1000 live births for Brazil[1]. Even some countries, which are economically less developed compared to South Africa, had under-five mortality in 2016 that was not much higher (e.g. 46.4 and 45.2 for Madagascar and Namibia, respectively). Although the degree of uncertainty of Namibian and Madagascan estimates is higher than South Africa, there is not much difference between the South African estimates in 2016 and the estimates from these countries.

Apart from this, there are large geographical differences in child mortality for South Africa (Rademeyer 2017). This is probably the result of differences in socio-economic standards, levels of HIV prevalence and the provision and access to health care by population group, coupled with differences in the proportions of the population by population group for provinces and districts.

Despite the efforts to reduce mortality in South Africa, there is a problem when it comes to reviewing the estimates from different sources because they differ. The problem lies with the quality of different sources of death data. The Vital Registration (VR) data are the primary source of death data, and it is important to note that, like most other developing countries, not all deaths are registered in South Africa. Thus, the number of registered deaths should be corrected for under-registration when estimating mortality rates. Moreover, Statistics South Africa (Stats SA) is responsible for the release

[1] Prepared by the Data and Analytics Section; Division of Data, Research and Policy, UNICEF. From the website https://data.unicef.org/topic/child-survival/under-five-mortality/.

of these data via annual cause-of-death reports. These reports were released with a time lag – two years up to 2011 but the lag was reduced after this and is currently (the 2015 report) 15 months. A two-year time lag was problematic especially during the years in which the HIV/AIDS epidemic was developing because it was difficult to monitor over time the impact of this epidemic on mortality.

The South African Medical Research Council (SAMRC) in collaboration with the University of Cape Town set up a project (the Rapid Mortality Surveillance (RMS) project) in 1999 to address the absence of VR data. This project was designed to make use of data on deaths recorded on the National Population Register (NPR) by the Department of Home Affairs, to identify and monitor the impact of HIV on mortality and to monitor the trends in mortality as timeously as possible (Dorrington, Bradshaw, Laubscher *et al.* 2016). Although nowadays the time-lag in the release of cause of death data has been reduced to just over one year, the NPR data allow one to produce estimates of mortality a few months after the end of the calendar year of death (and also provide a check on the changing completeness of reporting of the VR deaths relative to those on NPR. More recently, the RMS data, which comprises of this NPR data and VR data, have been used to produce estimates of demographic indicators, which include life expectancy, adult mortality, under-five mortality, infant mortality, neonatal mortality and maternal mortality (Dorrington, Bradshaw, Laubscher *et al.* 2016). However, to date, the estimates are confined to demographic indicators for the country as a whole.

It is important to have these up-to-date and reliable estimates of mortality for a country like South Africa, which is heavily affected by the HIV/AIDS epidemic. However, having up-to-date estimates at a sub-national level (for example at the provincial level) is much more useful for several reasons. The estimates would help with planning and management (because much budgeting and management occur at this level, and the provinces are socio-economically quite different). It is also useful demographically because the provinces are demographically different, and reliable provincial estimates may improve estimates nationally. Estimates produced at the provincial level over time provide a way of monitoring the contribution of each province towards the achievement of Sustainable Development Goals for the country.

However, few studies have attempted to estimate mortality at a sub-national level in countries where death registration is incomplete, and census data are only available every 10 years. Migration at a subnational level can be both sizeable and difficult to estimate accurately. This means that the use of Death Distribution Methods

(DDMs) to estimate completeness of death registration at a subnational level produces unreliable results.

In addition, it is much more difficult to estimate the trends in mortality over time at a provincial level. Besides AIDS population projection models, only Msemburi, Pillay-van Wyk, Dorrington *et al.* (2016) and the Institute of Health Metrics and Evaluation (IHME)[2] have attempted to estimate the trends in infant, child and adult mortality over time at a provincial level for South Africa. Moreover, HIV/AIDS population projection models require detailed time series estimates of age-specific rates to update the baseline population to the current year and to extrapolate demographic indicators into the future. Thus, to produce adequate projections at a provincial level requires estimates of these demographic indicators for each province.

Unfortunately, as Dorrington, Timæus, Moultrie *et al.* (2004) point out, surveys in South Africa interview too small a sample to produce series of estimates of child mortality, total fertility and adult mortality at a subnational level to be accurate. Thus, the objective of this research is to seek to establish whether the Rapid Mortality Surveillance system can be extended to produce estimates of infant, child, and adult mortality, as well as measures of maternal and neonatal mortality, at a provincial level in South Africa.

1.2 Research question

Is it possible to produce consistent and reliable estimates of mortality at the provincial level for South Africa using data from VR, NPR and DHIS?

1.3 Objectives

1. To assess the reasonableness of the allocation of NPR deaths according to 2011 provincial boundaries by the MRC.
2. To derive estimates of under-reporting of the NPR relative to VR for each province for each year from 2000 to 2016, and to use these estimates to produce estimates of VR deaths from NPR deaths for each province.
3. To derive estimates of completeness of VR deaths of those living in each of the provinces from 2000 to 2016 where the late registrations are yet to be included in the VR data and VR data are yet to be released by Stats SA.

[2] The Burden of Disease estimates (at least from 2015). Source: http://www.healthdata.org/south-africa

4. To use these estimates of completeness of VR deaths to adjust both numbers of VR deaths and estimates of VR deaths for under-notification (i.e. for notified deaths not on the population register) for each province for each year, and use these estimates to produce a set of provincial mortality indicators currently produced for the country as a whole (except the MMR and the NMR).
5. To derive estimates of numbers of maternal deaths from VR maternal deaths adjusted for misreporting of cause for maternal mortality for each province for each year from 2000 to 2015, and use these to produce estimates of the MMR at the provincial level.
6. To derive estimates of neonatal deaths adjusted for incompleteness of registered deaths and those recorded by the District Health Information System (DHIS) for each province for each year from 2000 to 2016, and use these to produce estimates of the NMR at the provincial level.

1.4 Structure of thesis

Chapter 2 reviews the literature relevant to this research project. It comprises of the history, methods, and results of the RMS. In addition, estimates and trends in the child mortality, adult mortality, maternal mortality and neonatal mortality for South Africa (both national and at the provincial level) are reviewed.

Chapter 3, methods, starts by evaluating the RMS data (VR and NPR data), followed by a description of how the NPR data for each province and country as a whole is adjusted for under-registration relative to the VR. The process of how the estimates of completeness of death (child and adult) registration (both national and at the provincial level) is also discussed in this chapter, together with methods of estimating maternal and neonatal mortality.

Chapter 4 presents the results and analysis obtained in this study. The final chapter, chapter 5, provides a discussion of the results before drawing conclusions from the results.

2 LITERATURE REVIEW

This chapter comprises of three sections. The first covers the history of the Rapid Mortality Surveillance (RMS) project, the method, and its results. The second covers past research on mortality on South Africa (child mortality, adult mortality, neonatal mortality and maternal mortality). The last covers levels and trend in the completeness of the National Population Register (NPR) data relative to Vital Registration (VR) data and the general completeness of death registration (both child and adult) at both the provincial and national level and the national completeness of death registration of the NPR.

2.1 History of RMS

Statistics South Africa is responsible for the release of VR statistics. Under Apartheid the Civil Registration and Vital Statistics (CRVS) suffered from the social and political system, which segregated and disadvantaged the majority of the population before the 1990s. However, it was the three major events, according to Bah (2009), which gave the promise of a complete and accurate civil registration system. These were the Births and the Deaths Registration Act of 1992, the interim constitution, which was implemented in 1993 and the agreement among the three groups (Department of Health (DoH), Department of Home Affairs (DoHA) and the National Statistics Agency (NSA)). These events spearheaded a range of initiatives including the introduction of a new death notification form (to enable local data to be in line with international standards), study visits by government officials to vital statistics offices in developed countries and the establishment of provincial task teams to enhance registration of births and deaths (Joubert, Rao, Bradshaw *et al.* 2012). Even though the VR system is still incomplete, there has been significant improvement over the years (Dorrington, Moultrie and Timæus 2004).

However, there was a significant delay in the release of annual mortality statistics. This delay was problematic particularly after the start of the HIV epidemic because an awareness of the substantial changes in the mortality due to the HIV epidemic in the population was essential.

For these reasons and to prove that people were dying of HIV/AIDS, the South African Medical Research Council (SAMRC) in collaboration with University of Cape Town (UCT) reached an agreement to access the National Population Register (NPR) data. The main purpose of negotiating access was to be able to assess mortality data rapidly to inform policy action about the changes in the mortality as evaluated by the qualified mortality researchers. They set up a project system in 1999 to capture the NPR data and to monitor, continuously, the trends in mortality. The indicators include IMR, U5MR, adult mortality ($_{45}q_{15}$), life expectancy (e_0 and e_{60}), the NMR and MMR. Currently, these indicators are produced at the national level only and the database system is updated monthly, allowing mortality to be monitored in more or less real time. Therefore, the system allows monitoring the changes in the mortality due to intervention programs such as the prevention of HIV transmission from mother to child (PMTCT) and the provision of the antiretroviral drugs.

2.2 The RMS approach

The RMS uses two main data sources to provide the mortality indicators, deaths registered on the National Population Register (NPR) and deaths from the cause of registered deaths (VR) from data released by Stats SA. VR death data consists of data from all Death Notification Forms (DNFs) completed once death occurs, sent to the DHA and then processed by Statistics South Africa.

The NPR death data consists of all deaths for which the birth has been registered or for which a national Identification Document (ID) number has been issued, and unlike VR data, which are released annually, at least a year in arrears, these data are received monthly by MRC. In other words, only registered births and people with ID numbers will be on the NPR. Therefore, the NPR can be expected to capture fewer deaths than the VR system, which processes all the DNFs. Thus, the NPR data needs to be adjusted for two forms of under registration, that to approximate VR data and then further to approximate the general under-notification of deaths.

Evaluation of NPR and VR death data from the 2015 RMS report show that the proportion of VR deaths that are registered on the NPR has increased over time. The 2015 RMS report indicates that at least 95 per cent of the registered deaths for the age group 25 and over are on the NPR, while there has been a rapid increase in the completeness of NPR relative to VR over time among young children. This ratio increased from slightly below 20 per cent in 2000 to slightly below 70 percent in 2014. These changes over time are a result of improved birth and death registration.

The 2015 RMS report shows that after 2011 the numbers of VR deaths dropped possibly because of ARVs. However, relative to those on the NPR, VR deaths dropped to a point where there were more deaths for the age group 25 and over on the NPR than in the VR and in 2013 and 2014 the trend worsened significantly. Apart from errors in reporting age and the problem of late registration, it is argued in the 2015 RMS report that this suggests that Stats SA is failing to process all the deaths that are on the NPR. The same adjustment factors used to adjust 2011 NPR death data were used to adjust the NPR death data from 2012 to 2015, for which cause-of-death data are either unreliable or have yet to be processed.

The estimates of VR deaths and the numbers of VR deaths are then adjusted for general under-registration, and used to estimate the mortality indicators in RMS reports (except NMR and MMR). In the 2015 RMS report, VR deaths are used to produce series of estimates up to 2014 and up to 2015 using NPR data.

Data from the NPR does not provide the details on the cause of death to allow estimation of maternal mortality. Thus, the HDACC recommended the use of cause of death data from Stats SA. However, Dorrington, Bradshaw, Laubscher *et al.* (2016) noted that most systems fail to identify all maternal deaths. To correct for this, registered maternal death data are scaled up by 50 per cent to allow for the problem of misclassification of the cause of death. The adjustment was considered the most suitable for countries with good VR data from the results of 22 studies estimating the degree of misclassification of maternal cause of death (World Health Organization 2010).

The recent 2015 RMS national report indicates that neonatal deaths recorded on the NPR are inadequate to produce reliable neonatal mortality. If a death notification is received before the birth has been registered, then that individual will not be added to the NPR by the DHA. Thus, the infant deaths that are registered on the NPR are affected by improvements in birth registration. Bradshaw, Groenewald, Laubscher *et al.* (2003) point out that birth and death registration has been improving in South Africa, making it difficult to estimate infant mortality and assess trends using the NPR data alone. Also, to avoid the delay in the release of the cause of death reports from Stats SA, neonatal deaths from the District Health Information System (DHIS) are used to estimate the NMR.

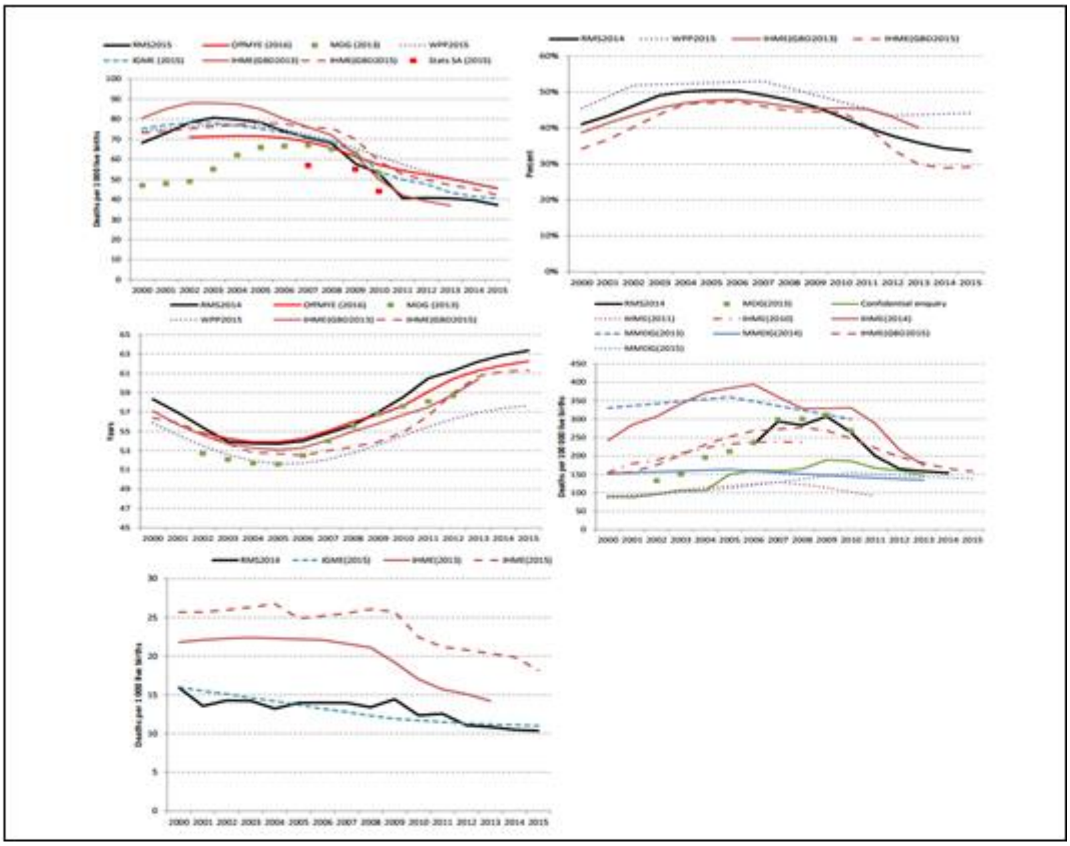
2.3 RMS results

The estimates of the indicators from the 2015 RMS report are compared to other estimates from different sources as shown in Figure **2-1** below. The top left panel shows under-five mortality rates (U5MRs) and the top right panel are adult mortality estimates ($_{45}q_{15}$), while the middle panels from left are life expectancy estimates (e_0) and maternal mortality ratios (MMRs). The last panel are neonatal mortality estimates (NMR). It can be seen that there is a great deal of uncertainty about the estimates of mortality in South Africa. However, those that are consistent with epidemiological expectations may be considered more reliable.

While the estimates from the recent report for under-five mortality show a similar trend and the estimates that are close to the estimates from the United Nations Interagency Groupon Child Mortality Estimation (2017) (IGME), they are not comparable to 2016 official mid-year estimates (OffMYEs) from Stats SA . Furthermore, there is a strong agreement between the estimates from the 2015 RMS report, the estimates from the United Nations (2015) and the IHME that from around 2003 to 2005 life expectancy reached its lowest level. For the adult mortality, estimates from the 2015 RMS report show a trend that is consistent with the United Nations (2015) estimates over the whole period 2000 to 2015.

In as far as the MMR and NMR are concerned, the 2015 RMS report shows that the MMR estimates are consistent only with estimates from the Stats SA Millennium Development goals (MDGs) 2013 report because they both used the same method and the same data for the estimates and the NMR estimates are only close to the United Nations Interagency Groupon Child Mortality Estimation (2017) estimates (smoothed version of RMS rates). However, the 2015 RMS national report indicates that the MMR and NMR estimates are subject to a great deal of uncertainty. Nevertheless these estimates from the 2015 RMS report clearly show the HIV/AIDS impact on the maternal mortality from 2004 to 2009 compared to those from other sources and so, in the 2015 RMS report, the estimates were deemed to be at least as reliable as the other estimates.

Figure 2-1 Comparison of RMS estimates with estimates from other sources



Dorrington, Bradshaw, Laubscher *et al.* (2016). Figures` 21 to 25; page 18-21.

2.4 Overview of trends in South African mortality

Several studies have attempted to estimate child mortality for South Africa but the degree of uncertainty around the estimates is high. Possible reasons for this include the lack of complete VR data and the approaches for approximating child mortality using surveys and censuses are biased in populations experiencing an HIV epidemic because such methods under-estimate child mortality due to the correlation between mortality for the mothers and mortality of the young children due to the HIV. Nannan, Dorrington, Laubscher *et al.* (2012) reviewed different sources of data on the level and causes of child mortality and indicated that the reason for the problem lies in the quality of the data. They mentioned that the total numbers of children borne by mothers surviving, a variable which is very important for estimating child mortality using indirect techniques, is poorly reported in censuses. Dorrington, Timæus, Moultrie *et al.* (2004) pointed out that the total number of the children ever-born was underreported in 2001 census. Thus, they argued that child mortality estimates derived from this census could not be trusted. In addition to the deficiencies and unavailability of data, one of the central problems is that despite using the same data estimates of different demographers differ because of misapplication of methods of demographic estimation (Zewdie 2014). In addition, there is a shortage of resources such as funding and competent demographers with sufficient critical skills to appraise the work of their peers, especially those responsible for the production of official statistics and census results in Africa (Ntozi 2011).

2.4.1 IMR

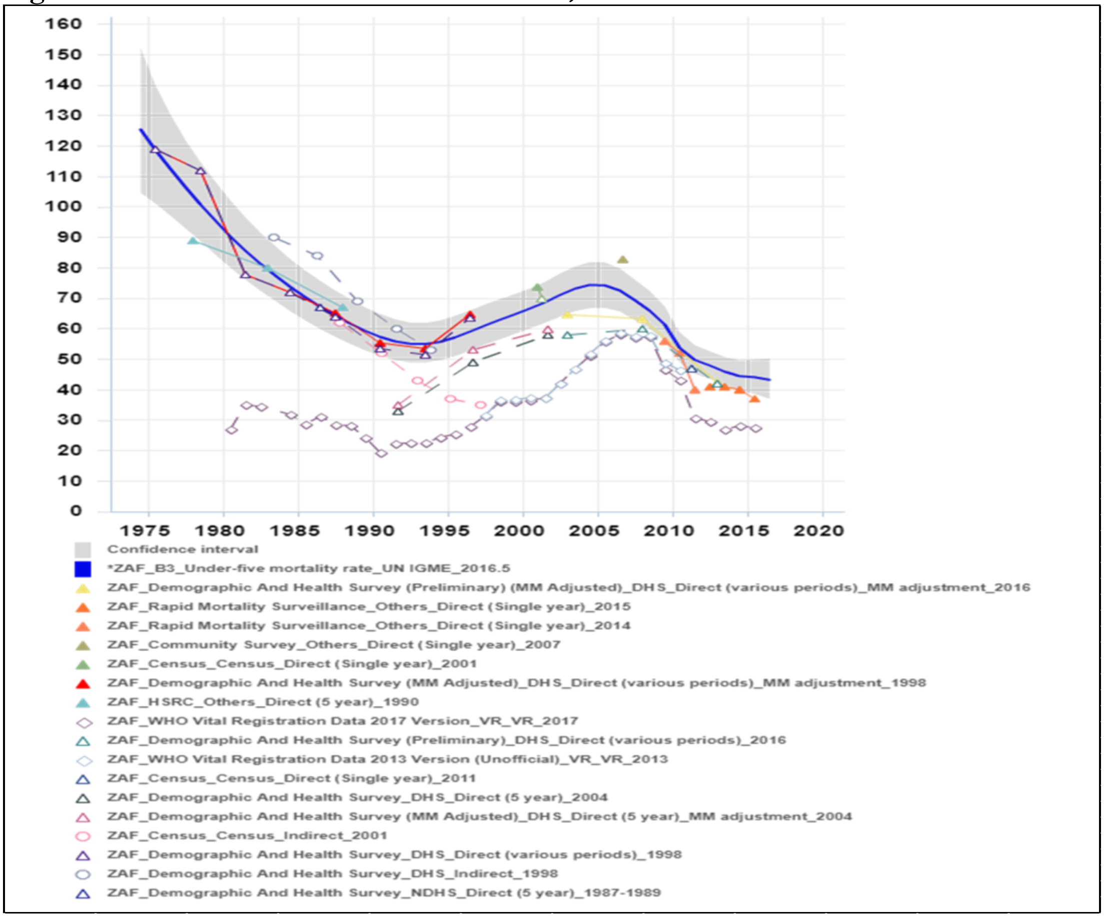
Infant mortality is still high in South Africa, and there is a marked geographical difference in infant mortality risks between provinces and within provinces (Sartorius, Sartorius, Chirwa *et al.* 2011b). Antenatal HIV prevalence, previous sibling mortality and being male were found to be more associated with higher infant mortality risks.

However, after the introduction of antiretroviral treatment, infant mortality has been declining and according to the South African Intitute of Race Relations (2018) report, it has now reached its lowest level in 15 years as the IMR fell from 48.1 deaths per 1000 live-births by 32 per cent between 2002 and 2017. The reason could be that the National Department of Health intensified awareness campaigns to persuade more women to visit health care practitioners for regular checks up before and after giving birth, and thus, antenatal visits since 2006 increased by 96 per cent (South African Intitute of Race Relations 2018).

2.4.2 U5MR

One of the attempts to estimate child mortality for South Africa are those produced by the United Nations Interagency Groupon Child Mortality Estimation (2017). They compile country data to derive mortality trends using the VR, DHS, census and other surveys for the countries. The trends of the U5MR estimates for South Africa are shown in Figure 2-2 below.

Figure 2-2 Trends in U5MR for South Africa, 1975-2015



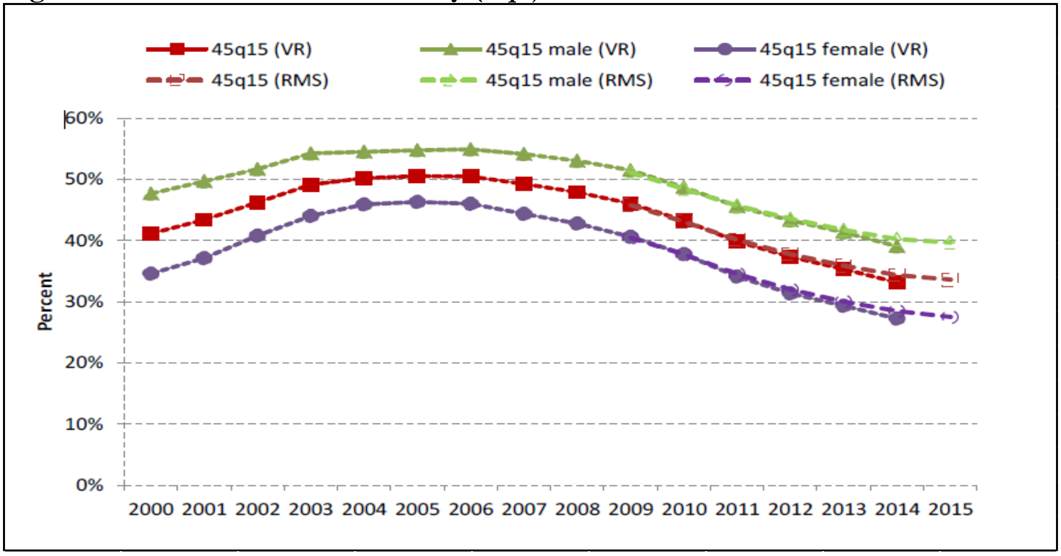
Source: UN IGME, 2017 website page
(http://www.childmortality.org/index.php?r=site/graph#ID=ZAF_South Africa).

It can be seen that U5MR has been declining especially over recent periods but the estimates from different sources show significant differences. This is an indication of the poor quality of the data and possibly misapplication of indirect techniques for demographic estimation for the country. Regardless of the reason for the differences, the general trend is that the under-five mortality declined rapidly over the period 1975 to 1990, and then reversed over the period 1995 to 2005 before reverting to a downward trend.

2.4.3 Adult mortality

A similar trend in adult mortality to that of child mortality for South Africa can be seen from the national estimates produced in the 2015 RMS report (Dorrington, Bradshaw, Laubscher *et al.* 2016). Figure 2-3 shows these estimates of adult mortality over the period 2000 to 2015. It can be seen that the adult mortality has been declining since 2007 for both sexes. The decline is mainly due to the extensive rollout of ARVs. Johnson (2012) concludes that though men and children seem to be accessing ARVs at a lower rate than women are, the number of patients on ART increased rapidly in South Africa in the period 2004 to 2011.

Figure 2-3 Trends in adult mortality ($_{45}q_{15}$) for South Africa



Source: Dorrington, Bradshaw, Laubscher *et al.* (2016) ; Figure 12; Page 12.

2.4.4 Overview and trends in maternal mortality in South Africa

There are challenges in monitoring the maternal mortality in poor countries where VR systems are generally incomplete and the cause of death data are inaccurate (Merdad, Hill and Graham 2013). Several methods have been developed to estimate maternal mortality. These include surveys with the direct death inquiry, reproductive age mortality surveys, and sisterhood methods (direct and indirect). However, these methods are not suitable for measuring maternal mortality at the subnational level (Ahmed and Hill 2011). Thus, some experts like Wardlaw and Maine (1999) recommend the use of the ratios of births attended by proficient providers as measures for the MMR. Graham, Ahmed, Stanton *et al.* (2008) used data from reproductive age mortality surveys to estimate maternal mortality at the subnational level. However, adopting this approach to developing countries is very expensive. Ahmed and Hill (2011) used an empirical Bayesian prediction method to estimate the subnational MMRs. Although the results offer an outline of the distribution of MMR across all subnational areas, they do not show a precise estimate for each subnational area.

Udjo and Lalthapersad-Pillay (2014) estimate the MMRs for South Africa at the national and sub-national level. They argued that since the hospital-based DHIS data varies in terms of completeness or coverage from one province to another they cannot be used to generate estimates of MMR at the national and subnational level. Therefore, they used data from the 2001 census and the 2007 Community Survey. The Brass Growth Balance (BGB) method was used to adjust the reported deaths at the national and provincial level. The Relational Gompertz model by Brass (1981) was used to adjust the reported number of live-births. However, they do not say how they dealt with the migration assumption at the provincial level. Hence, it appears they effectively assume that provincial populations were stable and closed to migration.

Nonetheless, results show that the maternal mortality increased between 2001 and 2007 in South Africa. For all the provinces except WC, results show that maternal mortality increased between 2001 and 2007. Comparing across all the provinces, maternal mortality was highest in FS (619 deaths per 1000 live-births) in 2001 but shifted to EC (1,639 deaths per 1000 live-births) in 2007. The WC is the only province that experienced a decline in maternal mortality and it had the lowest levels in both 2001 and 2007.

The researchers went further and analyzed the relationship between HIV/AIDS and maternal mortality in South Africa. If AIDS was responsible for the increase in the maternal mortality for the period 2001 to 2007 then there should be a correlation between the provincial distribution of HIV prevalence and the provincial distribution of the maternal mortality. A weak correlation (11 per cent) was found between HIV prevalence levels and maternal mortality. Thus, unlike Graham, Ahmed, Stanton *et al.* (2008) who argued that the increase in maternal mortality in South Africa between 1990 and 2007 was due to the HIV/AIDS, Udjo and Lalthapersad-Pillay (2014) concluded that much of the increase in the maternal mortality was due to other maternal conditions including parasitic diseases. However, considering the data sources used by Udjo and Lalthapersad-Pillay (2014), the misapplication of methods and that no effort was made to adjust reported maternal deaths for under-reporting, it is more likely that they arrived at wrong conclusions about the effect of HIV on maternal mortality.

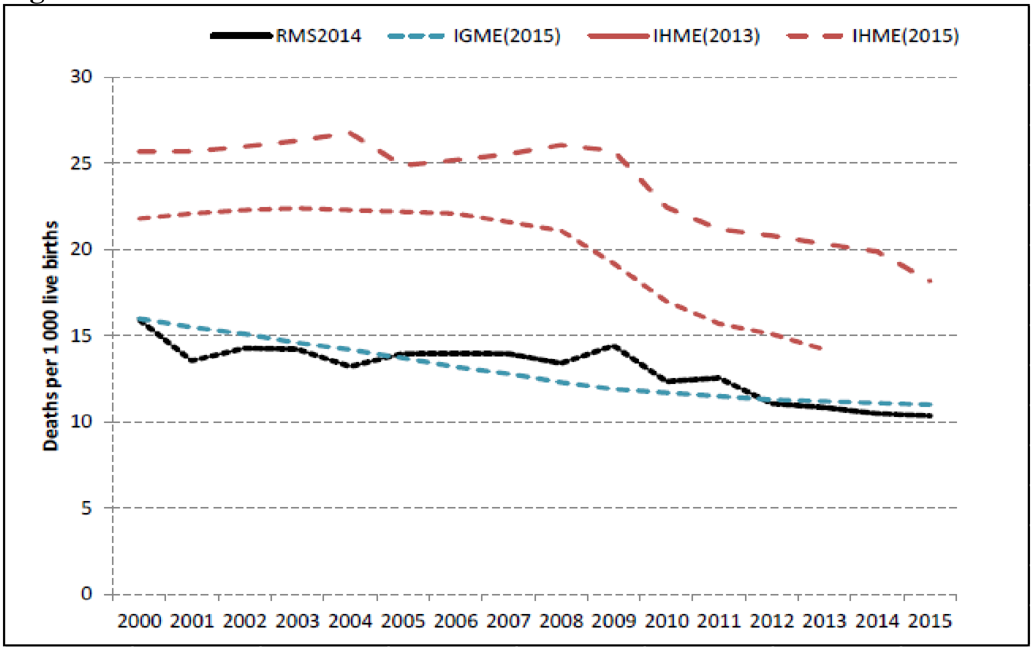
Garenne, McCaa and Nacro (2008) estimated the MMR using the 2001 census data (the number of maternal deaths and live-births in the past 12 months). The number of live-births was computed as the number of infants surviving at the time of the census back-projected to birth. The results obtained indicated a much higher level of MMR for South Africa of 542 per hundred thousand live-births, despite a relatively low proportion of maternal deaths (6.4 per cent) among deaths of women aged 15-49 years. This they attribute to the high levels of adult mortality, which was 4.7 times higher than they expected. Using the 2007 Community Survey, the MMR was estimated to have increased by more than 30 per cent given a major increase in adult mortality over this period because of HIV/AIDS (Garenne, McCaa and Nacro 2011). Similarly, results obtained by Dorrington and Bradshaw (2011) after examining MMR for South Africa shows that though it is difficult to estimate MMR more accurately given the known problems with the data, there was an upward trend in MMR over the period 2001 to 2007. Furthermore, estimates from Stats SA 2017 cause of death report show that over the period 1998 to 2009, there was a significant increase in MMR in South Africa but since 2010, MMR declined significantly to 141 deaths per hundred thousand live-births in 2013.

2.4.5 Overview and trends in neonatal mortality for South Africa

In South Africa, the major source of information about deaths that occurred in both the public and private health sectors within the first 28 days of life, required for estimating neonatal mortality, include the VR data, District Health Information System (DHIS), Perinatal Problem Identification Programme (PPIP) and the Demographic Health Survey (DHS) (Velaphi and Rhoda 2012). The DHS has been conducted only in 1998, 2003 and 2016.

The recent national 2015 RMS report estimated neonatal mortality from the VR and DHIS data for the periods 2006 to 2014 and 2011 to 2015 respectively. DHIS data from the public sector health facilities tend to focus on the early neonatal period (the first seven days of life) but now focus on the whole neonatal period (the first 28 days of life). The VR deaths were adjusted for the under-registration while the DHIS data were adjusted for under-coverage, relative to the VR and for the general incompleteness of the VR. Figure 2-4 shows these estimates of neonatal mortality obtained for the period 2000 to 2014 in comparison with other estimates. While for recent years the estimates show a decline in the NMR, estimates from different sources are quite different. Estimates from the IHME (2017) show that there was no reduction in the NMR from 2001 to 2008. Velaphi and Rhoda (2012) also indicated that in 2009, NMR was high and more than the baseline in 1990. However, Dorrington, Bradshaw, Laubscher *et al.* (2016) argue that while it is difficult to conclude that neonatal mortality is as low as the level estimated by the recent 2015 RMS report, the estimates from the IHME (2017), which differ significantly from the RMS estimates, are not reliable because they imply improbably high completeness of reporting of post-neonatal deaths. The general trend shown by the RMS estimates, which are similar to those from IGME (2017), is that neonatal mortality has been declining gradually from being slightly above 15 deaths per thousand live-births in 2000 to slightly above 10 deaths per thousand live-births in 2014.

Figure 2-4 Trends in NMR for South Africa



Source: Dorrington, Bradshaw, Laubscher *et al.* (2016); Figure 25; Page 21

2.5 Differentials and trends in provincial child and adult mortality for South Africa

There are nine provinces in South Africa namely Western Cape (WC), Eastern Cape (EC), Free State (FS), Northern Cape (NC), KwaZulu-Natal (KZN), North West (NW), Gauteng (GP), Mpumalanga (MP) and Limpopo (LP). There is a large geographical difference in both child and adult mortality in South Africa (Dorrington, Timæus, Moultrie *et al.* 2004).

2.5.1 IMR and U5MR

Two studies that have attempted to estimate infant and child mortality at the provincial level in South Africa are Sartorius, Sartorius, Chirwa *et al.* (2011a), and Zewdie (2014) who estimated child mortality at the provincial level and for the municipalities of South Africa and evaluated the relationship to the level of poverty and equality. The results show that there is a significant difference in infant and child mortality between the provinces and within the provinces. Factors such as HIV prevalence were found to have a substantial effect on child mortality. In addition to the effects of HIV on mortality, provinces with high proportions of poor people (e.g. less than R515 monthly income per capita) were found to have high levels of child mortality. However, there were some exceptions, for example, some municipalities in LM had low levels of child mortality despite high levels of poverty, possibly because of better health services. Moreover, differential composition of provincial population contribute to the differences in provincial mortality because the level of mortality in South Africa is different for different population groups (Bradshaw, Nannan, Laubscher *et al.* 2006; Nannan, Timæus, Laubscher *et al.* 2007; Pillay-van Wyk, Laubscher, Msemburi *et al.* 2016).

Dorrington, Timæus, Moultrie *et al.* (2004) estimate provincial mortality and fertility in South Africa using 1996 census data and indirect estimation techniques to estimates fertility, child mortality and adult mortality. On child mortality, they used the children ever-born and children surviving method originally proposed by Brass (1981). However, the method relies on the strong assumption of the independence between the child's mortality and the mother's age. However, since the start of the HIV epidemic in the early 1990s, this assumption has been violated. In addition, Dorrington, Timæus, Moultrie *et al.* (2004) compared indirect estimates from the 1998 Demographic Health Survey (DHS) against estimates calculated directly from the same data and found that there was a substantial difference in these estimates (indirect estimates were substantially higher than the direct estimates). This, in turn, means that using the census data and the CEB/CS technique over-estimated the U5MR, possibly because of errors in the reporting of the dates of birth and death and the long birth intervals that characterize the population. Although Dorrington, Timæus, Moultrie *et al.* (2004) tried to solve this problem by reducing the U5MR at the provincial level by 16 per cent, the adjustment shouldn't be the same across the provinces. Thus, such provincial estimates are unreliable.

Nonetheless, provinces known to have high HIV prevalence like KZN, MP, FS, and EC were found to have the highest child mortality levels compared to other provinces with lower HIV prevalence like WC. Child mortality has been falling more rapidly over the period 1986 to 1996 in the higher mortality provinces like EC and KZN compared to other richer provinces like WC and GP[3].

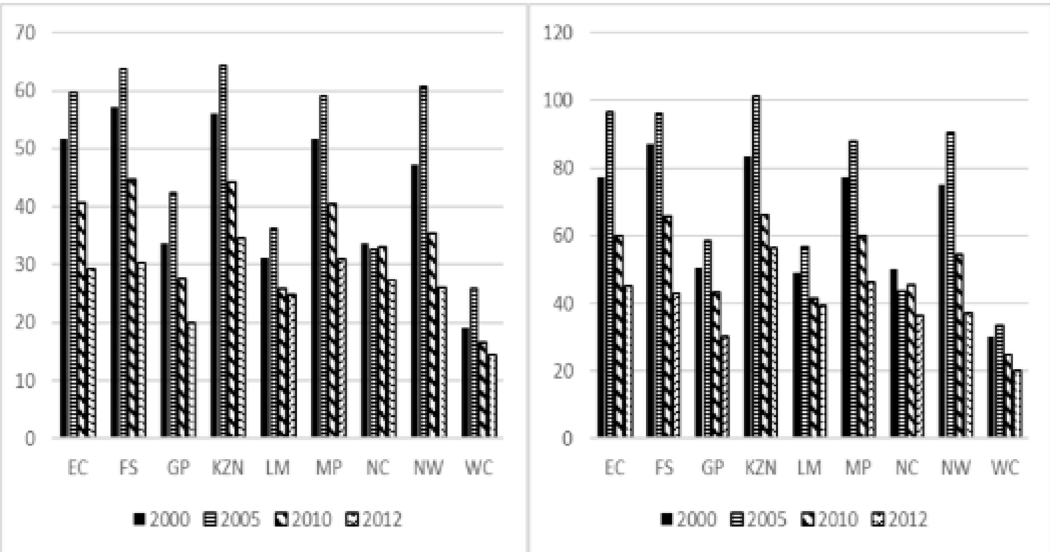
The second National Burden of Disease study (NBD) by Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016) derived estimates of IMR, U5MR and adult mortality adjusted for under-registration VR data. They first produced estimates of IMR and U5MR for the years 1996, 2001, 2006 and 2011. The estimates for 1996 for each

[3] In 2012, the prevalence levels for KZN, EC, MP, FS, NW, GP, LP, NC and WC were 16.9per cent, 11.6per cent, 14.1per cent, 14.0per cent, 13.3per cent, 12.4per cent, 9.2per cent, 7.4per cent and 5per cent respectively. Estimates from http://www.hsrc.ac.za/uploads/pageContent/4565/SABSSMper cent20IVper cent20LEOper cent20final.pdf

province were those from ASSA2008 while for 2001 the estimates are those from Dorrington, Moultrie and Timæus (2004). Those for 2006 and 2011 were derived by correcting the Ward and Zaba's variant of the CEB/CS method of estimating child mortality for stable HIV prevalence in a manner proposed by Darikwa (2009), assuming that 25 per cent of the deaths with unspecified age in 2011 census were adult deaths. (Ward and Zaba 2008). In addition, the numbers of births were estimated by projecting backward the population numbers counted in the 2011 census using survival factors from the ASSA2008 lite projection model. These estimates of child mortality were used to derive estimates of completeness to adjust VR death data and derive the estimates of IMR and U5MR shown in Figure 2-5.

It can be seen that both the IMRs and U5MRs show the same trend over time for all the provinces. That is, both the IMR and U5MR increased between 2000 and 2005 and in more recent years the rates have declined. All the rates for the provinces peaked between the period 2005 and 2010 and this pattern is driven by the changes in HIV/AIDS. These estimates at the provincial level are used to derive the estimates of completeness of child death registration in section 3.3.2

Figure 2-5 Trends in provincial IMR and U5MR



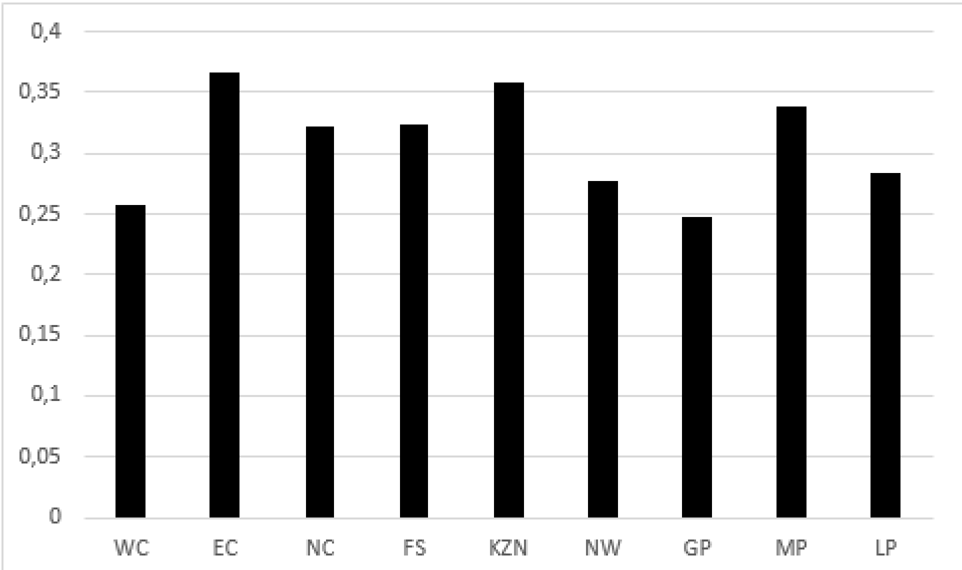
Source: Prepared using estimates derived by Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016) for each province from the MRC website.

2.5.2 Adult mortality

For the adult mortality rate, Dorrington, Timæus, Moultrie *et al.* (2004) used the VR data. The estimates of completeness of adult death registration for each province was derived from the completeness of registration of child deaths on the assumption that the completeness of the adult death registration is linearly related to the completeness of registration of child deaths. The completeness of the registration of child deaths was estimated using the recorded deaths and the expected deaths from the CEB/CS technique. Although the various constraints were placed to prevent the linearity assumption from producing the implausible results, the method used implausible results from the CEB/CS technique.

The results for adult mortality for each province in 1996 are shown in Figure 2-6 below. As with child mortality, poor provinces and provinces with the highest HIV prevalence levels were observed to have the highest adult mortality compared to other richer, provinces, and provinces with the lower levels of HIV prevalence.

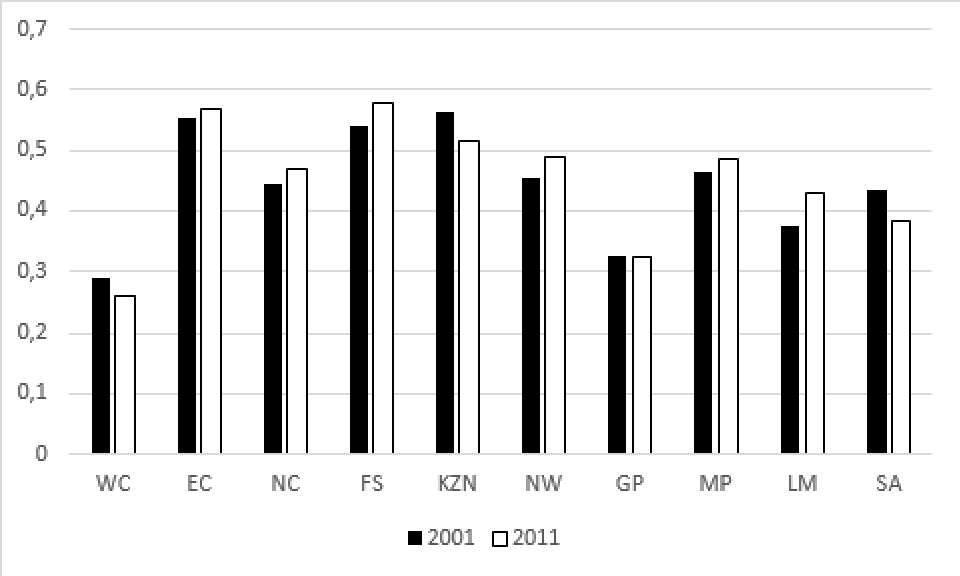
Figure 2-6 Adult mortality for South Africa at the provincial level, 1996



Source: Prepared using estimates produced by Dorrington, Timæus, Moultrie *et al.* (2004) (average of male and female estimates for each province); Tables 11 and 12; page 56 and 57.

Regardless of the fact that it is difficult to estimate mortality at the subnational level in developing countries, Dorrington and Timæus (2017) proposed a method that makes use of the strength of VR data and census data to produce reliable mortality estimates at a subnational level. They estimated adult mortality from deaths reported by households in the 2001 and 2011 censuses corrected for under/over-reporting. The correction factors (estimates for under/over-reporting) were estimated for each age, sex and population group were derived as the ratio of reported household deaths at the national level (by age, sex, and population group) to the numbers of VR deaths corrected for under-registration on the assumption that all the under-registration in VR was limited to rural areas (which was taken to be represented by the African population group). These estimates of adult mortality are shown in Figure 2-7. It can be seen that, probably due to the roll-out of ARVs, adult mortality in 2011 has dropped to the levels of 2001. These estimates at the provincial level are used in section 3.3.4 to derive estimates of completeness of adult death registration.

Figure 2-7 Provincial adult mortality for South Africa

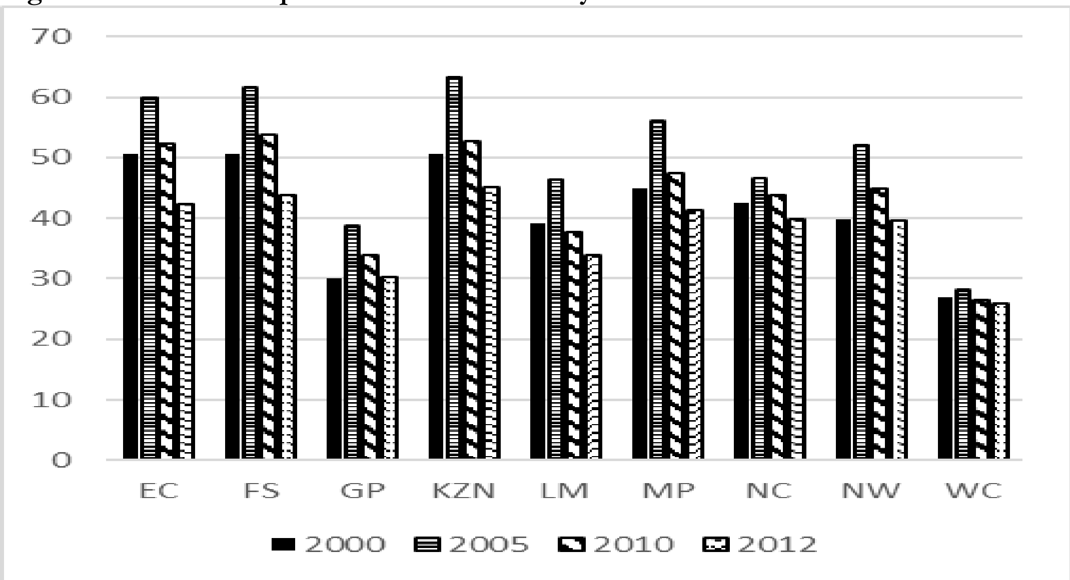


Estimates of adult mortality from the NBD were derived from VR deaths adjusted for the incompleteness of death registration for each province. The estimates of completeness at the provincial level were derived as the ratio of unadjusted mortality rates from VR deaths and the mid-year population derived by Dorrington (2013) to the adjusted mortality rates from the ASSA2008 provincial model. These adjusted mortality rates were derived as ASSA2008 provincial estimates scaled up and down such that the sum of the squared differences of the estimates derived from deaths corrected for under/over reporting by households in the censuses (2001 and 2011) and those of the 2007 Community Survey were minimised. The correction factors were estimated using the approach proposed by Dorrington and Timæus (2017).

The results derived are shown in Figure 2-8. The trend in adult mortality is the same trend as child mortality for all the provinces. That is, adult mortality increased from 2000, peaked around 2005 and then declined thereafter. The increase was more rapid for the high mortality provinces than the lower mortality provinces. The poor and high HIV prevalence-level provinces such as KZN and EC had higher levels of adult mortality compared to other lower HIV prevalence and richer provinces. However, there is a great deal of uncertainty around the estimates of adult mortality from the

NBD. The mortality estimates were derived before the release of registered VR deaths for the year 2011 and the release of the corrected data on deaths reported by households in the 2011 census (Pillay-van Wyk, Laubscher, Msemburi *et al.* 2016) . In addition, there was evidence of data capturing problems in the numbers of deaths reported by households in the 2011 census, as 25 per cent of the death data had missing age and sex. This was subsequently corrected by Stats SA.

Figure 2-8 Trends in provincial adult mortality

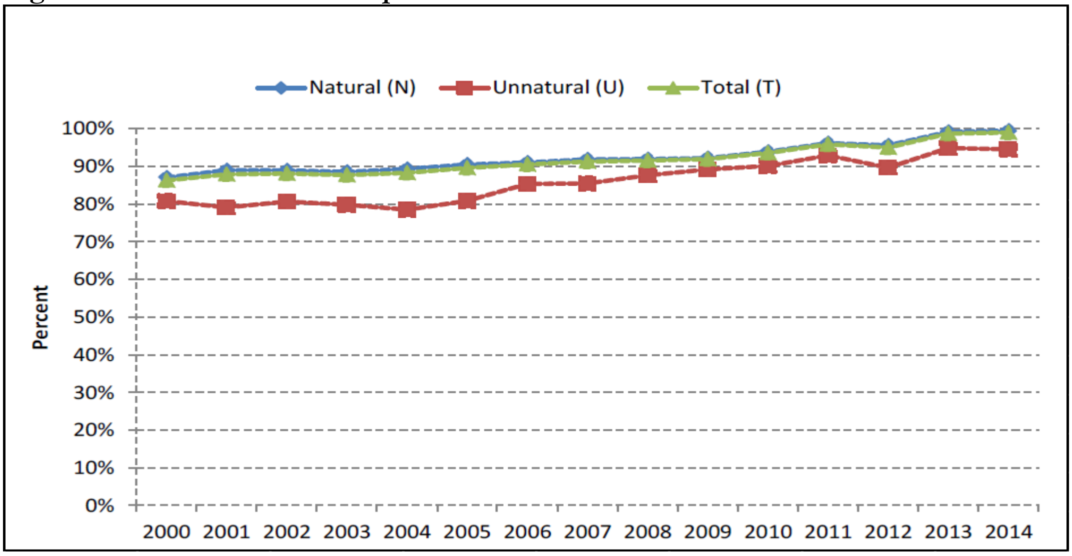


Source: Prepared using estimates obtained by Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016)for each province from the MRC website under the section burden of disease.

2.6 Completeness of NPR data relative to VR data

Trends in the completeness of the NPR relative to the VR derived from the RMS shows that there has been an improvement in birth or ID registration and hence a reduction of under-recording of deaths on the NPR relative to the VR (Dorrington, Bradshaw, Laubscher *et al.* 2016). Figure 2-9, from the most recent 2015 RMS report, shows the proportions of the VR deaths that are in the NPR in total, and by natural and unnatural causes of death. There was an increase in the ratios of the total NPR deaths that are in the VR from slightly below 90 per cent in 2000 to above 95 per cent in 2014.

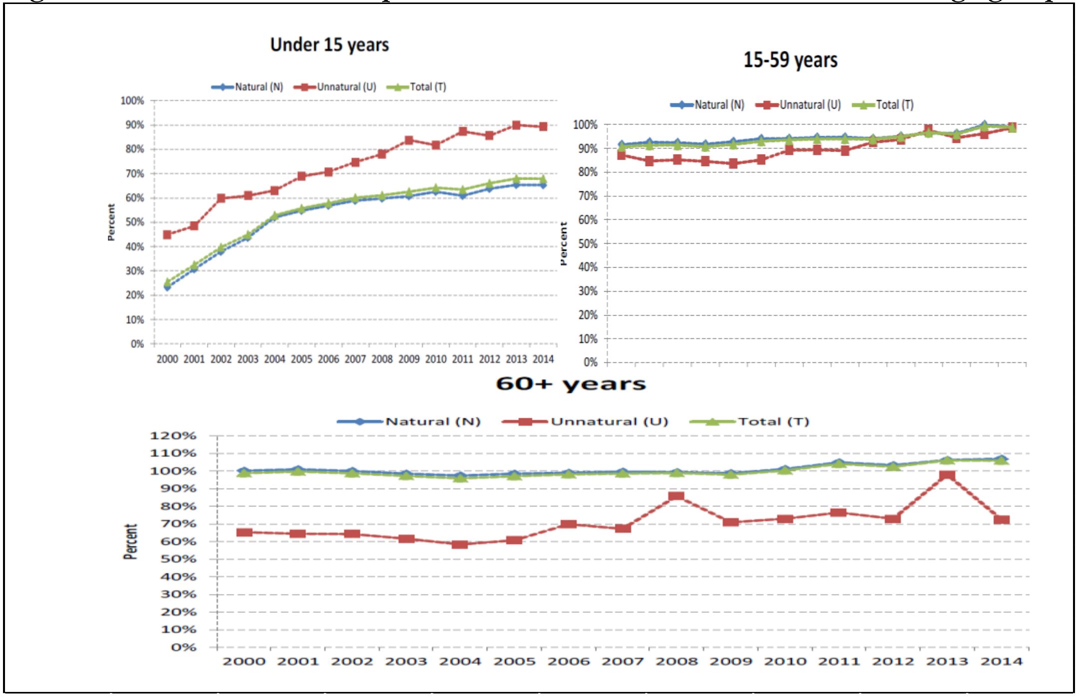
Figure 2-9 Trends in the completeness of NPR deaths relative to VR



Source: Dorrington, Bradshaw, Laubscher *et al.* (2016); Figure 3; Page 5.

Comparison of the completeness of the NPR at different ages shows that the completeness is higher in the adult ages than the young ages (Figure 2-10). For the period from 2000 to 2014, almost all deaths that are recorded in the NPR are in the VR for those aged 60 and above compared to those that are aged 15 and below where the proportion increased from slightly above 20 per cent in 2000 to slightly below 70 per cent in 2014. For the young ages, the recent 2015 RMS report argues that many deaths under the age of one occur before the birth has been registered. Thus, even though the death notification form may have been completed the death and birth are not registered in the NPR.

Figure 2-10 Trends in the completeness of NPR relative to VR for different age groups



Source: Dorrington, Bradshaw, Laubscher *et al.* (2016); Figure 4; Page 7.

Moreover, since 2011 it appears that NPR has captured more deaths than the VR for those aged 60 and above. However, it is not possible for a death to be in the NPR before being notified first. Thus, Dorrington, Bradshaw, Laubscher *et al.* (2016) argue that while some differences might be due to the efforts by the Stats SA to accelerate the issue of the cause of deaths statistics, Stats SA might not be processing all deaths that are in the NPR and hence that one shouldn't rely on mortality estimates derived from the VR data in more recent years.

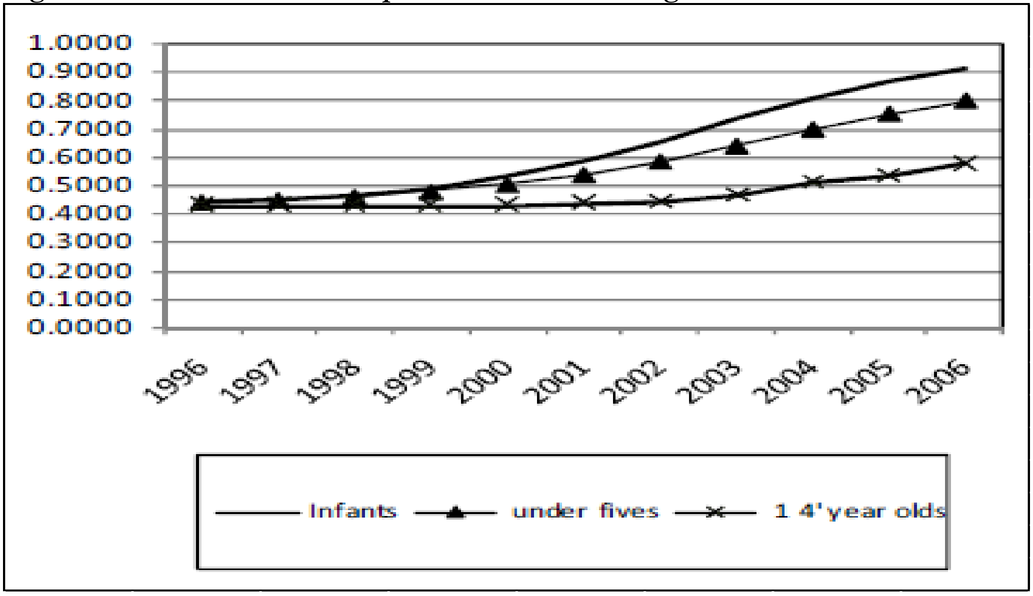
2.7 Overview of levels and trends in the completeness of death registration in South Africa

2.7.1 Completeness of registration of deaths of children

Past research shows that there have been some improvement in the registration of childhood deaths in South Africa (Anderson and Phillips 2006; Dorrington, Bradshaw, Laubscher *et al.* 2016; Dorrington, Moultrie and Timæus 2004). However, the completeness of child death registration is lower than the completeness of the adult death registration.

Darikwa and Dorrington (2011) compared direct and indirect estimates of the child mortality rate and the corresponding indirect estimates to estimate the completeness of childhood death registration. The results from 1996 to 2006 for infants, 1 to 4-year olds and under-five completeness of the death registration is shown in Figure 2-11 below.

Figure 2-11 Trends in the completes of child death registration for South Africa



Source: Darikwa and Dorrington (2011); Figure 1; Page 168.

For all the categories, the completeness of death registration has been increasing over time. Much of this increase can be observed for the period 2000 to 2005.

2.7.2 Adult completeness

Estimates of national completeness of death registration for South Africa were not available before the 1980s (Dorrington 1989). However, since then several researchers have attempted to evaluate the completeness of death registration in both the VR system and reporting of deaths in censuses and surveys (Dorrington 1989; Dorrington, Bourne, Bradshaw *et al.* 2001; Dorrington and Bradshaw 2011).

Dorrington, Bourne, Bradshaw *et al.* (2001) consolidated fragmented data sources, considered the heterogeneity of the population age structures of all the population groups, distortions to the data by the HIV and administrative problems of data to estimate the national completeness of the death registration from 1994 to mid-2000. The Synthetic Extinct Generations (SEG) method by Bennett and Horiuchi (1984) was applied to death data from the VR system, the population estimates from the Actuarial Society of South Africa (1998) population projection model (ASSA600) showing some improvements in the national completeness of registration of the adult deaths. Although the estimates for 1997/1998 to 1999/2000 were marked provisional estimates because this was before the release of the 2001 census, an increase from 73 per cent in 1994 to 89 per cent in 1999/2000 in the completeness of the adult death registration (15+) was derived.

The census conducted in 2001 allowed Dorrington, Moultrie and Timæus (2004) to use the 1996 census count and numbers of deaths estimated from the VR and apply the Generalised Growth Balance (GGB) (Hill 1987) method with an adaptation to account for migration to derive the estimates of completeness for the country as a whole. For the period 1996-2001, the national estimates of completeness were found to be 83.4 per cent for males and 84.5 per cent for females. However, in 2004, Anderson and Phillips (2006) suggested that the completeness of death registration for male adults was 80 per cent, 83 per cent for female adults, 102 per cent for the females aged 65 and above and 90 per cent for the males aged 65 and above. But these higher estimates of completeness especially for females aged 65 and over are a result of age exaggeration at older ages and undercounts in the censuses (Zinyakatira 2007).

Furthermore, Dorrington and Bradshaw (2011) applied the GGB method to data from the 2007 Community Survey, the 2001 census and deaths from the VR to estimate national female completeness. The completeness of death registration at the national level for females was found to have increased to 91 per cent for the period 2001 to 2007. Stats SA also applied the GGB method using the VR deaths, and Stats SA official mid-year estimates and estimated the overall completeness for the period 2011 to 2016 of male adult death registration to have increased to 97 per cent and for females to have increased to 95 per cent. Furthermore, the Global Burden of Disease study 2010 estimated the national completeness of adult death registration since 2000 at 95 per cent (Wang, Dwyer-Lindgren, Lofgren *et al.* 2013). All these studies suggest that completeness of adult death registration in South Africa has been improving and in more recent years it is now more than 90 per cent.

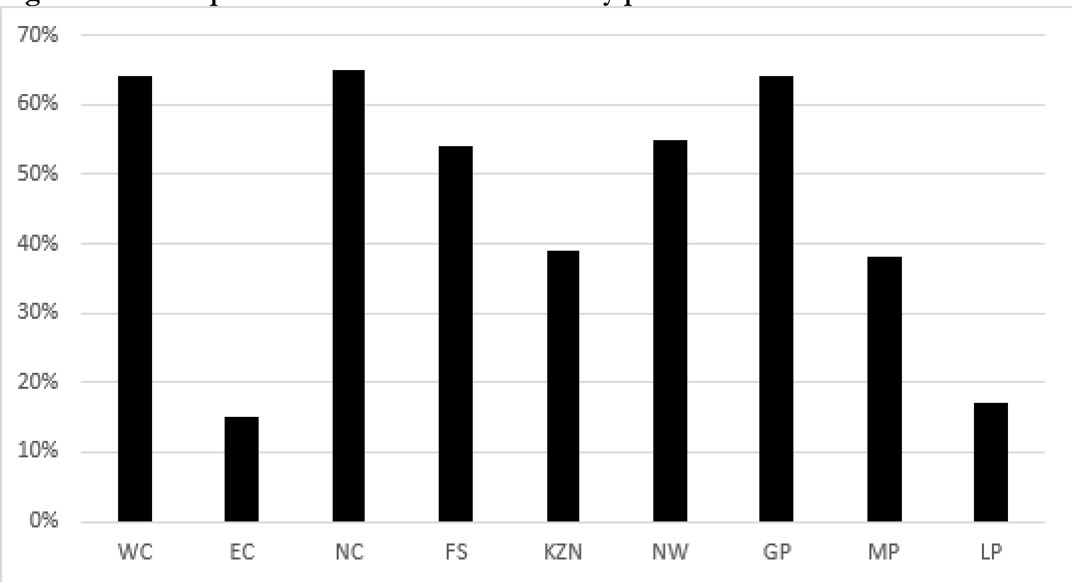
2.8 Differentials and trends in the completeness of death registration at provincial level

Estimating mortality at the provincial level using death data from the incomplete VR system requires death data to be adjusted for under-registration. But the application of indirect methods for estimating the completeness of adult deaths at the provincial level is hindered by the unavailability of consistent estimates of migration at the provincial level (Dorrington, Timæus, Moultrie *et al.* 2004).

Dorrington, Timæus, Moultrie *et al.* (2004) estimated the completeness of adult death registration in the provinces using completeness of child death registration.

Completeness of the child death registration for each province in 1996 was estimated by dividing the recorded child deaths in 1996 by the expected child deaths in 1996 for each province obtained using the CEB/CS data from the 1996 census corrected using the data from the 1998 DHS data. Then, they assumed that the completeness of registration of adult deaths was a linear function of that of the child deaths. The results obtained for the completeness of the under-five deaths in 1996 are shown in Figure 2-12 below.

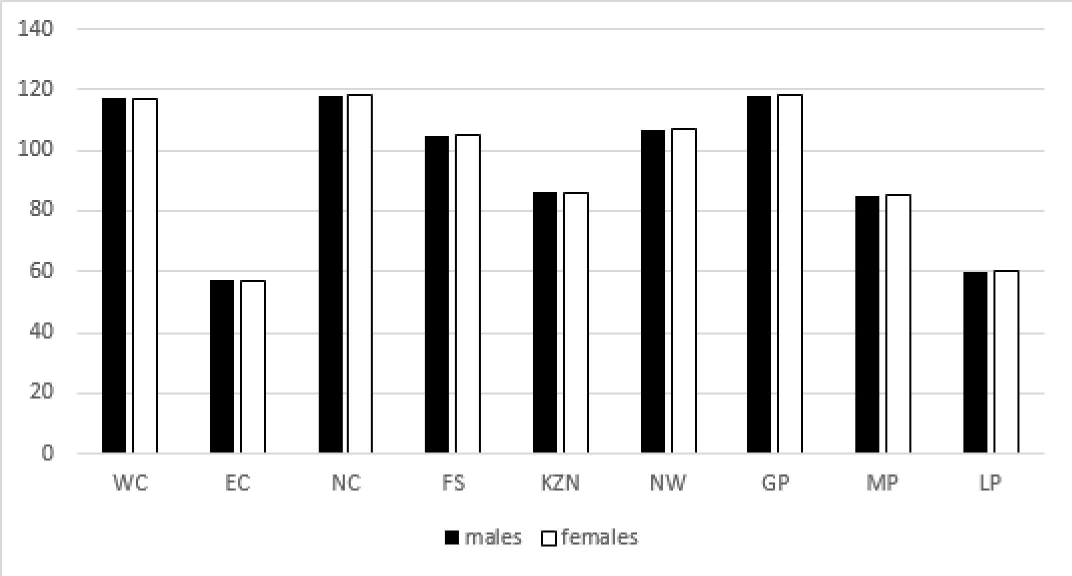
Figure 2-12 Completeness of under-five deaths by province in South Africa



Source: Prepared using estimates obtained by Dorrington, Timæus, Moultrie *et al.* (2004); Table 2; Page 37.

As expected, low levels of child death registration were observed in poor provinces like EC and LP while high levels were observed in richer provinces that are associated with in-migration like WC and GP. Corresponding completeness of the death registration for the adults for each province are presented in Figure 2-13 below.

Figure 2-13 Completeness of adult death registration by province



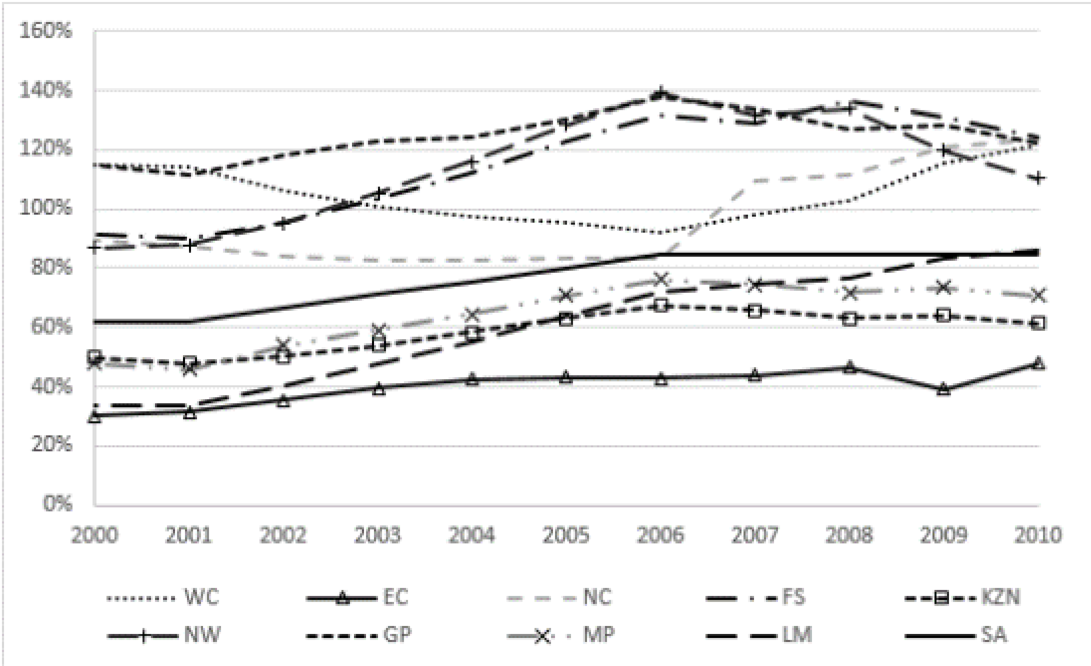
Source: Prepared using the estimates obtained by Dorrington, Timæus, Moultrie *et al.* (2004); Table 2; Page 41.

Like child death registration, economically better off or more urban provinces like WC and GP show high levels of completeness of death registration while poor or more rural provinces like EC, MP, and LP show low levels. However, Dorrington, Timæus, Moultrie *et al.* (2004) argue that while high levels of completeness in WC and GP were perhaps also due to the fact that some people die in provinces other than where they normally live, high levels in provinces like FS and NW are probably the result of incompleteness of census coverage in relation to the death registration in these provinces.

Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016) estimated the completeness of death registration for children and adults for the period 1997-2010 at the provincial level. To estimate the completeness of reporting of the childhood (infant and the under-five), reported deaths and expected deaths in 1996, 2001, 2006 and 2011 were used for each province. The expected deaths were derived by multiplying the number of births in the year by estimates of the true IMR and U5MR derived using the method described by Dorrington, Timæus, Moultrie *et al.* (2004) for 2001 estimates, the method described by Darikwa (2009) for 2006 estimates and reported deaths by households in the 2011 census for the 2011 estimates from Stats SA. For the 2011 census, deaths with unspecified ages were assumed to be adult deaths and allocated proportionally across adult ages.

The estimates of completeness for 1997were derived by linear interpolating the estimates for two-time points (1996 and 2001) and 2010 using the estimates for 2006 and 2011. Estimates of completeness in 1998 for each province were then estimated by increasing estimates of completeness in 1997 by the ratio of registered deaths in 1998 to those in 1997 assuming the increase in the numbers of registered deaths was due to an increase in the completeness of death registration over the period 1997 to 1998. For other years, estimates of completeness were derived by linear interpolation. The results obtained for the period 1997 to 2010 for death registration of the infants for each province are shown in Figure 2-14. It can be seen that for most provinces the completeness was largely constant from 1998 to 2001, thereafter, completeness increased up to 2006 and levelled off after that. Furthermore, poorer provinces had lower completeness of death registration compared to wealthier provinces.

Figure 2-14 Trends in the completeness of infant deaths registration

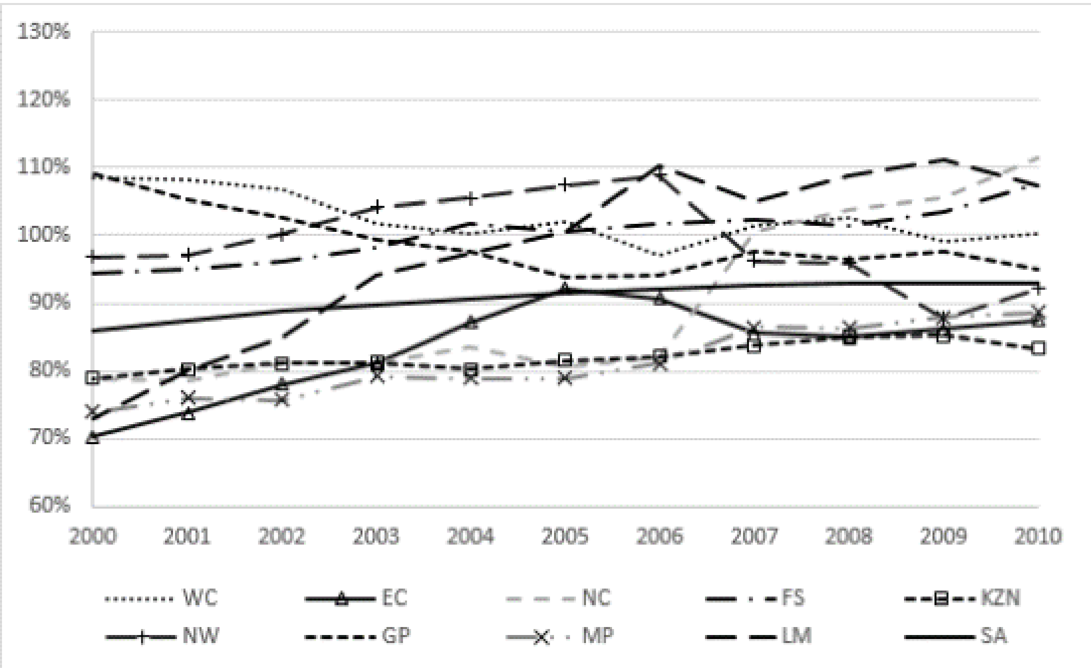


Source: Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016); Table A2; Page 50

Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016) avoided the application of the Death Distribution Methods (DDMs) at the sub-national level to estimate the completeness of adult (15+ years) death registration by first estimating unadjusted mortality rates for both sexes for each province for each year between the period 1997-2010 using recorded deaths and the mid-year population produced by (Dorrington 2013). They estimated mortality rates for both sexes for each province using deaths from households corrected for under-reporting/over-reporting one year before the 2001, 2011 census and the 2007 Community Survey. These rates were then used to adjust the ASSA 2008 provincial mortality rates to produce estimates of the true rates for each province and for each year. Then the completeness for each province for each year was estimated by comparing rates from the VR deaths and the estimates of the true rates derived by adjusting the ASSA2008 projection model provincial rates. The results of the completeness of adult death registration are shown in Figure 2-15.

The general trend for all the provinces is that completeness increased from 1997 to 1998 followed by a decline to 2003 and a gradual increase after that. Similar to infant completeness, wealthier provinces like WC show high levels of completeness of adult death registration compared to other poorer provinces like EC. However, LP shows much higher levels of adult completeness compared to WC, which might indicate the effects of under-coverage of the censuses and the Community Survey relative to death registration or misallocation of VR deaths.

Figure 2-15 Trends in the completeness of adult (15+) deaths registration



Source: Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016); Table A4; Page 53

3 DATA AND METHOD

This chapter has five sections. The first describes the data sources used and asseses the quality of data with two subsections which evaluate the NPR and VR deaths, and then the MRC's method of alloction of NPR deaths to provinces. The second section determines the first adjustments of NPR deaths relative to VR deaths at the national and sub-national level. The third section looks at the method for estimating the overall completeness of death registration to correct the adjusted NPR death data and the VR data for general under-registration at the national level and subnational level. The fourth section focuses on the estimation of all mortality indicators excpect for MMR and NMR, which are covered in the final section.

3.1 Data source and data quality assessment

The study uses two main sources of data, VR deaths and deaths recorded on the NPR to provide estimates of province-level mortality-based high-level indicators currently produced at national level in the RMS reports. Once a death occurs, a Death Notification form (DNF) is supposed to be completed and sent to the Department of Home Affairs (DHA) which then issues a burial order. These forms are legal evidence of death and are collected for data processing by Stats SA. Stats SA is responsible for the release these vital statistics in its annual cause of death reports. Initially, the time lag in the release of the statistics was two years, but recently, the efficiency of the system has improved and for the most recent report, the time lag is just over a year to 15 months. The unit record of the causes of death by province of death can be accessed freely online. Recently, VR data have been recast by Stats SA to 2011 provincial boundaries but before that, it was difficult to track the provincial trends in these data over time because provincial boundaries have been changing. However, it is important to note that it is not possible to evaluate the method of allocation of VR deaths to 2011 provincial boundaries by Stats SA because their method of allocation is not available. For this project, these data, in single ages by province from 2000 to 2015, were provided by a special request to the MRC because they were not yet available on Stats SA's website.

The second source, the NPR data, also provided by the MRC in single ages by province from 2000 to 2016, are a subset of VR data in that, for each death notification sent to the DHA, if a birth certificate or ID has been issued, the NPR is updated to record the death. This implies that in order to estimate the true number of deaths, the NPR data should be adjusted, first, to approximate VR deaths and then, for the fact that not all deaths are registered (via a DNF). However, the NPR data are available at least one year sooner than published vital statistics, thus making it possible to provide mortality information more rapidly. NPR data are received monthly by the MRC and together with the VR data are used to provide mortality indicators reported in the RMS reports by MRC. However, the NPR data do not record the province of death or province of residence. Thus, to get the data according to 2011 provincial boundaries, the MRC inferred provinces of South Africa from the location of the office at which the death was reported.

3.1.1 Evaluation of the MRC's method of allocation of NPR deaths to provinces

Before proceeding it is necessary to check the accuracy of the allocation of the Department of Home Affairs (DHA) offices to the provinces by the MRC. The list of HA offices allocated to each province by the MRC was compared to the list of all offices by province downloaded from the Departement's home page[4]. It is assumed that the offices in the list from the Department's home page that are not included in the list provided by the MRC are those which do not record deaths. The name of each office classified by province from the list provided by the MRC is then checked to see whether it is included in the list of the from DoHA for the same province. The allocation of the offices that do not match with the DoHA list is assessed by checking the physical address of the office online on the Google Maps. The offices with repeated or mis-spelled names, for example, 'Khayelisha' and 'Khayaletsha' from the list provided by the MRC are assumed to be mistakes by the officials who mistyped or misspelled the name of the office recorded on the NPR record of death.

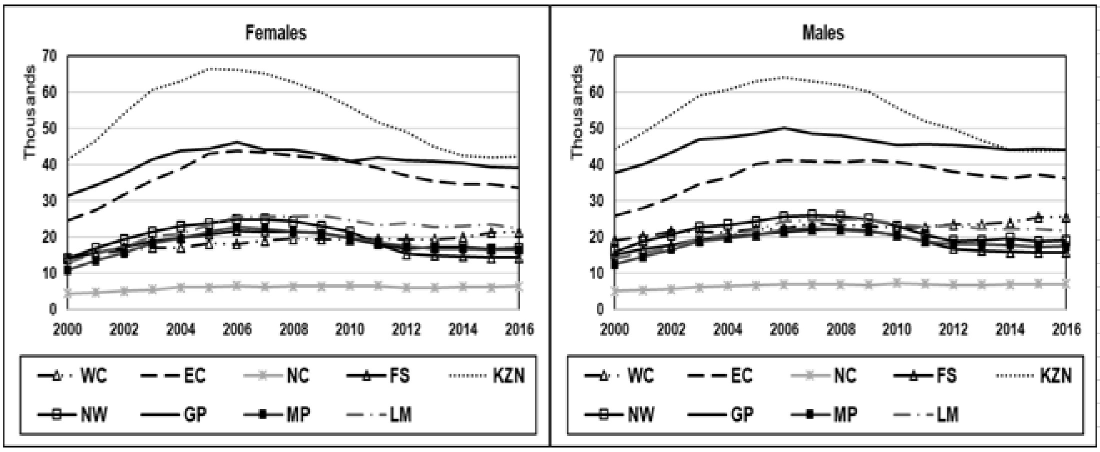
3.1.2 Evaluation of NPR and VR data

Before deciding on the extent of possible correction of NPR data and VR data, the quality of these data is evaluated to help with these adjustments. Trends over time in the total numbers of NPR deaths for each sex and each province are examined. Examination of the trends in the numbers of NPR deaths for each province for males and females in Figure 3-1 shows that they follow similar trends over time for each province. That is for all the provinces except NC and for both sexes, NPR deaths increased from 2000, peaked around 2007 and then declined thereafter. This increase

[4] The list was extracted from the homepage of the website http://www.dha.gov.za/ under the section office contacts for each province [accessed on [07/04/2017].

from 2000 to around 2007 can be explained by an increase in mortality, probably due to HIV, and improved death and birth registration. However, the rapid decline from 2008 to around 2011 is not a decline in the NPR death registration but a decline in mortality, probably due to the roll-out of ARVs.

Figure 3-1 Total numbers of NPR deaths for each province (males and females)



In addition, the ratio of NPR deaths relative to VR deaths in age groups 0, 1-14, 15-24 and 25+ for each province are examined and the results are discussed and presented in the section 4.1.

3.2 NPR relative to VR

As mentioned earlier, NPR data for all the provinces and the country as a whole are adjusted in two steps. The first adjustment is for the fact that the NPR doesn't include those without birth certificates or national IDs and the second adjustment is for general under-registration. The first adjustment is done for infants and in broad age groups (1-14, 15-24 and 25+) for each sex and for all the provinces and at the national level.

Initially, the proportions of NPR relative to VR are obtained by dividing NPR deaths by the VR deaths (including one-year late registrations) for these age groups. These proportions are then used to derive the factors for adjustment for approximating Stats SA VR numbers for all the years from 2000 to 2014 and also for 2015 for which there is no late registration in the VR data and for 2016 for which VR data are yet to be released. Results of the adjustments are presented and discussed in the section 4.2

3.3 The general completeness of death registration

For this form of under-registration, the estimates of completeness are derived for the infants, under-five, adults (15+) and for individual ages from 1 to 14 for all the provinces and country as a whole from 2000 to 2016.

3.3.1 Estimates of completeness of registration of child death in SA

The estimates of completeness of registration of infants and children aged one to four (1-4) last birthday for the country as a whole for the years from 2000 to 2010 are those from the second NBD study (Pillay-van Wyk, Laubscher, Msemburi *et al.* 2016). These estimates are then used to derive the completeness for the under-five deaths together with the CARe3.2 births (births in the year of death) and VR deaths (allowing for one-year late registration) for these years.

Infant and under-five mortality rates implied by the NPR data from the 2015 RMS report are used to derive completeness for children under-five and infants for the years from 2012 to 2014. First, infant mortality and under-five mortality implied by the VR is calculated by dividing VR deaths (allowing for one-year late registration) by CARe3.2 births. The estimates of infant and under-five completeness are then used to derive the completeness for the age group (1-4) last birthday.

For 2015, for which there is no late registered deaths, in the VR data, and for 2016 for which VR data are yet to be released, completeness are derived using the rates of growth of the numbers deaths projected by the CARe3.2 model and estimates of VR estimated from the NPR data in section 3.2.

However, since the reduction of the time lag in the release of the cause of death data by Stats SA data from 23 months to 11 months, there has been a noticeable increase in the proportions of deaths registered late (Richman 2017). Thus, to cater for the deaths that are reported late for the most recent years, estimates of completeness are reduced by using the same approach as applied by Richman (2017). The procedure requires the calculation of developmental factors, derived as the proportions of the cumulative total deaths in each elapsed reporting year to the cumulative total deaths in the prior reporting year. The application of the process together with the results and some discusion are presented in the section 4.3.

3.3.2 Estimates of completeness of registration of child deaths for the provinces

In order to estimate the completeness of registration of child deaths at the provincial level, the estimates of child mortality from the second NBD for the years 2000, 2005, 2010 and 2012 and the direct estimates from the VR are used. The direct estimates from the VR are obtained by dividing VR deaths for each year by estimates of births from the CARe3.2 model.

For both infant and under-five completeness of death registration, the estimates of completeness for the years 2000, 2005, 2010 and 2012 are derived first by dividing direct estimates of mortality from VR (infant and under-five mortality) by the estimates of the NBD for all the provinces. Then for all the years between these point estimates, estimates of completeness are obtained by linear interpolation. For example, the estimates of completeness for the year 2001 are derived by linear interpolating the values for 2000 and 2005.

For 2013 to 2014, estimates of both infant and under-five completeness for all the provinces are derived by first finding the expected true number of deaths for these years. The expected true numbers of deaths are derived using the rates of growth of the numbers of the infant and under-five deaths projected by the CARe3.2 model. For example, the expected true number of infant deaths for WC in 2014 are derived by multiplying expected true number of infant deaths for WC in 2013 by the growth rate in the period 2013 to 2014 implied by the CARe3.2 projection model. The completeness is derived by dividing the VR deaths by these expected true numbers of deaths.

For 2015, for which there is no late registration in the VR data, and for 2016, for which VR data are yet to be released, estimates of infant and under-five completeness are derived using the rate of change in the growth rate of infant and under-five deaths implied by the CARe3.2 death data and the estimate of VR deaths derived from the NPR data for each the province.

These estimates of completeness for each province are then rebalanced such that the total number of deaths, adjusted for under-registration by province for each year, give the same total of numbers of deaths adjusted for under-registration at the national level. The derived estimates of completeness are then adjusted for deaths that are reported as late registration for all the provinces by employing the same procedure as used for the country as a whole for the most recent years (2015 and 2016) .

3.3.3 Completeness of adult death registration at the national level

The estimates of completeness of registration of adult (15+) deaths at the national level are those from the NBD (Pillay-van Wyk, Laubscher, Msemburi *et al.* 2016) study from 2000 to 2010. The estimates of completeness from 2012 to 2014 are derived using the adult (aged between 15 and 59 last birthday) mortality estimates for males and females separately from the most recent 2015 RMS report. First, age-specific mortality rates (for the five-yearly age groups 5-9 to 85+) for each sex and for each year from 2012 to 2014 are derived by dividing VR deaths for the whole calendar year (allowing for one-year of late registration) by mid-year population estimates with an age distribution that is consistent with 2001 and 2011 censuses from Dorrington (2013). These age-specific mortality rates for the years 2012 to 2014 are then converted to the estimates of the probability of dying (${}_nq_x$) assuming a constant force of mortality within each age interval. Then, the estimates of completeness are derived as the adjustment that needs to be made to the age-specific mortality rates to get the same estimates of adult mortality (${}_{45}q_{15}$) from the 2015 RMS report.

The estimates of adult completeness for 2015 for which there is no late registration in the VR data and for 2016, for which VR data are yet to be released, are derived assuming that adult (15+) deaths grew at rates implied by CARe_3.2 death data. However, for the year 2011, estimates of completeness are derived by linear interpolation between the values for 2010 and 2012, assuming a linear change between these two years. Like child completeness, the estimates of adult completeness for the most recent years (2015 and 2016) are adjusted to accommodate deaths that are to be reported as late registration in the future.

3.3.4 Provincial completeness of reporting of adult deaths

The completeness of adult death registration at the provincial level is estimated using the estimates of adult mortality (${}_{45}q_{15}$) from Dorrington and Timæus (2017) for the years 2001 and 2011 and the estimates of mortality derived using the VR death data and the census population numbers for the years 1996, 2001 and 2011.

First, age-specific mortality rates by age group (5-9 to 85+) and sex for each province for the year 2001 are estimated as the ratio of VR deaths for the whole calendar year allowing for one-year late registrations divided by the estimate of mid-year population numbers for the year 2001. The mid-year estimates of population numbers are derived by linear interpolation between the values at the reference date for the 1996 and 2001 censuses, assuming the population numbers for each age group changed linearly between the two census dates and that there is no differential undercount by age between the two censuses. The procedure is repeated to get mid-year estimates of mortality rates for the year 2011 but using the 2001 and 2011 censuses and 2011 VR deaths allowing for one-year of late registrations. The assumption of no differential undercount by age and between censuses was made despite controversy about the last three South African censuses due to high undercount (Gumbo 2016). Stats SA's revised

2011 census report reported high estimates of undercount of 10.7%, 17% and 14.6% for the1996, 2001 and 2011 censuses respectively. However, it is important to note that the accuracy of the adjustments to correct for the undercount using Post Enumeration Surveys (PES) is contested in part because of concerns over the small sample sizes used. The mortality rates are then converted to the probability of dying assuming a constant force of mortality for individual ages in each age group.

After this, the completeness of adult (15+) death registration by sex, for each year (2001 and 2011) and each province is derived as the adjustment that needs to be made to the age-specific mortality rates to get the same adult mortality from Dorrington and Timæus (2017). Then, to combine the estimates of males and females for each province, one may be tempted to take the average of the two for each of the years. However, there are some provinces like WC, GP, EC, and NC where the difference between male and female estimates of completeness and female estimates in 2001 is large. Thus, estimates of true numbers of deaths implied by the estimates of completeness for each sex, each province and each year are derived first. Then, the estimates of completeness (combined for males and females) are estimated as the ratio of VR deaths allowing for one-year late registration to these combined (males and females) true estimates of deaths for each province and each year.

The estimates for each province for the years between 2001 and 2011 are derived by linear interpolation between the values for 2001 and 2011, assuming completeness changes linearly over time between 2001 and 2011 estimates.

The estimates for 2000, 2012 to 2016 are derived using the assumption that the changes in the estimates of the true numbers of deaths (15+) are proportional to the changes in the numbers of deaths from the CARe3.2 model for each province. However, for the years 2015, for which there is no late registration in the VR data, and for 2016, for which VR data are yet to be released, estimates of adult completeness are derived using the rate of change in the numbers of adult (15+) deaths from the CARe3.2 projection model and estimates of VR estimated from the NPR data. After this, the estimates of adult (15+) VR completeness are rebalanced to ensure that the sum of the implied estimates of provincial VR deaths equals the implied estimates of national VR deaths. The estimates of completeness for all the provinces for the most recent years are then adjusted to accommodate deaths that are to be reported as late registration in the future in the same way as child deaths. . The estimates of completeness of infant, under-five, and adult death registration are used to derive the estimates of completeness for individual ages from 1-14 assuming completeness changes linearly with age from age 1-15 such that the average of the completeness for ages 1-4 matched the completeness for the 1-4 age group. These estimates of completeness are then used to adjust estimates of VR deaths from NPR deaths for general under-registration and VR deaths for under-registration.

3.4 Mortality indicators

Estimates of the numbers of VR deaths from the NPR data (from 2000 to 2016), the actual numbers of VR deaths (from 2000 to 2015), both adjusted for the general under-notification, and the births from the CARe3.2 model (by calendar year) and population numbers, are used to produce the mortality indicators for all the provinces and the country as a whole.

The IMRs are derived by dividing the NPR and VR deaths under age one adjusted for under-registration by the births from the CARe3.2 model for each calendar year from 2000 to 2016 and 2000 to 2015 respectively. The same procedure is used for the U5MRs, but using the under-five deaths.

The adult mortality indicator (${}_{45}q_{15}$), life expectancy at birth (e_0) and life expectancy at age 60 (e_{60}) are obtained by first deriving mortality rates. This is done for each province and the country as a whole. Mortality rates are derived by dividing the NPR and VR deaths in five-year age intervals (with an open interval of 85+), adjusted for under-registration, by the corresponding CARe_3.2 population numbers. These observed mortality rates are then assumed to approximate the mortality rates for the life tables assuming constant force of mortality within each age interval. To complete the life tables, the equation

$e_a^o = \frac{-1}{M_a} \exp\left(-0.0951 \cdot r_a \cdot M_x^{-1.4}\right),\ a \geq 65$ from Horiuchi and Coale (1982) is used to derive the life expectancy at age 85, that is, assuming that the population above age 85 is stable and using the growth rates at 85+ implied by CARe_3.2 population numbers, where r_a is the growth rate of the open interval, and M_a is the mortality rate of the last open age interval.

The reasonableness of the adjustments made to the NPR and VR is assessed by looking at the implied mortality levels across all the provinces and the trends in these estimates over time. The results obtained are presented in sections 4.8 to 4.13.

3.5 Maternal and neonatal mortality

In as far as maternal mortality is concerned, as is indicated in the recent 2015 RMS report, the NPR data does not give details about the causes of death for the estimation of maternal mortality. So, following the approach in this report, data on the cause of death (for women of the age group 15 to 49) from Stats SA are used to derive maternal mortality for each province from 2000 to 2015. However, there are problems with the quality of these data as indicated in the 2015 RMS report. These include the problem of misclassification of the causes of death, ill-defined causes of death and the general under-notification of deaths. Thus, in order to estimate the true number of maternal deaths for each province from 2000 to 2015, all the ill-defined natural deaths are apportioned in proportion to those with recorded causes of death. Then, for each year from 2000 to 2015 and for each province, all maternal deaths are adjusted for the general under-registration using the estimates of completeness for adults obtained in the section 3.3.4 and these deaths are then increased by 50 per cent[5] to allow for the problem of misclassification of the cause of some deaths as non-maternal causes. The maternal mortality ratio is then derived as the number of maternal deaths divided by the total live-births from the CARe3.2 model for each calendar year from 2000 to 2015 and for each province.

As far as neonatal mortality is concerned, as is pointed out in the 2015 RMS report, although registration of neonatal deaths in the NPR appears to have been increasing over time, these are too few from which to estimate neonatal mortality reliably. For these reasons, the 2015 RMS report recommended the use of other sources for estimating neonatal mortality. Therefore, similar to this report, neonatal deaths from the DHIS (2008-2015) systems (provided by special request to the MRC) and VR (2000-2015) are used to derive neonatal mortality for each province from 2000 to 2015.

However, it is important to note that the DHIS only captures deaths that occur in public health facilities, missing those that occur at home, in private hospitals, and even some that occurring in public health facilities. For deaths that did not occur in the public facility an assumption these births have lower or negligible NMR is made before adjusting for the general under-registration of deaths assuming the same level of completeness as experienced by infant deaths. On the other hand, the VR misses neonatal deaths that have not been registered and for this reason, these neonatal deaths are adjusted in the same way as those from DHIS. However, it is important to examine the ratio of VR neonatal deaths to DHIS deaths, for each province from 2008 to 2015 to assess the appropriateness of using DHIS data. The results and discussions are presented in the section 4.7.

3.6 Conclusion

This chapter discussed data sources used in this research, as well as the evaluation of the method of allocation of NPR deaths to provincial boundaries by the MRC. In addition, adjustment of NPR death data to approximate VR data for the fact that NPR data does not include all deaths for which a DNF completed. The methods of extrapolation into the future from the year yet to include late registration are described.

The chapter also describes the adjustments of VR deaths and estimates of VR from NPR data for the general under-registration. This include methods of extrapolation into the future (from the year yet to include late registrations to the year where VR data are yet to be released by Stats SA.

The chapter also describes methods used to estimate maternal mortality from VR data and neonatal mortality from the DHIS data and VR data.

[5] The same adjustment made in the RMS national reports as advised by the UN advisory group based on the experience of some studies estimating the extent of miss-classification in countries with good VR data

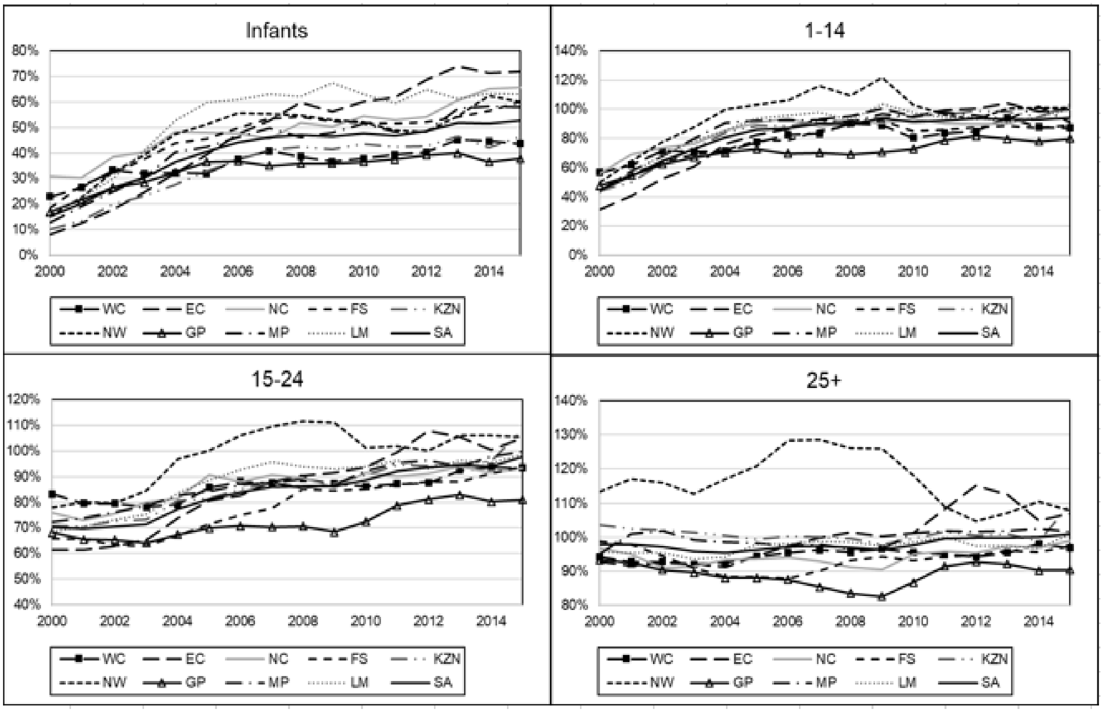
4 RESULTS

This chapter is divided into nine sections. The first section presents an evalution of NPR data relative to VR while the second is a discussion of the first adjustement of NPR. Sections 4.3 to 4.6 cover the developmental factors used to adjust estimates of completenss to cater for deaths already occurred but yet to be reported as late registration for the second adjustement of NPR data and for the general under-registration of VR data. Section 4.7 presents the ratios of VR neonatal deaths to DHIS neonatal deaths and section 4.8 to section 4.15 present all mortality indicators derived after adjusting the VR and NPR data for all forms of under-registration, as well as estimates of the MMR and NMR. The last section assesses the reasonableness of the estimates produced by comparing them with estimates from other sources.

4.1 Ratios of NPR deaths relative to VR deaths

Figure 4-1 shows the proportions of NPR deaths relative to VR deaths in each province and the country as a whole. The VR deaths for all the years include only one year of late registrations, except for 2015, which has no late registration. While the proportion of infant deaths captured by the NPR for all the provinces has been increasing over time, the level is generally lower than other age groups. This implies that a larger adjustment is needed to correct for the deaths of infants that are not in the NPR, which is explained by the fact that these deaths occur before the birth is registered and thus are not recorded on the NPR even if a death notification form is completed. It can be seen that, for all the provinces, NPR deaths as a proportion of VR deaths for deaths under 25 years of age, increase in a linear fashion but more rapidly for the period from 2000 to 2006 and more gently after 2006.

Figure 4-1 NPR deaths as a proportion of VR deaths for age groups 0, 1-14, 15-24 and 25+



For the 1 to 14 age group, the trend is similar to that of the infants. This is to be expected since this age group is probably dominated by deaths in the 1-4 age group, which probably has a similar trend to the infants. We would expect a general increase in the completeness of NPR deaths relative to VR deaths for all the provinces over time but there is an implausible increase in the proportions of NPR relative to VR for NW from 2005 to 2009, followed by a rapid decline to 2011, while for GP there is the opposite trend during the same period. This clearly shows some problems with the NPR or VR data.

The general trend for all the provinces for the 15-24 age group is different to that of the 1-14 age group. The proportions for all the provinces from 2000 to 2003 are fairly level before starting to increase slowly over time. However, the proportions for NW and GP for the period from 2005 to 2010 show the same issue as observed for the age group 1-14.

For the 25+ age group, the proportions of all the provinces except NW, FS, and GP appears to have been fairly constant over time. More than 90 per cent of the death notification forms for the 25 and above age group are in the NPR dataset for all the provinces except GP from 2005 to 2010 and FS from 2004 to 2006. For some provinces, it appears that more deaths for the age group 25+ are recorded in the NPR than in the VR data. This trend is most apparent in KZN (from 2000 to 2015), EC from 2007 to 2015, MP from 2010 to 2015 and NW for all the years. It is possible for the completeness to be more than 100 per cent for some provinces because deaths in the NPR data had to be allocted to the offices where the death was registered and this is a problem because some some deaths are registered in provinces other than the one in which the deceased lived (or even, possibly, where the death occurred). It is also quite possible that some problems might have emanated from the reallocation of deaths to 2011 provincial boundaries and from the fact that place of residence for some VR deaths are probably simply recorded as the same as the place of death when unknown. A similar trend to the age group 1-14 and 15-24 is observed for the 25+ for NW and GP.

Examining the trend in proportions for the 25+ age group for the country as a whole shows that the proportions of registered deaths in the NPR increased and reached a plateau of 100 per cent in 2011. However, after 2011 the proportions increased to a level of slightly above 100 per cent and this is more apparent in 2015. One would not expect the completeness at the national level to be more than 100 per cent. This clearly suggests that not all deaths in the NPR are being processed by Stats SA and the problem can be traced back to 2011 when the time lag in the release of the cause of death data was reduced from two years to one year. For 2015, apart from the errors in recording (e.g age), the main problem is late registration in that the forms have been processed by the Department of Home Affairs but not yet by Stats SA.

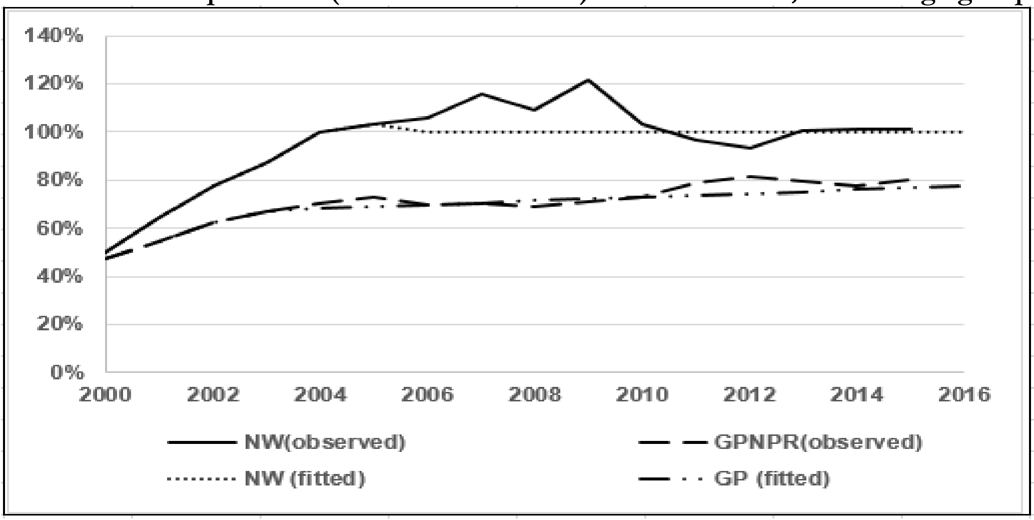
4.2 The adjustments of NPR relative to VR

The estimates of completeness of reporting the infant deaths for each province and each sex for the years 2000 to 2006 are derived by fitting a linear function using the points from 2000 to 2006, thereby allowing a rapid increase in the completeness during that period, and for the period 2007 to 2014 using the points from 2007 to 2014, thus allowing for a more gradual increase. For each province, the country as a whole and for males and females, the estimates for 2015 and 2016 are derived assuming a constant change in the completeness since 2013. This is a reasonable assumption to make considering that the completeness for the infants for all the provinces is still low (less than 75 per cent) and we expect it to continue increasing over time. But this assumption should be monitored in future especially when the completeness is high (say over 90 per cent) as it is expected to level off as it approaches 100 per cent.

The same procedure followed for the infants is followed for all the provinces and both sex except NW and GP for the age group 1 to 14 (last birthday) but allowing for the rapid increase in the completeness for the period from 2000 to 2004 and the more gradual increase thereafter.

The rapid increase in the completeness from 2005 to 2009 followed by a rapid decline to 2011 for NW and, at the same time, an opposite trend for GP, as shown in Figure 4-2, is assumed to be a problem with the quality of VR data. Considering that there were no problems with MRC's method of allocation of NPR data, it is assumed that some VR deaths from NW might have been wrongly allocated to GP by Stats SA when allocating these deaths according to 2011 provincial boundaries. To correct for this, one could consider smoothing the ratios for each province such that each curve levels off from 2006 onwards. However, this is a problem since the provinces are different in size. Thus, the ratios have been corrected on the basis of transferring numbers from GP to NW such that the final estimates of completeness from 2006 level off as shown in Figure 4-2 below.

Figure 4-2 Combined (average for males and females) observed and fitted completeness (NPR relative to VR) for NW and GP, the 1-14 age group



For the 15 to 24 age group for each province and both sexes, the estimates of completeness are derived by finding the average of the proportions from 2000 to 2003, thereby allowing observed constant completeness over this period and by fitting a linear function using the observed proportions for the period from 2004 to 2014. Since the completeness for this age group is already leveling off in the most recent years, the estimates for 2015 and 2016 are obtained by applying the same procedure used for the infants. The same procedure applied for the 1-14 for NW and GP for the same period suggesting that there might be some VR deaths from NW wrongly allocated to GP is repeated for the 15-24.

For all the provinces except NW and GP, the proportions for the 25+ age group are fairly level over the period from 2000 to 2014. Moreover, the proportions for EC, KZN, NW, and MP for the period 2012-2014 are slightly more than 100 per cent. But as mentioned before, it is quite possible for the completeness to be more than 100 per cent at the sub-national level. However, since at national level and for this age group, completeness from 2012 is more than 100 per cent, this clearly implies that Stats SA missed some deaths that are in the NPR. It is assumed that the problem persists only in the provinces which show a completeness of more than 100 per cent.

For these reasons, for the 25+ age group and for each province except EC, KZN, GP, NW, and MP the adjustment factors for the period from 2000-2014 are derived by taking the averages of these proportions. For example, for the period 2000-2004, estimates of completeness are the average of the ratios between the period 2000 to 2004. The procedure is repeated for the period 2005-2010 (the average of the ratios between the period 2005-2010) and also for the period 2011-2014 (the average of the ratios between the period 2011-2014). The same factors used for the period 2011-2014 are assumed for 2015 and 2016 for these provinces.

For EC, KZN, and MP the estimates of completeness are derived by taking the averages of these proportions from 2000 to 2011. That is, the factors for the period 2000-2004 are the average of the ratios in the period 2000-2004 and the factors for the period 2005-2011 are the average of the ratios in the period 2005-2011. The same factors as used for 2011 are assumed to apply for the years from 2012 to 2016 for which VR data are unreliable (including 2015, where there is no late registration, and 2016, where data are yet to be released). The same procedure applied to NW and GP data for the age group 1-14 is repeated for this age group for the period that suggests there might be some VR deaths from NW that were wrongly allocated to GP. For example, new ratios for these two provinces are derived on the basis of transferring the numbers of deaths from GP to NW such that the resulting completeness is constant in the period 2000 to 2014. Then after deriving these estimates, the final estimates of completeness for GP are derived by applying the same procedure used for WC, FS, LM, and NC, while for NW, by applying the procedure used EC, KZN, and MP, because the ratios for NW for the years from 2012 are more than 100 per cent.

However, for the country as a whole and for the age group 25+, the proportions for females imply that there are more deaths recorded in the NPR compared to the VR. This trend is more pronounced from 2012 to 2015. As mentioned in the RMS national reports by Dorrington, Bradshaw, Laubscher *et al.* (2016), apart from errors in recording age this might imply that not all death notification forms are processed by Stats SA especially for the years when the time lag in the releasing of the cause of death data was reduced from 2-years to 1-year and the problem of late registrations. Thus, the estimates of VR deaths are obtained by applying the same approach used for the national RMS reports, that is, for the period from 2012 to 2016 for which VR data are yet to be released or are unreliable, the same factors used to adjust for the year 2011 are used. The factors for the 25+ age group are taken as the average of the proportions from 2000 to 2011.

After this, these estimates of VR deaths are rebalanced to ensure that the sum of the estimates of provincial VR equals the estimates of national VR. Finally, rebalanced estimates of deaths for all the provinces and from 2000 to 2016 are adjusted for the general under-notification of deaths.

4.3 Developmental factors for the infants and under-five at national level

Table 4-1 shows total numbers of infant deaths in each year from 2000 to 2014 and cummulative additions made in subsequent reports from Stats SA used to derive developemental factors with which to adjust estimates of completeness discussed in the section 3.3.1. The number of late registrations in most recent years are estimated by first tabulating the number of late registrations from 2006 to 2014 as shown in Table 4-1. The second column shows the number of infant deaths that occurred in the same year they were processed. The subsequent columns add late registrations recorded in the consecutive annual reports to that total.

Table 4-1 Infant deaths occurring in each year from 2006 to 2014, and cumulative adjustments made in subsequent reports from Stats SA

Death Year	Number of years of late registration									
	0	1	2	3	4	5	6	7	8	9
2006	47,418	48,235	48,290	48,307	48,314	48,316	48,327	48,353	48,359	48,367
2007	45,791	46,718	46,934	46,949	46,956	46,982	47,004	47,015	47,026	
2008	45,102	45,784	45,830	45,842	45,867	45,903	45,908	45,921		
2009	38,258	39,190	39,215	39,236	39,262	39,271	39,285			
2010	34,234	34,759	34,813	34,840	34,854	34,859				
2011	28,063	28,560	28,601	28,621	28,626					
2012	26,560	27,106	27,137	27,156						
2013	26,336	26,706	26,737							
2014	26,214	26,639								

The numbers from Table 4-1 are used to derive the developmental factors for the infants shown in Table 4-2 below. For example, the ratio of 26,639 to 26,241 gives the developmental factor of 1.016 for the year 2014.

Table 4-2 Individual development factors, infants

Death Year	Number of years of late registration 1	2	3	4	5	6	7	8	9
2006	1.017	1.001	1.000	1.000	1.000	1.000	1.001	1.000	1.000
2007	1.020	1.005	1.000	1.000	1.001	1.000	1.000	1.000	
2008	1.015	1.001	1.000	1.001	1.001	1.000	1.000		
2009	1.024	1.001	1.001	1.001	1.000	1.000			
2010	1.015	1.002	1.001	1.000	1.000				
2011	1.018	1.001	1.001	1.000					
2012	1.021	1.001	**1.001**						
2013	1.014	**1.001**							
2014	**1.016**								

It can be seen that most of the late registration is occurs in the year after birth and that there was not a big difference in the proportions of late registration in most recent years (2013 to 2014).

The most recent proportions, in bold, are then used to derive the late registrations for each year of death with the proportion in bold in the second column (1.016) used to get deaths reported late one year after the death year 2015 in 2016 and the proportion in bold in the third column (1.001) to get an estimate of deaths reported late two years after death-year 2015 (i.e. in 2017) on the assumptions that these proportions will remain the same for the next year. For example, it is expected that infant deaths that occurred in 2015 that will be reported in 2016 as late registration will be equal to 1.6 per cent of the infant deaths reported by Stats SA for the year 2015, and for 2016 it is expected that infant deaths that occurred in 2016 that will be reported in 2017 as late registration will be equal to 1.6 per cent of the infant deaths estimated to have occurred in 2016. These deaths are accounted for by reducing the estimates of infant completeness by 1.6 per cent for the years 2015 and 2016 and again by 0.1 per cent for these two years.

The same procedure is repeated to estimate the number of deaths under-five using the individual development factors shown in Table 4-3 below.

Table 4-3 Individual development factors, under-five

Death Year	Number of years of late registration 1	2	3	4	5	6	7	8	9
2006	1.017	1.001	1.000	1.000	1.000	1.000	1.001	1.000	1.000
2007	1.022	1.004	1.000	1.000	1.001	1.001	1.000	1.000	
2008	1.015	1.001	1.000	1.001	1.001	1.000	1.000		
2009	1.023	1.001	1.001	1.001	1.000	1.000			
2010	1.015	1.002	1.001	1.000	1.000				
2011	1.020	1.002	1.001	1.000					
2012	1.025	1.001	**1.001**						
2013	1.015	**1.001**							
2014	**1.015**								

It can be seen from Table 4-3 the second column that proportions of under-five deaths registered late in more recent years are constant. For example, 2013 deaths registered late in 2014, were equal to 1.5 per cent of the deaths reported in 2013 and this proportion didn't change for 2014 deaths registered late in 2015.

4.4 Developmental factors for the infants and under-fives for the provinces

Individual development factors for the under-fives not shown are similar to those for the infants shown in Table 4-4. It can be seen that higher proportions of infant deaths are reported late in more recent years compared to earlier years for WC, KZN, and FS while for the other provinces the situation is the opposite. Moreover, for all the provinces except WC, it can be seen that the proportions of infant deaths reported late for the death years 2013 and 2014 are more or less constant.

Table 4-4 Individual development factors (infants)

Death Year	WC	EC	NC	FS	KZN	NW	GP	MP	LM
2006	1.037	1.019	1.010	1.010	1.015	1.019	1.015	1.014	1.029
2007	1.026	1.019	1.012	1.009	1.014	1.023	1.030	1.015	1.027
2008	1.036	1.021	1.014	1.007	1.013	1.011	1.015	1.010	1.023
2009	1.044	1.047	1.009	1.010	1.019	1.019	1.027	1.015	1.032
2010	1.031	1.016	1.003	1.010	1.013	1.017	1.016	1.015	1.015
2011	1.048	1.022	1.008	1.013	1.013	1.012	1.019	1.016	1.014
2012	1.038	1.023	1.007	1.013	1.029	1.011	1.018	1.017	1.016
2013	1.036	1.016	1.002	1.011	1.020	1.004	1.012	1.010	1.012
2014	1.050	1.017	1.006	1.011	1.024	1.007	1.010	1.008	1.015

The most recent proportions for each province shown in Table 4-5 and Table 4-6 for the infant and under-five deaths respectively are then used to derive the estimates of late registrations for the years 2015 and 2016. The average of the last three years proportions may have provided a better approximation of the future for WC but it was decided to use the most recent proportion. The reason is that the difference between the most recent proportion (2014) and the other previous two years is too large to consider the average. The proportions corresponding to one year time elapsed since death year are used for the years 2015 and 2016 before adjusting for two years of late registrations for these two death years on the assumption that these proportions will remain constant.

Table 4-5 Individual development factors (infants) for adjustments

Number of years of late registration	WC	EC	NC	FS	KZN	NW	GP	MP	LM
2	1.002	1.002	1.000	1.000	1.002	1.000	1.000	1.000	1.004
1	1.050	1.017	1.006	1.011	1.024	1.007	1.010	1.008	1.015

Table 4-6 Individual development factors (under-five) for adjustments

Number of years of late registration	WC	EC	NC	FS	KZN	NW	GP	MP	LM
2	1.001	1.002	1.000	1.000	1.003	1.000	1.000	1.000	1.003
1	1.046	1.015	1.005	1.011	1.023	1.007	1.009	1.008	1.012

4.5 Developmental factors for the adult at national level

Developmental factors to adjust estimates of adult completeness at national level are presented in Table 4-7 below. It is expected that adult deaths that occurred in 2015 and reported as one-year late registration will be equal to 1.4 per cent of the adult deaths reported by Stats SA for the year 2015, and for 2016 it is expected that adult deaths that occurred in 2016 that will be reported with one-year late registration will be equal to 1.4 per cent of the adult deaths estimated to have occurred in 2016. These deaths are accounted for by reducing the estimates of adult completeness by 1.4 per cent for the years 2015 and 2016 and again by 0.1 per cent for these two years for two years late registration.

Table 4-7 Individual development factors (adult)

	Number of years of late registration								
Death Year	1	2	3	4	5	6	7	8	9
2006	1.016	1.002	1.001	1.000	1.000	1.000	1.000	1.000	1.000
2007	1.018	1.004	1.000	1.000	1.000	1.000	1.000	1.000	
2008	1.014	1.001	1.000	1.000	1.000	1.000	1.000		
2009	1.015	1.001	1.000	1.000	1.000	1.000			
2010	1.015	1.001	1.001	1.000	1.000				
2011	1.014	1.001	1.000	1.000					
2012	1.016	1.001	1.000						
2013	1.012	**1.001**							
2014	**1.014**								

4.6 Developmental factors for the adult for the provinces

The developmental factors for one-year of late registration for each death year for each province are shown in Table 4-8 below. As with child deaths, it can be seen that higher proportions of adult deaths are reported late in more recent years than earlier years, for WC, KZN, and FS, while for the other provinces the trend is different. Moreover, for all the provinces except WC, it can be seen that the proportions of adult deaths reported late in the most recent years of death, years 2013 and 2014 are not very different.

The most recent proportions for each province shown in Table 4-9 below for adults are then used to derive the estimates of late registrations for the years 2015 and 2016. The same concept applied to WC to account for infants and under-five deaths reported late is repeated for adult deaths. The proportions corresponding to one-year of late registration are used for the years 2015 and 2016 before adjusting for two-year late registrations for these two death years on the assumption that these proportions will remain constant.

Table 4-8 Individual development factors (adult), provinces

Death Year	WC	EC	NC	FS	KZN	NW	GP	MP	LM
2006	1.031	1.020	1.010	1.010	1.016	1.018	1.014	1.014	1.025
2007	1.023	1.020	1.013	1.009	1.014	1.027	1.031	1.016	1.033
2008	1.032	1.021	1.012	1.006	1.014	1.011	1.014	1.009	1.023
2009	1.040	1.041	1.009	1.009	1.019	1.018	1.024	1.017	1.029
2010	1.028	1.023	1.006	1.009	1.014	1.014	1.014	1.015	1.015
2011	1.044	1.034	1.010	1.012	1.019	1.012	1.018	1.017	1.016
2012	1.037	1.031	1.006	1.011	1.047	1.013	1.017	1.018	1.018
2013	1.034	1.016	1.003	1.011	1.024	1.006	1.011	1.010	1.010
2014	1.046	1.015	1.005	1.011	1.023	1.007	1.009	1.008	1.012

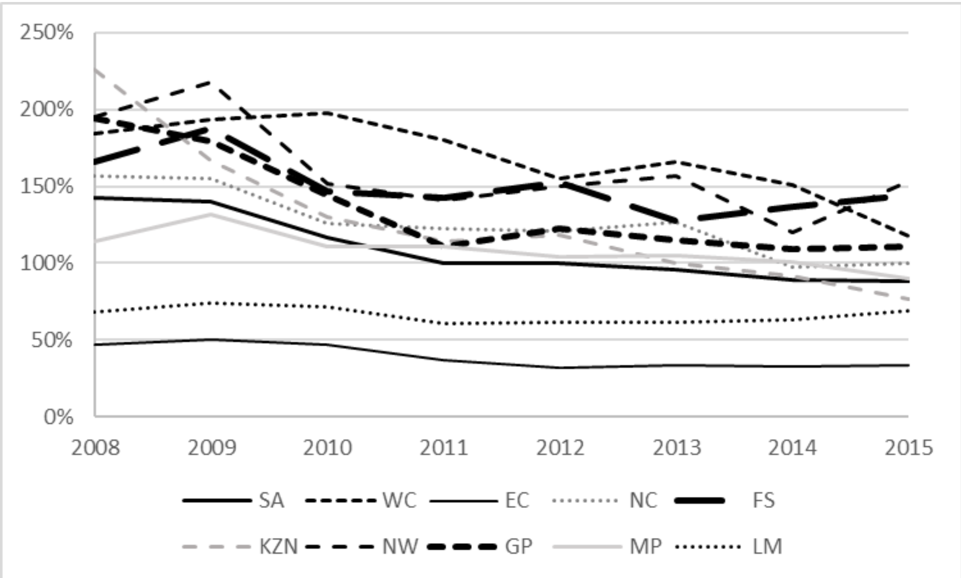
Table 4-9 Individual development factors (adult) for adjustments

Number of years of late registration	WC	EC	NC	FS	KZN	NW	GP	MP	LM
2	1.001	1.002	1.000	1.000	1.003	1.000	1.000	1.000	1.003
1	1.046	1.015	1.005	1.011	1.023	1.007	1.009	1.008	1.012

4.7 Ratio of VR neonatal deaths to DHIS neonatal deaths

Figure 4-3 presents the proportions of VR neonatal deaths to DHIS neonatal deaths for each province from 2008 to 2015. From this, it can be seen that the VR system captures more deaths than the DHIS for WC, FS, GP, and NW for all years from 2008 to 2015. Because of this, neonatal deaths from the DHIS are scaled up, using the ratios of DHIS neonatal deaths to VR neonatal deaths, to estimate the number expected to be captured by the VR. However, from 2008 to 2015 the DHIS captured more neonatal deaths for EC and LM, and from 2013 to 2015 for NC, MP and KZN, and in comparison with the other four provinces the difference is large. For these reasons, neonatal deaths from the DHIS are used to estimate neonatal mortality going forward, making similar assumptions to those made in the 2015 RMS report, namely, that the decline in neonatal deaths in VR is mostly likely to be the decline in completeness of registration. NMR is then estimated as the ratio of adjusted neonatal deaths to live-births from the CARe3.2 model for the calendar year from 2000 to 2015 and each province.

Figure 4-3 Ratio of VR neonatal deaths to DHIS neonatal deaths, 2008-2015

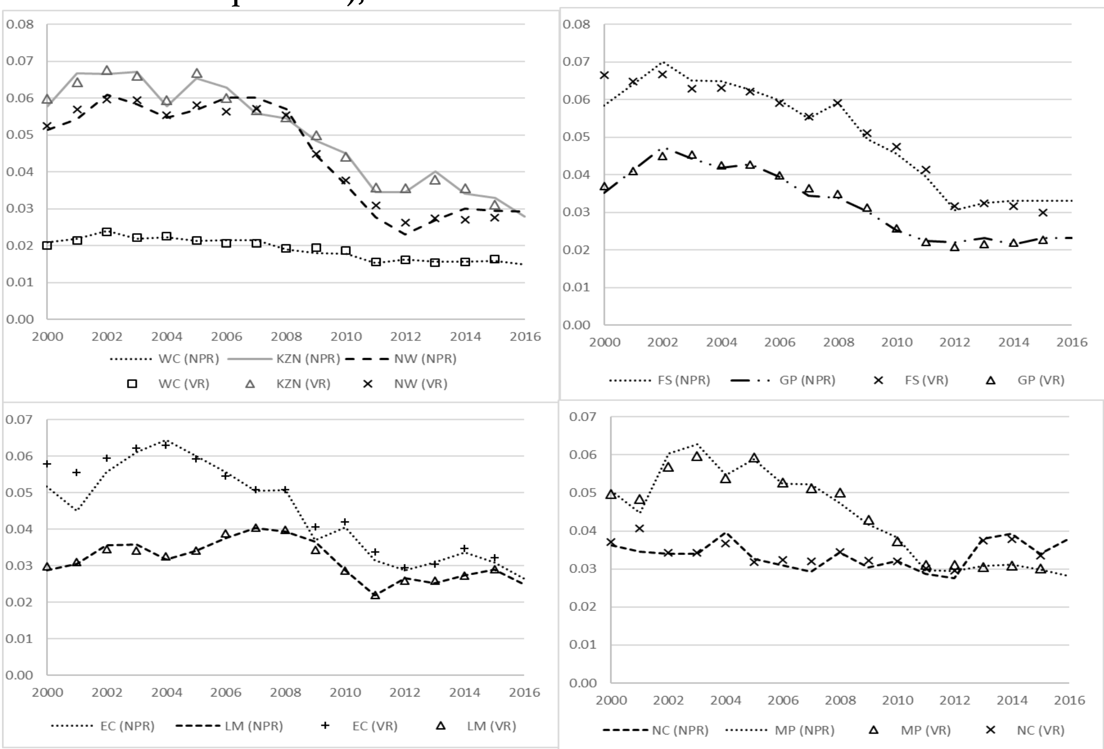


4.8 IMR for the provinces

Figure 4-4 below shows the trend in infant mortality estimated from the NPR and VR data after correction for all the provinces. As expected from the nature of the adjustments made, the estimates derived from the VR data are quite similar to those derived from the NPR data for all the provinces over the whole period from 2000 to 2015, except for EC (in 2001), NC (in 2001) and NW (in 2012) where the difference is much higher (percentage difference of more than 10 per cent). Most of the difference can be seen in earlier years where the completeness of NPR relative to VR is much lower. Compared to other provinces the estimates derived from the VR data and those from the NPR data for WC are much more stable over time.

We would expect to see the effect of the HIV epidemic and the impact of prevention of mother to child transmission and antiretroviral treatment programs on the trends in infant mortality and a reasonable ranking of the provinces according to levels of mortality over time. Poor provinces and those known to be most affected by the HIV epidemic for all the years are expected to have higher levels of infant mortality. It can be seen that for all the high mortality provinces, IMR increases since 2000, peaks between 2002 to 2005, probably due to the HIV epidemic, before declining rapidly until 2011 and then remaining constant in most recent years. The rapid decline in infant mortality cannot be explained without mentioning the role of ARVs and the prevention of mother to child transmission programs. These internal consistencies suggest that the adjustments made to NPR data and VR worked fairly well for the infants.

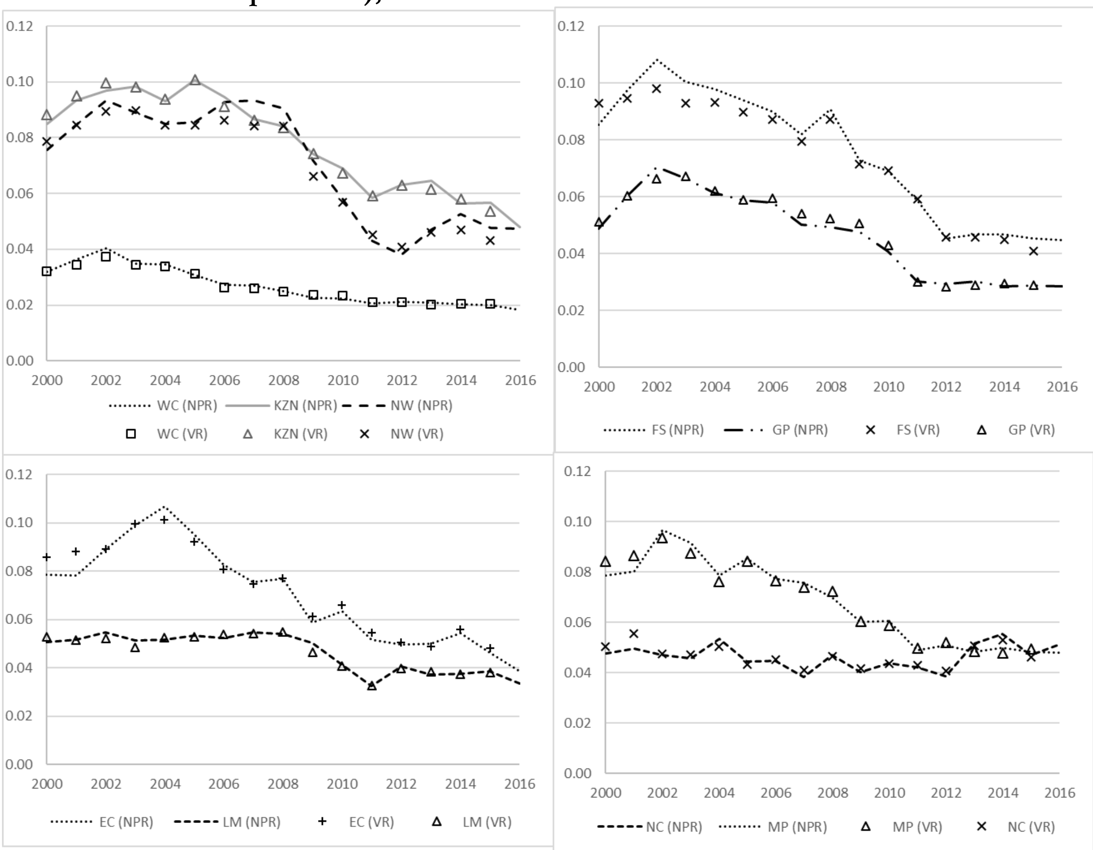
Figure 4-4 Infant mortality from NPR and VR for all the provinces (after adjusting for incompleteness), 2000 - 2016



4.9 U5MR

The trends in under-five mortality for all the provinces are shown in Figure 4-5 below. Although there are minor differences between the estimates derived using VR data and NPR data for WC, FS, and EC for the period 2000 to 2003, 2000 to 2002 and 2000 to 2004 respectively, the estimates appear to be highly consistent with each other. These estimates imply a similar trend for the high mortality provinces. The ranking of the provinces implied by these estimates is sensible and the U5MR have a similar trend to the IMRs except peaking a few years later for the majority of the provinces. The estimates suggest that for the high mortality provinces, under-five mortality fell rapidly from 2006 to around 2011 and leveled off thereafter. For the economically better off provinces like WC and GP, these estimates suggest that the under-five mortality is lower and has been declining slowly from a peak in 2002 before appearing to have remained constant in more recent years.

Figure 4-5 Under-five mortality from NPR and VR for all the provinces (after adjusting for completeness), 2000 - 2016

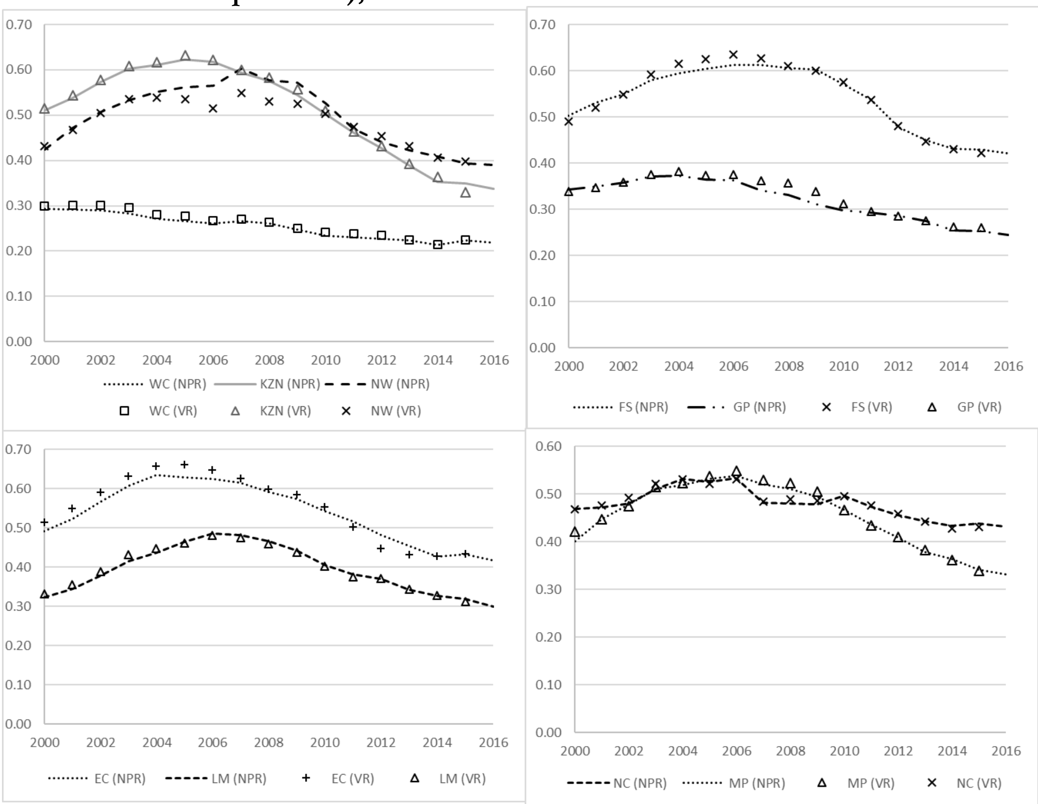


4.10 Adult mortality

Figure 4-6 show trends in adult mortality ($_{45}q_{15}$) for all the provinces. While the estimates from the NPR data and VR data appear to be consistent with each other for all the provinces and all the years, there are small differences between these estimates for NW and GP from 2004 to 2010 with percentage differences ranging between 3 per cent and 9 per cent. These are due to the assumption made previously that some VR deaths belonging to GP were wrongly allocated to NW during the process of recasting these deaths according to 2011 provincial boundaries.

As can be seen from Figure 4-6, the adjustments to the NPR and VR data imply that for all the provinces except WC adult mortality increased rapidly since 2000, peaked in the period 2004 to 2009 before declining rapidly thereafter and in more recent years it has been fairly constant. For WC, the adjustments imply that adult mortality has been declining very slowly from around 30 per cent in 2000 to 22 per cent in 2016. Again, poorer provinces and those that are known to have been most affected by HIV most, like KZN, FS, NW, MP, and EC, are shown to have high adult mortality levels for all the years from 2000 to 2016 compared to richer provinces like WC and GP. These internal consistencies give some confidence on the adjustments made to NPR data and VR data.

Figure 4-6 Adult mortality from NPR and VR for all the provinces (after adjusting for incompleteness), 2000 - 2016

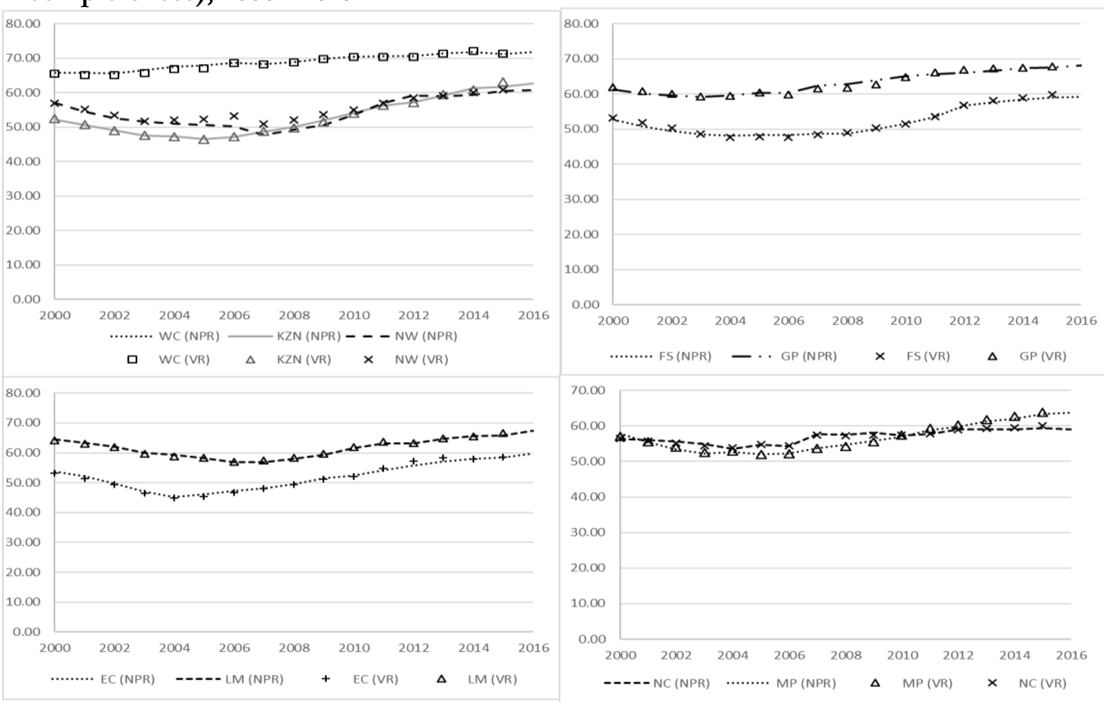


4.11 Life expecatncy at birth

Trends in life expectancy at birth for all the provinces is shown in Figure 4-7.

As expected, the estimates from the VR data and NPR data are consistent with each other for all the provinces. For all the provinces, estimates from NPR and VR show a trend that is impacted by HIV and the rollout of ARVs. Life expectancy declined from 2000 to 2004 and then increased from 2005 for NW, KZN, LM, NC, MP, FS and GP. Much of the improvement is between 2008 to 2011, after that there is a certain leveling off in more recent years. The trends implied by these adjustments for WC is different to all other provinces. Life expectancy is higher than all other provinces and slowly increasing from 66 years in 2000 to 73 years in 2016. This increase in life expectancy for all the provinces is possibly due to a substantial decline in child mortality and also, in part, to a decline in adult mortality (${}_{45}q_{15}$), probably due to the effects of ARVs.

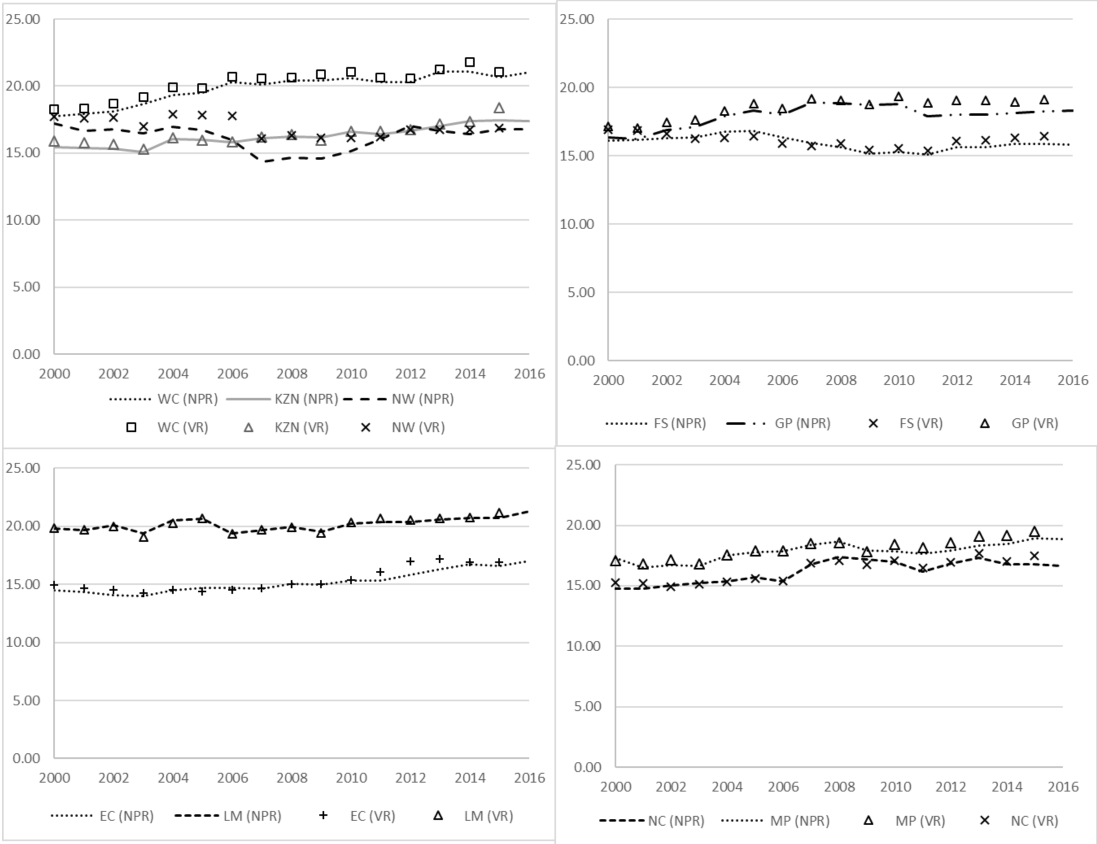
Figure 4-7 Life expectancy from NPR and VR for all the provinces (after adjusting for incompleteness), 2000 - 2016



4.12 Life expecatncy at age 60

The life expectancy after the age of 60 (e_{60}) is used to track mortality at older ages. The trend for all the provinces is shown in Figure 4-8. As expected, the results from the NPR and VR data yields estimates that are consistent with each other and they imply that older age mortality has been declining slowly over time (and not yet affected by the HIV epidemic).

Figure 4-8 Life expectancy at age of 60 from NPR and VR (after adjusting for incompleteness), 2000 to 2016

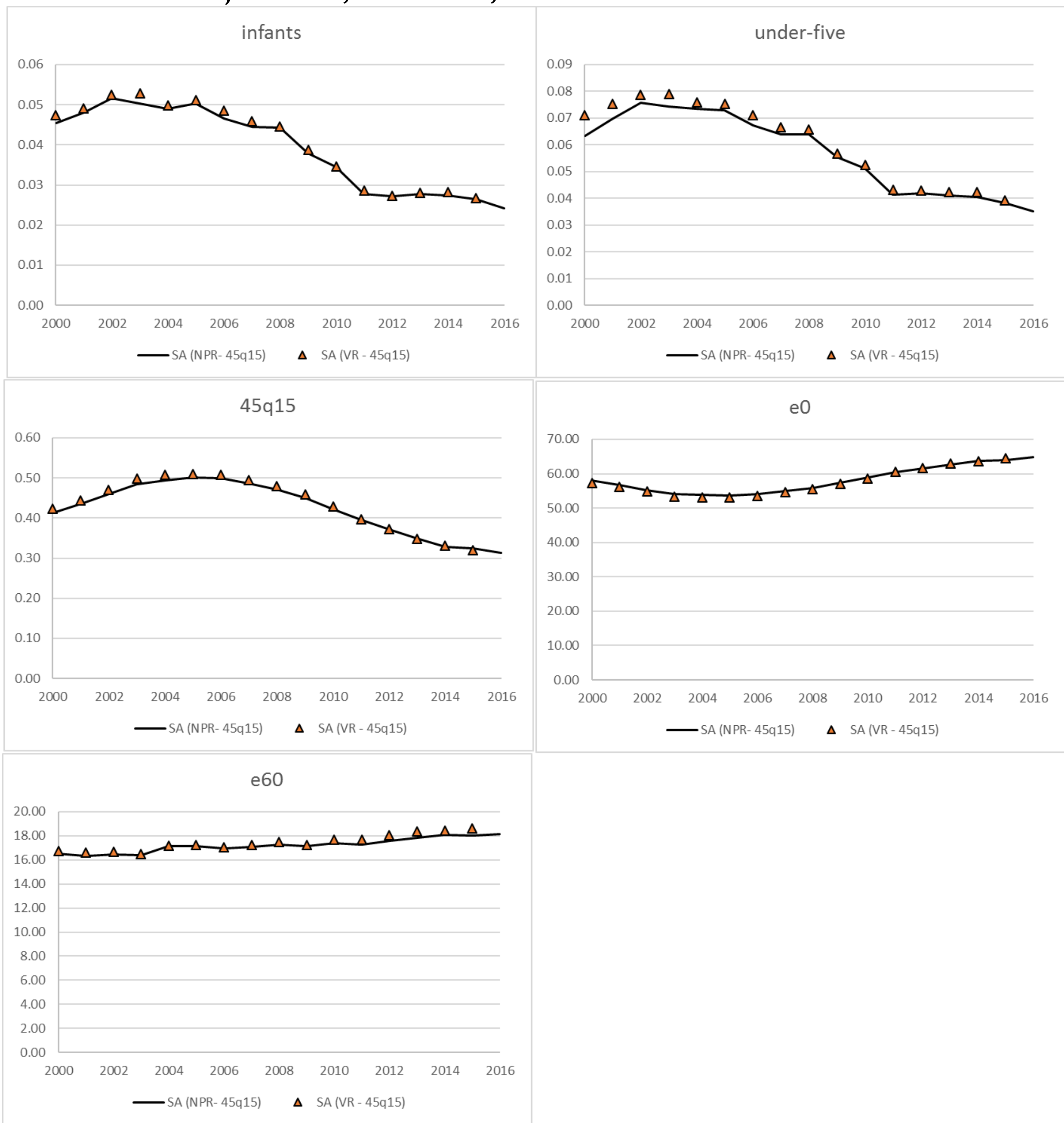


4.13 Mortality indicators at the national level

Figure 4-9 shows the trend in child mortality, adult mortality life expectancy at birth, and life expectancy after the age of 60 derived using the same approach as for the provinces.

As can be seen from Figure 4-9, the estimates from the NPR data and VR data are consistent with each other and the trends in IMR are similar to U5MR. The estimate of adult mortality (${}_{45}q_{15}$) derived from VR is slightly lower, those of (e_0) and (e_{60}) are slightly higher for the year 2015, compared to estimates from the NPR, reflecting that deaths in the VR are slightly lower to those from NPR. This might be due to the effect of late registration in 2015. Trends in older age mortality show that there is a slight decrease in the older age mortality in the period 2000 to 2016.

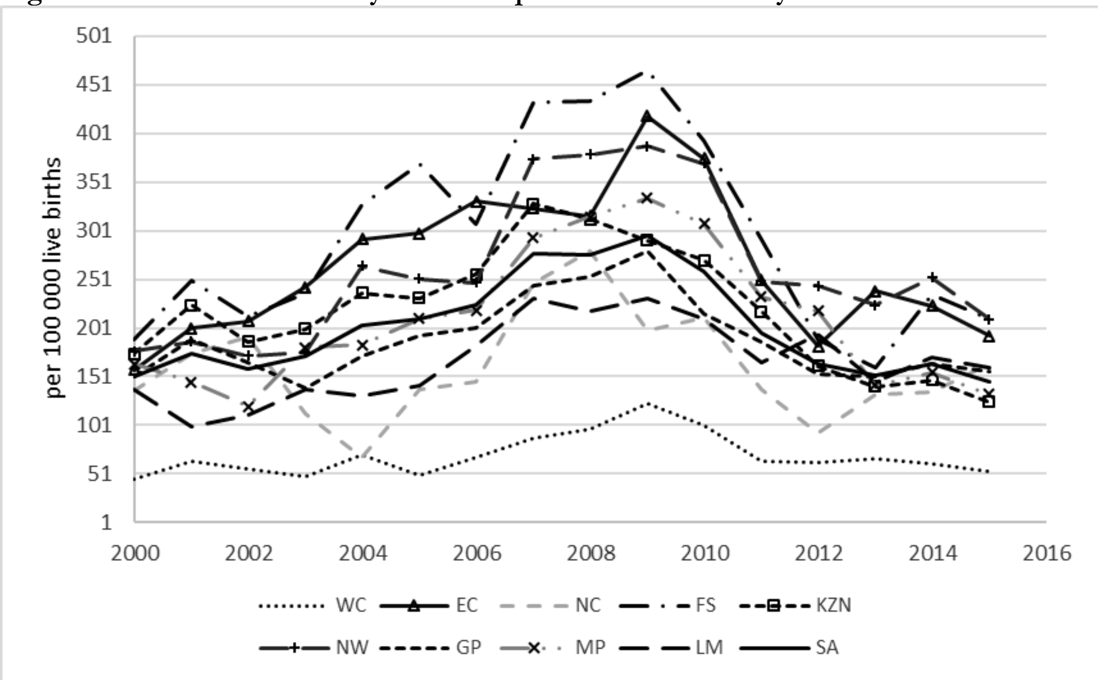
Figure 4-9 Child mortality, Adult mortality from and Life Expectancy from NPR and VR adjustments, 2000 – 2016, for SA



4.14 Maternal mortality

Adjusted maternal deaths for non-registration and misspecification as described in section 3.5 are used to derive maternal mortality for each province and the country as a whole by dividing these deaths by CARe_3.2 births. Figure 4-10 shows these estimates of MMR for all the provinces over time. Although there is great uncertainty in the level of the estimates of this indicator as documented in the RMS reports, the estimates for all the provinces tell a similar story. For all the provinces and from the year 2000, maternal mortality increased, peaking between 2006 and 2010 and then declining after 2010. There is a great deal of consistency in this trend driven by the impact of HIV, the provision of ARVs and the change in the ARV guideline. In addition, it can be seen that MMR is substantially lower in WC than all other provinces.

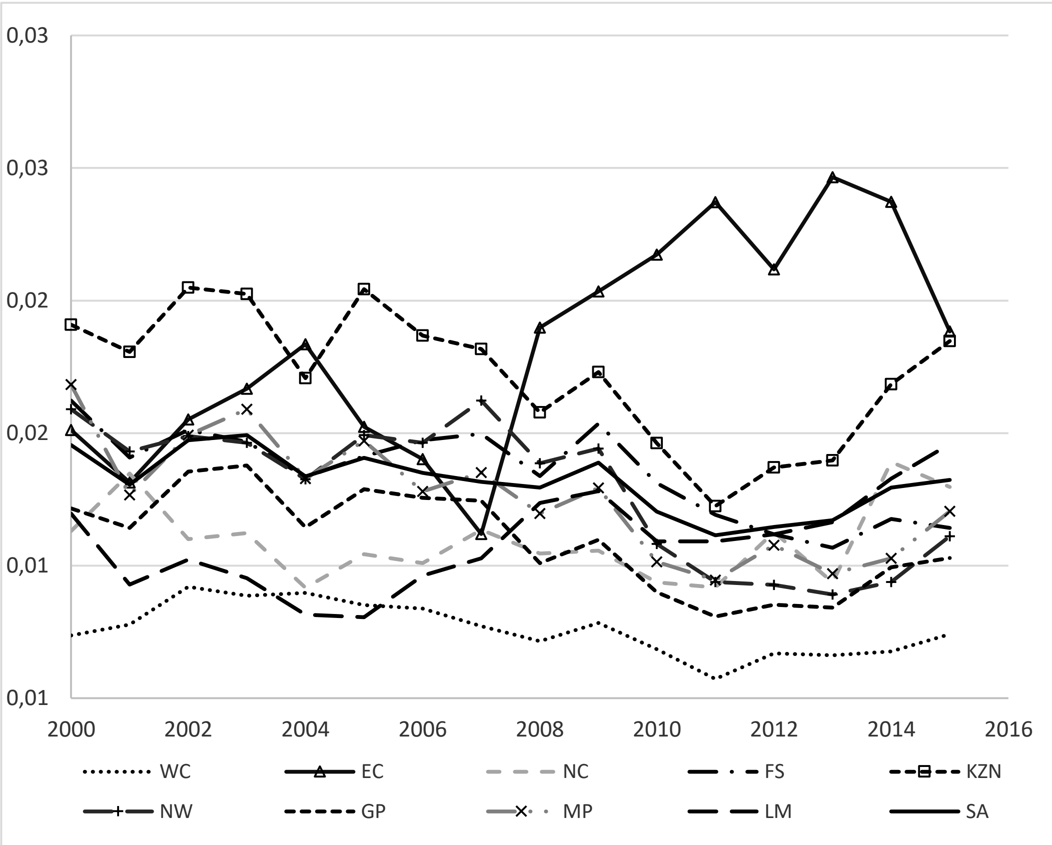
Figure 4-10 Maternal mortality for all the provinces and country as a whole



4.15 Neonatal mortality

Neonatal mortality per 1000 births is estimated as the ratio of adjusted neonatal deaths described in section 3.5 for each year over live-births from the CARe_3.2 model. The estimates are shown in Figure 4-11. There is slight evidence that neonatal mortality for the provinces such as WC, FS, MP, GP and NW has been declining gradually over the period 2000 to 2015 while for LM and NC it remained roughly constant. However, it can be seen that for EC using different data sources (VR and DHIS) yields inconsistent trends over time. The estimates derived using VR data from 2000 to 2007 and DHIS data from 2008 to 2015 imply an implausible change in the estimates from a low level in 2007 to a high level in 2008 to 2015. This changeover is due to the effect of using data from the DHIS, which captured more deaths than the VR. Thus, there is a great deal of uncertainty in neonatal mortality estimates.

Figure 4-11 Neonatal mortality (per 1000 live-births) for all the provinces and country as a whole



4.16 Comparison with estimates from other sources

An important question after deriving estimates of mortality is how they compare with estimates from other sources. The estimates derived from the NPR and VR data at the provincial level are judged by comparing them with estimates from other sources. However, it must be noted that there are few sources with which to compare our estimates because it is difficult to estimate mortality at the subnational level in developing countries where vital registration is incomplete and census questions are prone to coverage and content errors (specific patterns of under-reporting or over-reporting). Standard indirect techniques for estimating the completeness of adult mortality at a subnational level perform poorly because of interprovincial migration which is usually substantial and difficult to measure accurately.

4.16.1 IMR

The estimates of infant mortality are compared with estimates from three sources Dorrington, Moultrie and Timæus (2004), Udjo (2014) and Zewdie (2014).

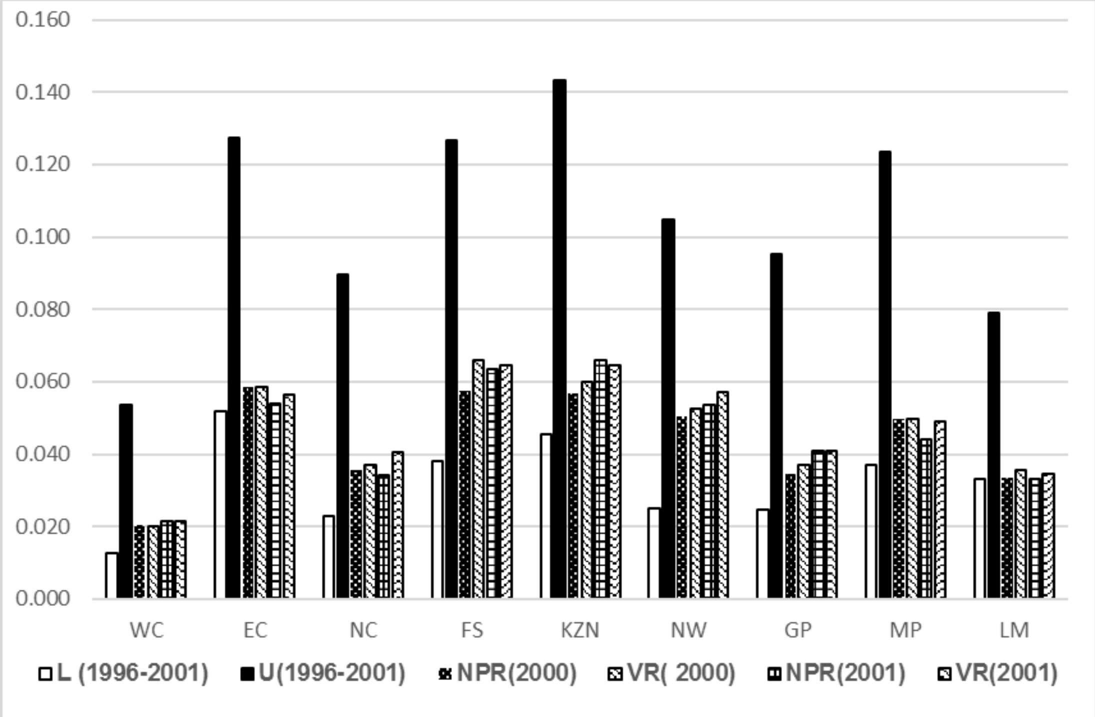
The first source of estimates, Dorrington, Moultrie and Timæus (2004), covering the years 1996 to 2001, are their lower and upper mortality estimates based on extreme assumptions of low and high mortality. The lower mortality estimates are derived by ignoring the impact of HIV and the upper mortality estimates are derived by considering HIV/AIDS but ignoring the impact of prevention of mother to child transmission and antiretroviral treatment programmes, which were largely non-existent at that time. One would expect that plausible estimates to lie between the lower and upper limits.

The second source of estimates, Zewdie (2014), for the year 2011, are the smoothed estimates computed by aggregating the municipal level Bayesian smoothed estimates and the direct estimates derived using reported household deaths and births occurred twelve months before the 2011 census.

The last source of estimates, Udjo (2014), are derived using reported household deaths that occurred twelve months before the 2011 census.

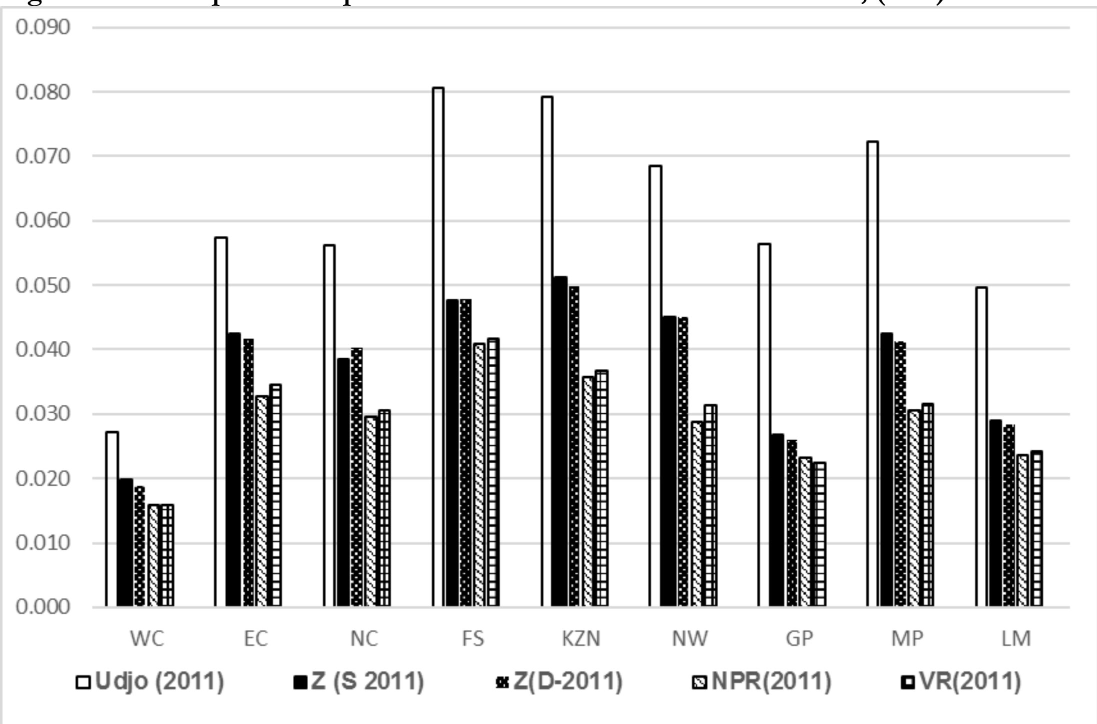
The comparisons of the infant mortality with the first source are shown in Figure 4-12 below. "L(1996-2001)" and "U(1996-2001)" are lower and upper estimates of infant mortality from Dorrington, Moultrie and Timæus (2004), NPR(2000), VR(2000), NPR(2001) and VR(2001) are the estimates from NPR and VR data for the years 2000 and 2001.

Figure 4-12 Comparison of provincial level IMR from various sources, (2000 to 2001)



It can be seen that both pairs of estimates from NPR and VR data for the years 2000 to 2001 for all the provinces for the infants fall within the lower and upper bounds of the estimates produced by Dorrington, Moultrie and Timæus (2004) except LM. Our estimates for LM, if correct, suggest that the lower bound for IMR is slightly high.

Figure 4-13 Comparison of provincial level IMR from various sources, (2011)



It can be seen from Figure 4-13 that the estimates for the year 2011 both from NPR and VR data are similar to the estimates of Zewdie (2014) but they are noticeably lower than those from Udjo (2014) for all the provinces. Despite using the same data source, the 2011 census, Udjo's estimates are implausibly higher than estimates of Zewdie (2014) and they are almost double estimates from NPR and VR data for most provinces. Although it is difficult to know in which range the true estimates of child mortality lie, it is probable that, unlike Udjo (2014)'s estimates, which are implausibly high as they imply improbably low levels of child completeness of death registration for all the provinces and the country as a whole, our estimates are sensible. Using CARe_3.2 births and calculating the completeness of infant death registration implied by Udjo (2014)'s estimates in 2011 for the country as a whole produces an estimate of completeness of death registration for the infants of 39 per cent. Completeness of death registration has been improving in South Africa and these levels are substantially lower than would be expected.

Comparison of the rankings of the provinces according to the levels of child mortality shows that estimates from NPR and VR data are consistent with the estimates from Zewdie (2014). They all suggest that both IMR and U5MR are high in high mortality provinces (provinces that are known to be affected by HIV, like KZN, and poor provinces, like EC, compared to other provinces, like WC and GP.

4.16.2 U5MR

The comparison of the NPR and VR estimates with lower and upper bound estimates from Dorrington, Moultrie and Timæus (2004) is shown in Figure 4-14 below. Our estimates fall within the bounds for all the provinces except, for a few instances, in EC, KZN and LM. Estimates for LM and for the other two provinces, which are known to have high HIV prevalence, fall slightly below the lower bounds. It is quite possible that the lower bound estimates are too high because the assumptions and procedures made did not do enough to ignore the impact of HIV on mortality.

Figure 4-14 Comparison of provincial level U5MR from various sources, (2000 to 2001)

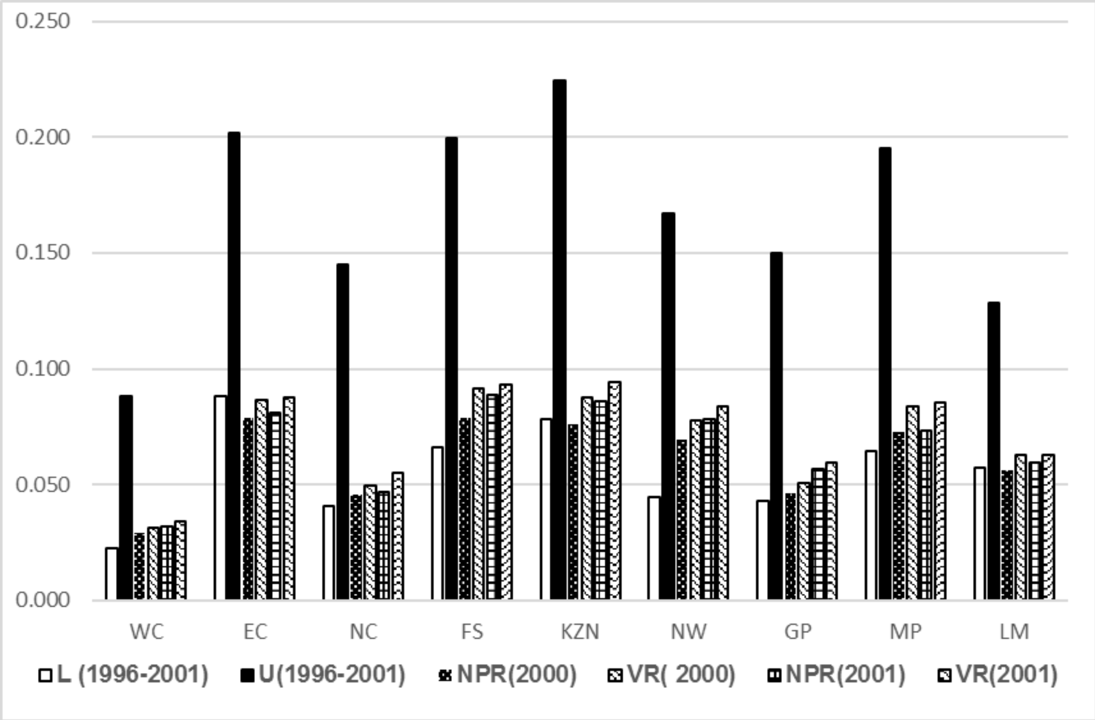
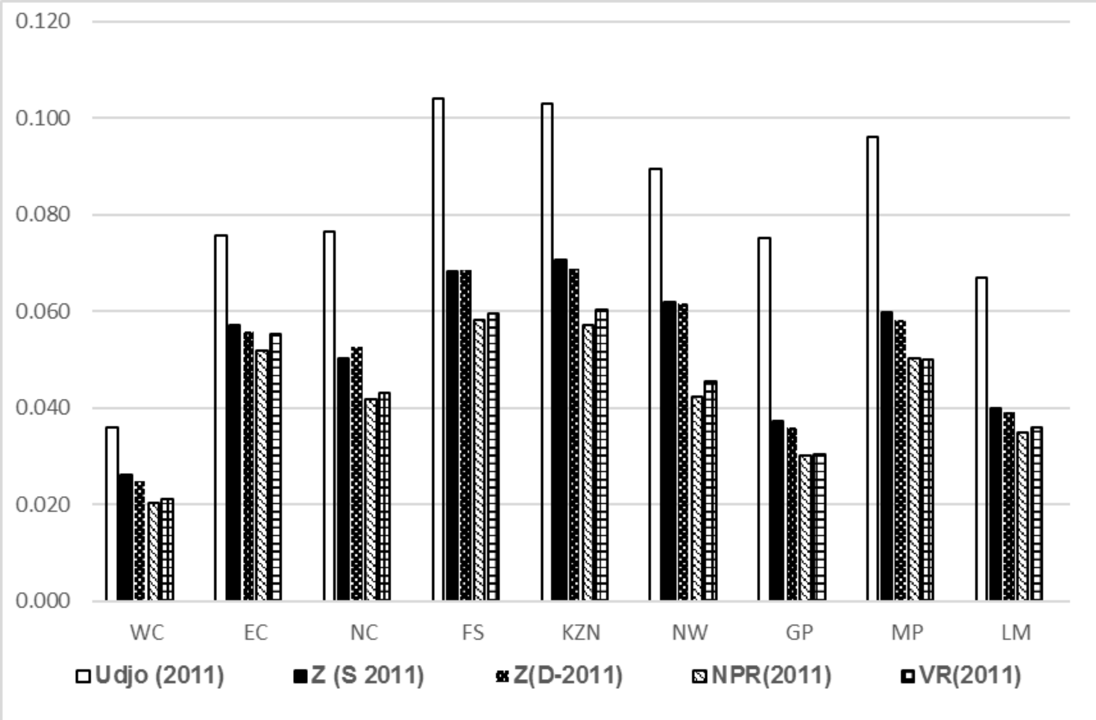


Figure 4-15 shows the comparison of our estimates with estimates from Udjo (2014) and the direct and smoothed estimates from Zewdie (2014) for the year 2011 for all the provinces. For all the provinces both estimates from NPR and VR data are comparable to estimates from Zewdie (2014). Again estimates are implausibly high for all the provinces. Repeating the same procedure as applied to the infants to estimate the implied estimates of completeness shows that Udjo (2014)'s estimates again imply an implausibly low completeness of registration of 40 per cent for the under-five deaths.

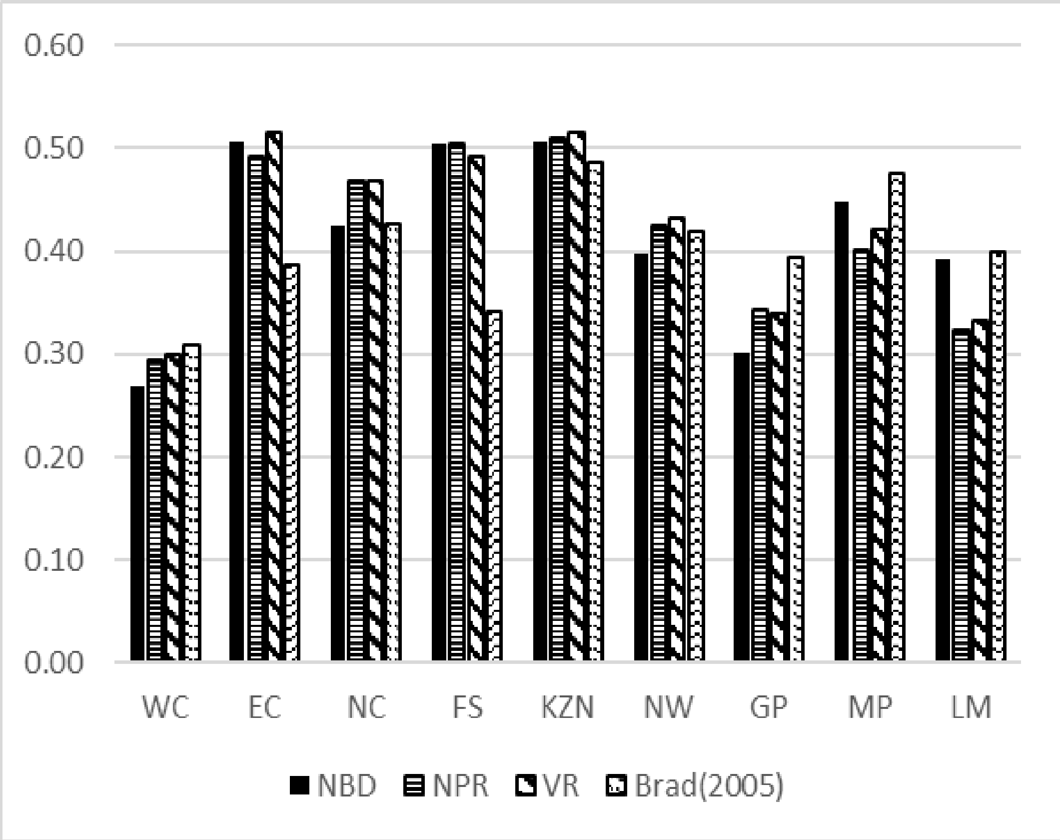
Figure 4-15 Comparison of provincial level U5MR from various sources, (2011)



4.16.3 Adult mortality

For the comparison of adult estimates from NPR and VR data, estimates by Bradshaw, Nannan, Groenewald *et al.* (2005) for the year 2000 as shown in Figure 4-16 and estimates from the NBD study by Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016) for the years 2000, 2005, 2010 and 2012 as shown in Figure 4-17 are used. It can be seen from Figure 4-16 that estimates from NPR and VR data are reasonable and consistent with estimates from the NBD and Bradshaw, Nannan, Groenewald *et al.* (2005) for all the provinces except EC and FS. The estimates from Bradshaw, Nannan, Groenewald *et al.* (2005) suggest that adult mortality in 2000 for the EC and FS provinces was significantly lower than the estimates from NPR and VR data and NBD. In terms of rankings, the estimates are consistent with each other. They all suggest that in 2000 adult mortality was high in KZN and was low in WC compared to all other provinces.

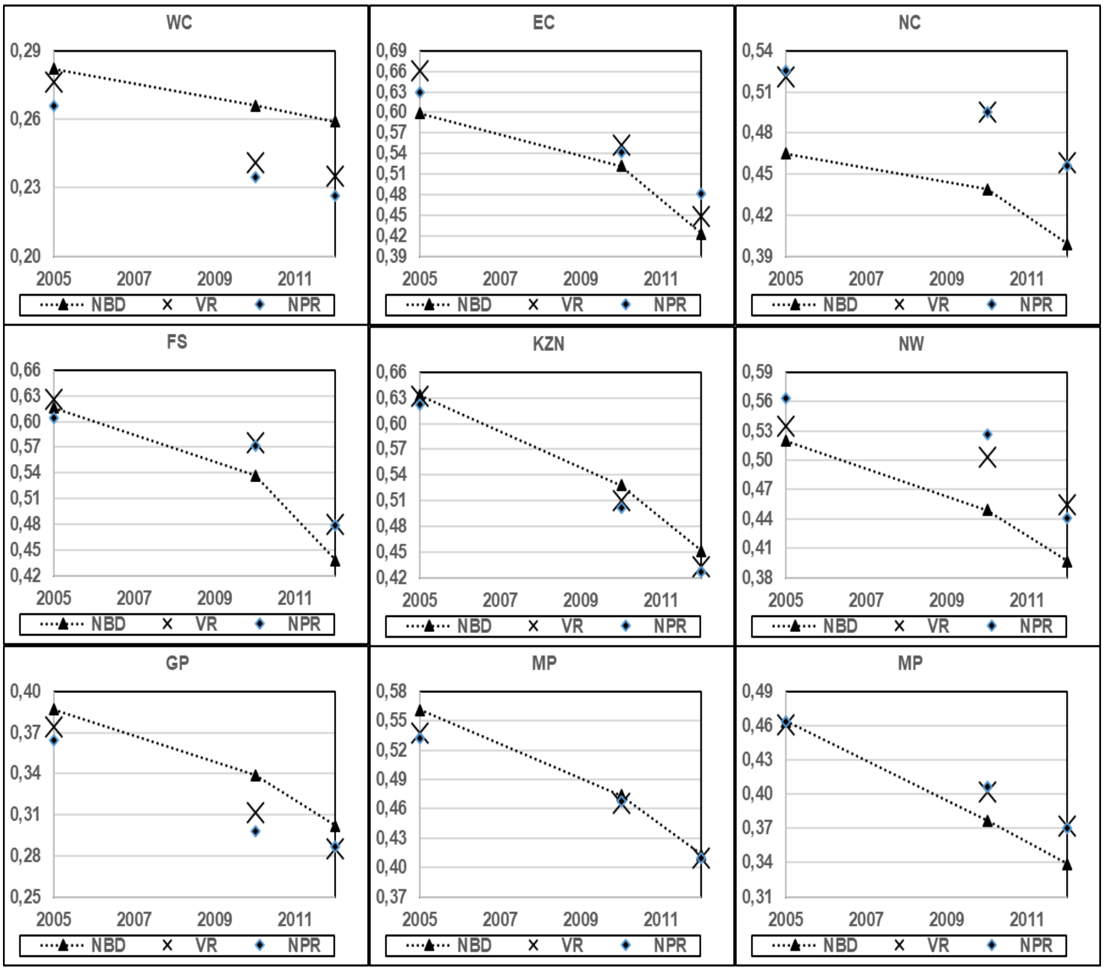
Figure 4-16 Comparison of provincial adult mortality from other sources, 2000



As far as estimates for the years 2005, 2010 and 2012 are concerned, it appears from Figure 4-17 that for all the provinces, estimates from the NPR and VR data are consistent as they show a similar trend to the estimates from the NBD study. They all suggest that adult mortality for all the years (2005, 2010 and 2012) was high in KZN, EC, and FS and was lower in WC and GP. In addition, they all suggest that in recent years, adult mortality has been declining, and the decline is more rapid in high mortality provinces like EC, KZN compared to WC and GP. However, for LM, NC, NW, GP, and FS, one can see that estimates from NBD study are closer to the estimates from the NPR and VR data in 2005 than more recent years, 2010 and 2012. Considering that the estimates from the NBD study were derived before the release of registered deaths for the year 2011 and the problem of missing ages in deaths reported by households in 2011 census (25 per cent of the deaths had age unrecorded), it is possible that the estimates from NPR data and VR data are probably more reliable than these estimates.

There is a noticeable difference between the estimates from the VR data and those from the NPR data for NW and GP between 2005 and 2010. However, considering the problems in the quality of VR data outlined in the section 3.1.2, estimates from the NPR are considered to be the better estimates.

Figure 4-17 Comparison of provincial adult mortality from other sources, 2005, 2010 and 2012



4.16.4 MMR

Dorrington and Bradshaw (2015) observe that there is a great deal of uncertainty regarding estimates of MMR. This can be seen from the comparison of our estimates from VR data to those of Garenne, McCaa and Nacro (2007) for the year 2000 and Moodley, Pattinson, Fawcus *et al.* (2014) covering the years 2005-2014 in Figure 4-18.

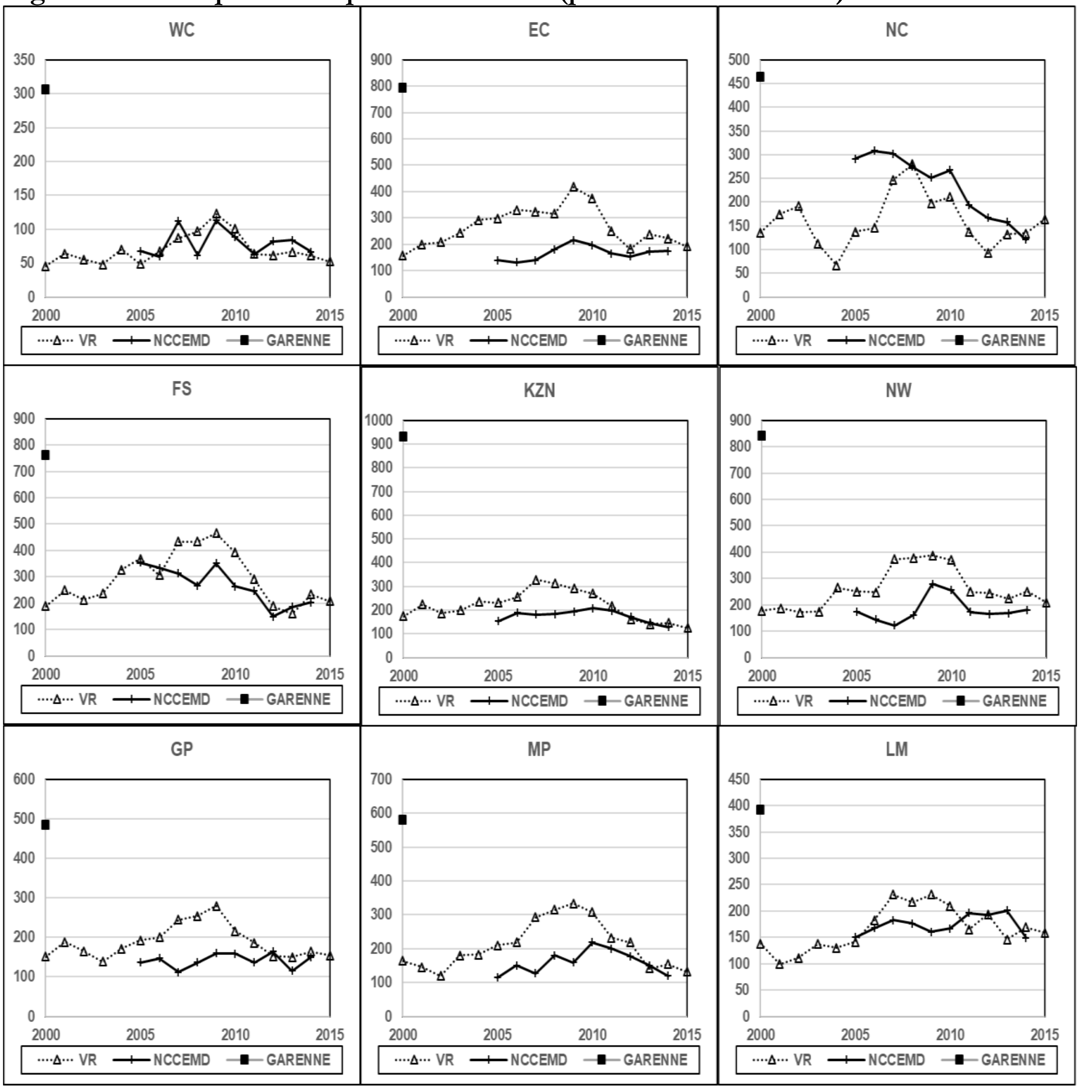
The estimates from Garenne, McCaa and Nacro (2007) were derived using household deaths reported from the 2001 census. The numbers of births were derived by back-projecting the number of infants counted in 2001 census using survival factors computed directly from the data. Those from Moodley, Pattinson, Fawcus *et al.* (2014) were derived using deaths reported to National Committee for the Confidential Enquiries into Maternal Deaths (NCCEMD).

The estimates from Garenne, McCaa and Nacro (2007) for the year 2000 for all the provinces are high compared to all other estimates. Differences in these estimates are to some extent due to the fact that Garenne et al's estimates are actually pregnancy related mortality ratios, which one would expect to be higher (although not that much higher). Regardless of the fact that the estimates from Garenne, McCaa and Nacro (2007) appear to be too high compared to all other estimates, all sources suggest the same ranking of the provinces according to the levels of maternal mortality. They all suggest that, for provinces like WC that are known to approach developed countries living standards, maternal mortality was low in 2000, while for those provinces that are known to have living standards closer to rural areas of sub-Saharan Africa and mostly affected by HIV epidemic, maternal mortality was high.

Our estimates appear to be higher than the estimates from Moodley, Pattinson, Fawcus *et al.* (2014) for all the provinces. The reason is that the data sources differ and MMR of births outiside public facilities could be higher (which is, of course, uncertain, since this include births from private facilities). In addition NCCEMD includes only deaths that can be clearly defined as due to maternal cause, whereas our approach not only relies on the VR recorded causes, but adds 50% for misclassifications.

However, both sources are in agreement that FS has shown the biggest decline in MMR. In addition, both sources imply that all provinces except LM have shown a decline in maternal mortality in more recent years. This recent decline in MMR is in line with the declining maternal deaths reported in the most recent 2015 RMS report by Dorrington, Bradshaw, Laubscher *et al.* (2016).

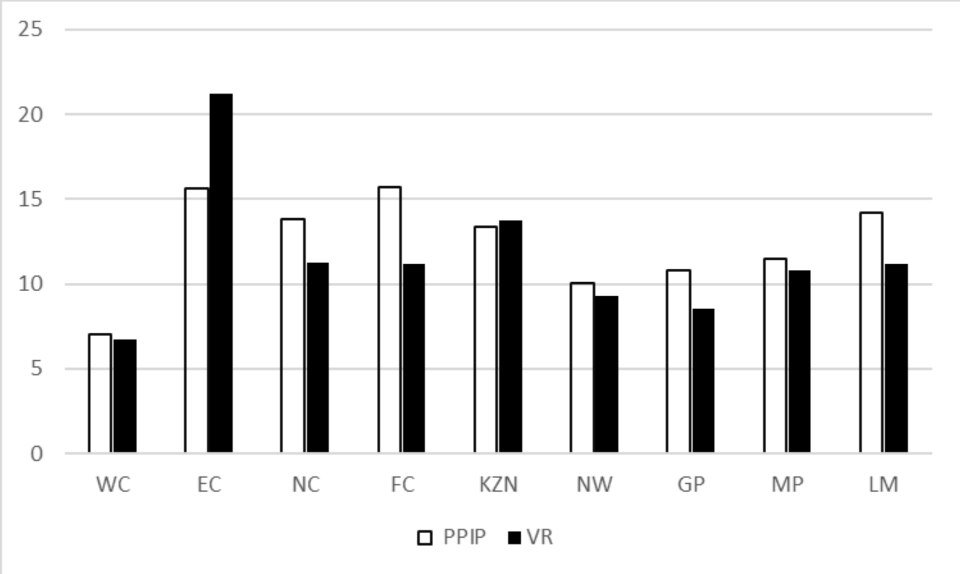
Figure 4-18 Comparison of provincial MMR (per 100 000 live-births) from other sources



4.16.5 NMR

Figure 4-19 shows the comparison of our estimates and NMR estimates derived from the early neonatal rates in the most recent Saving Babies report (2012-2013), by scaling up for an estimate of late neonatal (using the ratio of late to early neonatal from VR data for each province). Although it is difficult to know in which range the true estimates of NMR lie for the country as a whole, and even more challenging at the provincial level, it is fair to say that our estimates are in agreement with estimates from the Saving Babies 2012-2013 report for the majority of provinces. There is a noticiable difference between our estimates and those from the Saving babies report for EC and FS. While it is not clear for FS, the fact that the Perinatal Problem Identification Programme (PPIP) misses a lot of births for EC relative to DHIS in comparison to other provinces as documented in the most recent Saving Babies report could explain the difference for the EC. The ranking of the provinces shown by both sources is sensible. They show that NMR in 2012 was higher in provinces like EC and FS that are known to have poor healthcare services (delay in calling for skilled help, delays in referring the patient, no intervention for the lengthy second phase of labor and failure to monitor and detect fetal distress).

Figure 4-19 Comparison of provincial NMR (per 1000 live-births) from other sources



4.17 Conclusion

This chapter has presented the evaluation of NPR and VR data, the adjustment of NPR data and developmental factors used to adjust estimates of completeness of death registration to cater for deaths that are to be reported in future as late registration. The mortality indicators obtained after adjusting NPR deaths for two forms of underreporting and VR deaths for the general under registration have been dicussed as well as estimates of MMR and NMR. The reasonableness of these estimates has been assesed by comparing with estimates from other sources.

The estimates from NPR and VR data presented in this chapter appear to be reasonable. They are sensible in terms of epidemiological expectations. For example, both estimates from NPR data and VR data show the impact of HIV, poverty, and underdevelopment, the major leading causes of death noted by Bradshaw, Groenewald, Laubscher *et al.* (2003) for high mortality provinces and the impact of PMTCT and HAART on mortality in more recent years.

However, taking into consideration problems identified in the VR data in the section 3.1.2, the estimates from NPR data may be more reliable. Despite uncertainties around the estimates of MMR and NMR as mentioned in sections 2.4.4 and 3.5, the estimates show some internal consistency for the majority of provinces.

5 DISCUSSION

5.1 Introduction

In order to reduce mortality in a country like South Africa (heavily affected by HIV), efforts need to be placed on lowering mortality at the subnational level. Having up-to-date reliable mortality estimates at sub-national level might help these efforts to work effectively. Thus, the overall objective of this study was to examine whether one can use RMS data (NPR data and VR data) at the provincial level to produce up-to-date, reliable, and consistent estimates of child (infant and under-five) mortality rates, adult mortality rates and life expectancy at the provincial level. In addition to this, the research investigates whether VR and DHIS data at the provincial level can be used to produce consistent and reliable estimates of neonatal and maternal mortality at the provincial level. The purpose of this final chapter is to reflect on the results attained, to determine whether the objectives of this study were accomplished. Overall conclusions are drawn on whether these objectives have been met and possible areas of future research that arises from this work and the limitations of the study are identified.

5.2 Evaluation of RMS data and the completeness of NPR relative to VR

RMS data had to be evaluated for internal consistencies before being used to estimate mortality indicators. A list of offices by province downloaded from the DHA's home page was used to check the accuracy of the allocation of offices in each province by MRC. No problems with MRC's method of allocation were detected and this is good in terms of the quality of NPR data.

The evaluation of the NPR and VR data, and adjustment of NPR data relative to VR data was achieved by calculating the ratios of NPR deaths to VR deaths for each sex and in age groups 0, 1-14, 15-24 and 25+ for each province. The findings showed that the completeness of NPR deaths relative to VR deaths for the infants is increasing and there are no signs of levelling off yet, and it is lower than for other age groups. This, in turn, suggests the need for larger adjustments to NPR deaths to estimate VR deaths for the infants. In addition, continuous extrapolation into the future after 2015 (the year yet to include late registrations) assuming a constant change in completeness from 2013 will eventually produce implausibly high estimates of completeness as the trend is expected to level off after reaching high levels (i.e. as it approaches 100 per cent like other age groups). However, since the completeness of birth registration has been increasing over time and the extrapolated estimates of completeness for the infants using this assumption for all the provinces are still low (less than 75 per cent) in 2016, we can expect the estimates of completeness to continue increasing at this constant rate. However, this assumption should be monitored in the future especially when the completeness reaches more than 90 per cent as the change in the completeness can be expected to level off as it approaches 100 per cent like all other age groups. Then, the logistic extrapolation could be an alternative assumption.

This research identified a problem in the RMS data from the ratios of NPR data to VR data for the age groups 1-14, 15-24 and 25+ for NW and GP. It was argued in section 4.2 in particular that there is some evidence that Stats SA might have misallocated some VR deaths from NW to GP when allocating VR deaths to 2011 provincial boundaries. However, this reduces our confidence in extrapolated estimates of completeness of NPR deaths relative to VR deaths.

In line with Dorrington, Bradshaw, Laubscher *et al.* (2016) this research found that for the 25+ age group the ratios of NPR deaths to VR deaths are slightly more than 100 per cent at the national level from 2012. It was argued in section 4.2 that, it is quite possible for the numbers of the NPR deaths to be more than VR deaths at the sub-national level because NPR data only considers the offices where the death has been registered instead of province of death. However, unlike the 2015 RMS report, this research found that the problem is less pronounced with the ratios exceeding 100 per cent by less than 1 per cent since 2012 and by only 1 per cent in 2015. This leads to the conclusion that, it is more likely that most of the discrepancies noted in the 2015 RMS report and in this research are a problem of late registration especially after the reduction of the time lag in the release of the cause of death data by Stats SA. However, this needs to be monitored in future, in particular, why the problem is more pronounced in female deaths and this matter needs further investigations.

To produce the mortality indicators the irregularities in VR data were corrected using the same approach from the 2015 RMS report. Using the 2011adjustments factors to adjust NPR deaths where VR data are either unreliable or yet to be processed. Assuming that the problem of more than 100 per cent completeness of NPR data is only pronounced in provinces showing completeness of more than 100 per cent and that this started after the reduction of the time lag in the release of the cause of death data in 2012. In addition to this, anomalies in VR data between NW and GP were corrected by transferring the numbers of VR deaths from GP to NW such that the resulting completeness of NPR for these two provinces increases gradually between 2005 and 2010.

5.3 Completeness of vital registration

For the second adjustment to the NPR deaths and also for the general under registration, estimates of child mortality from the NBD study by Pillay-van Wyk, Laubscher, Msemburi *et al.* (2016) from 2000 to 2010, together with CARe3.2 births were used to derive estimates of child mortality and hence completeness of child death (infants, under-five and the 1-4) registration for all the provinces from 2000 to 2010. For the adult (15+) completeness, the two-time points of estimates of adult mortality rates for each province (2001 and 2011) by Dorrington and Timæus (2017) were used to estimate adult completeness of death registration assuming a linear change between these two periods.

The decision on what trend in the completeness to extrapolate for each province is difficult. A linear trend is problematic as it can lead to implausibly high estimates of completeness in the future, especially for the provinces showing a more rapid increase or decrease in the completeness. Instead, one could fit a logistic curve, but the decision on the maximum value for the curve for each province is not an easy one to make because some provinces like WC and GP are likely trend towards a completeness of more than 100 per cent. For these reasons, it was considered to be sensible to assume that for each province, the true numbers of child deaths for each year from 2010 changes with the same growth rate implied by projections of the numbers of death using the CARe3.2 model.

The research found that for WC, EC, KZN, NW, MP and LM estimates of completeness of child death registration (both infant and under-five) appears to have stabilised over reacent years and it is assumed that this trend might continue at this level going forward. However, for FS and GP, results showed that there is a gentle downward trend in the completeness of child death registration over recent years. The reasons for this downward trend for these two provinces is not clear but it is assumed that this could be continued, but only for the next 3 years or 5 years, checking with each annual update of VR deaths the reasonabless of this assumption. The same conclusion as drawn for child death registration can be drawn for adult death registration for WC, NC, NW, GP and LM, where the completeness appears to have stabilzed in recent years. In addition, for FS and EC where there is a gentle downward trend and for KZN and MP where there is a gentle upwrd trend in the completeness of adult death registartion in recent years, a similar conclusion drawn for FS and GP for child death registration is also made for these provinces.

5.4 Mortality Indicators

The IMR and the U5MR are key indicators of child health and overall development. While the indicators at national level are important for monitoring progress towards the achievement of MDGs, reliable estimates at the sub-national level are critical for prioritising child health care and services. Although VR is the primary source of death data, the rapid epidemiological change and the delay in the release of these statistics reduces the utility of these indicators. However, this research showed that after correcting for the anomalies in the VR data by making suitable assumptions it is possible to derive reliable, consistent and timeous child mortality estimates at provincial level sooner than the release of vital statistics by Stats SA.

The trends obtained across provinces shows plausible consistencies with what is known about the proximate determinats of infant and child mortality in South Africa. Nannan, Bradshaw, Timaeus *et al.* (2000) show that there is a correlation between infant mortality, poverty as measured by households with income less than R600 per month and HIV prevalence. However, as mentioned in sections 4.16 it is difficult to assess the external consistencies of the estimates as there are limited sources to which to compare our estimates. But from the few sources to which we compared, it appears that the estimates from this reasearch are quite reasonable and consistient with at least some of these estimates.

The results prodcued show that it is possible to estimate adult mortality, an indicator which has been overshadowed for many years in sub-Saharan Africa by focus on child mortality partly due to lack of reliable emperical data (Joubert, Rao, Bradshaw *et al.* 2012). Provinces which are mainly urban, such as GP and WC, are shown to have lower levels of adult mortality over time mainly because of population group composition and better socio-economic standard compared to other provinces. The WC, in particular, is estimated to have much lower levels of adult mortality over time because of the lower levels of HIV prevalence compared to other provinces.

While the findings imply that there is much uncertanity about the actual levels of MMR, it was possible to derive estimates that show internal consistencies across all provinces and over time. Abdool-Karim, AbouZahr, Dehne *et al.* (2010) point out that there is no clear understanding of the dimensions and pathways of HIV on the risks of maternal death but findings of this study shows that provinces known to have high HIV prevalence have high levels of MMR and the trends over time are in line with epidemilogical expectations. This is important and implies that reducing maternal mortality require a comprehensive approach to the prevention and treatment of HIV among women.

Data from VR and DHIS can be used to derive sensible trends over time of estimates of NMRs at provincial level for South Africa. However, it is difficult to assertain with a high degree of certanity the actual levels of mortality for this indicator because different data sources produce inconsistient levels of estimates of NMR. South Africa has several sources of neonatal death data, but the quality for each source undermines efforts to combine these by making use of the strength of each to produce reliable estimates of sub-national level mortality. These sources include VR which is incomplete especially for child deaths and in rural areas. Data obtained from the Agincourt HDSS indicated that less than 30 per cent of child deaths (under the age of 14) were registered (Kahn, Garenne, Collinson *et al.* 2007). The DHIS data, on the other hand, misses deaths occuring outside health facilities, and the DHS is not always available and uses a different defination to DHIS for neonatal death (Rhoda, Velaphi, Gebhardt *et al.* 2018).

5.5 Limitations of the study

More challenging has been the decision on the adjustement of maternal deaths for the problem of mis-classification of cause of death to estimate MMR across all provinces. VR is the optimal source for estimating cause-specific mortality estimates, but it suffers from a number of problems such as incomplete death registration, and urban bias in registration (Joubert, Rao, Bradshaw *et al.* 2012). The registration of deaths suffer from incomplete medical certification of the cause of death, including a high proportion of ill-defined cause of death and misclafficification of cause of death (Bradshaw, Schneider, Darrington *et al.* 2002; Groenewald, Bradshaw, Dorrington *et al.* 2005). These problems with registration are more likely to be pronounced in rural provinces as a proportion of natural deaths are registered by traditional headmen, on the basis of information about deaths provided by a relative (Joubert, Rao, Bradshaw *et al.* 2012). While this improves the overall completeness of death registration it may affect up to 10 per cent of the cause of death classifications of rural deaths (Bradshaw, Pillay-Van Wyk, Laubscher *et al.* 2010). Therefore the 50 per cent increment of matenal deaths for the problem of mis-classifiction, an adjustement made in section 3.5 may work for predorminantly urban provinces but not be enough for rural provinces. However, in this study, there was not enough time to consider how the 50 per cent adjustment should be modified to take into consideration possible differences in the problem of misclassification across all provinces. In addition, it was difficult to asssess the appropriateness of this adjustement for all the provinces as there are fewer sources to compare the reasonableness of our estimates.

It is reasonable to assume that births in private health facilities have lower or negligable NMR because most neonatal deaths are due to preventable causes that could have been avoided within the health care system and these private facilities are charecterised by high quality health care systems (Mabaso, Ndaba and Mkhize-Kwitshana 2014). However, the South African 2013 Child Death Review (CDR) pilot study at two mortuaries in KZN and the WC have indicated a high proportion, 44.4 per cent, of infant deaths that were associated with prematurity with a number of them occuring within 72 hours after discharge from the hospital (Mathews, Martin, Coetzee *et al.* 2016). This means some neonatal deaths occuring outside health facilities are unknown and in this study, by using the DHIS and CARe3.2 births they are not been accounted for. Had the numbers of births in the public facilties available for this research, the estimates could have been improved by dividing DHIS neonatal deaths by these births. But this will require an assumption that the out-of-facility NMR is the same as that in the public health facilities.

5.6 Scope of future research

The most important research going forward is to measure completeness of registration at the provincial level (e.g. by a survey identifying deaths in households and then checking to see if they were registered). Such a study would not only improve provincial estimates but give a sense of urban vs rural completeness and also by district.

Knowing that using NPR and VR data one can produce reliable estimates of mortality over time at the provincial level is an important step towards improving mortality measurement in South Africa. The next important logical step is to extend the RMS aproach to cover cause-specific mortality rates both at national level and provincial level. Trends in major causes of death can be monitored and the information used to estimate cause-specific-death estimates from the NPR data or for the years when VR data are yet to be released by Stats SA. This requires recognition of the problmes in the quality of cause-specific mortality data outlined in section 5.5 and finding solutions to these issues.

For South Africa and in rural areas or in case of home deaths, verbal autospy interviews may be used to provide information about the cause of death. If the deceased had visisted a health facility, then the members of the household may poseses some information about the likley cause of death to provide together with the signs and symptoms experienced by the deceased prior to their death. This will require adequate and on-going training in administering the interview and reviewing of questionnaires to ascertain cause of death (Rao, Bradshaw and Mathers 2004).

Apart from the efforts to accelerate the release of the cause of death reports as suggested by Dorrington, Bradshaw, Laubscher *et al.* (2016), there is a need for research to determine what the reasons are for missing deaths from the VR for all the provinces. These investigations should explore, in particular, the reasons for missing VR females deaths in order to determine whether it is the problem of age mis-recording that is more pronounced for females than males or if there are other reasons. Furthermore, this should involve investigating whether this problem for the provinces started after the reduction of the time-lag in the release of the cause of death reports and which provinces are affected most by this problem.

There is a need for thorough investigation of the VR data for the inconsistencies identified in the NW and GP for the period from 2005 to 2010. This involves checking the reasonableness of the method of allocation of VR deaths according to 2011 provincial boundaries by Stats SA.

Since the ultimate completeness of the NPR is mostly affected by the completeness of birth registration, there is also the need for investigations of NPR completeness for all the provinces relative to true number of births The information on birth registration at provincial level will add value to the accuracy of estimates of completeness of infant deaths registration.

5.7 Conclusion

The overall conclusion that can be drawn from this study is that despite some problems in the quality of VR data, RMS data can be used to produce consistient and reliable mortality estimates at the provincial level. There are efforts already in place by some researchers to estimate mortality at district level for South Africa and this could help in extending the RMS approach to district level. These include the infant and under-five mortality estimates by Zewdie (2014) and adult mortality estimates by Chinogurei (2017). Doing similar studies at different time points can make it possible to estimate time series estimates of completeness of death registration at district level and help extend the RMS method to cover district mortality. This allows researchers to point out significant differences at this level, thus assisting health district officials to plan for a locally-appropriate response towards achieving targets of SDGs.

There should be prioritization of the capturing of neonatal and maternal deaths. In South Africa where there is near complete urban birth and death registration while in rural areas there is under-servicing of the civil registration, sample registration system (SRS) in rural areas may be useful interim measures of collecting death data towards developing a complete vital registration (Rao, Bradshaw and Mathers 2004). SRS is based on continuous enumeration of births and deaths within a national representative set of population clusters. Use of this system together with verbal autopsy questionnaires could be followed by studies to measure the reliability and efficiency of these methods of collecting death data and cause specific data. This may help researchers and organizations in deriving consistent or more accurate estimates for tracking progress towards SDGs and evaluation of intervention programs concentrating on reducing maternal and neonatal mortality.

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APPENDICES

Table 10 Completeness of NPR relative to VR, infants

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
WC	23%	26%	33%	32%	32%	32%	38%	41%	39%	37%	38%	39%	40%	45%	45%	44%
EC	8%	13%	18%	25%	32%	39%	47%	53%	60%	56%	60%	62%	69%	74%	71%	72%
NC	31%	30%	38%	40%	48%	48%	48%	45%	52%	50%	55%	53%	54%	61%	65%	66%
FS	18%	27%	32%	38%	44%	46%	50%	54%	54%	52%	52%	52%	52%	54%	56%	60%
KZN	10%	14%	20%	23%	28%	33%	37%	41%	42%	41%	44%	42%	43%	46%	42%	46%
NW	16%	23%	33%	39%	47%	51%	56%	55%	55%	53%	52%	49%	48%	54%	62%	60%
GP	17%	22%	27%	28%	32%	36%	37%	35%	36%	36%	36%	38%	39%	40%	36%	38%
MP	13%	19%	25%	30%	40%	42%	46%	50%	46%	48%	51%	48%	48%	57%	58%	58%
LM	16%	23%	30%	41%	53%	60%	61%	63%	62%	67%	63%	59%	65%	61%	63%	63%
SA	15%	20%	26%	30%	36%	41%	44%	46%	47%	46%	48%	47%	49%	52%	52%	53%

Table 11 Completeness of NPR relative to VR, 1-14

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
WC	57%	62%	71%	71%	71%	77%	83%	83%	90%	89%	81%	84%	85%	94%	88%	87%
EC	31%	41%	53%	61%	76%	82%	87%	93%	95%	100%	95%	100%	101%	104%	99%	100%
NC	56%	69%	74%	76%	86%	91%	94%	88%	91%	91%	93%	90%	90%	90%	94%	93%
FS	44%	56%	64%	69%	72%	78%	79%	86%	88%	92%	85%	86%	88%	89%	87%	89%
KZN	44%	50%	63%	73%	84%	89%	88%	92%	92%	94%	96%	96%	99%	98%	95%	103%
NW	50%	64%	78%	88%	100%	103%	106%	116%	109%	122%	103%	97%	93%	101%	101%	101%
GP	48%	55%	62%	67%	70%	73%	70%	70%	69%	71%	73%	79%	82%	80%	78%	80%
MP	44%	58%	68%	80%	91%	92%	92%	93%	91%	97%	95%	98%	96%	93%	102%	91%
LM	43%	57%	69%	78%	85%	94%	96%	98%	93%	104%	98%	94%	95%	91%	95%	100%
SA	50%	57%	66%	74%	83%	89%	90%	94%	93%	97%	95%	95%	96%	96%	95%	96%

Table 12 Completeness of NPR relative to VR, 25+

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
WC	94%	93%	93%	92%	92%	94%	95%	96%	96%	97%	95%	95%	94%	95%	98%	97%
EC	93%	92%	92%	92%	91%	94%	97%	100%	101%	100%	101%	108%	115%	112%	105%	107%
NC	97%	95%	91%	91%	93%	94%	94%	93%	91%	91%	95%	96%	95%	97%	97%	99%
FS	99%	98%	95%	91%	88%	88%	88%	90%	93%	94%	93%	94%	95%	96%	96%	97%
KZN	104%	102%	102%	101%	101%	99%	100%	100%	100%	98%	100%	102%	100%	101%	99%	110%
NW	113%	117%	116%	113%	117%	121%	128%	129%	126%	126%	118%	109%	105%	107%	111%	108%
GP	93%	92%	90%	90%	88%	88%	87%	85%	84%	83%	87%	91%	93%	92%	90%	90%
MP	95%	101%	102%	99%	98%	98%	97%	98%	96%	97%	101%	102%	101%	102%	102%	102%
LM	96%	95%	95%	94%	94%	98%	98%	99%	98%	97%	99%	100%	97%	97%	97%	101%
SA	98%	98%	97%	96%	95%	96%	97%	97%	97%	96%	98%	100%	100%	100%	98%	101%

Table 13 Completeness of Vital Registration, infants

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
WC	119%	110%	111%	112%	112%	112%	110%	109%	108%	106%	106%	103%	101%	96%	95%	90%	89%
EC	30%	30%	34%	38%	42%	46%	49%	50%	51%	52%	54%	55%	55%	54%	56%	53%	52%
NC	117%	112%	118%	124%	130%	135%	141%	138%	134%	131%	129%	124%	121%	113%	112%	103%	101%
FS	84%	85%	95%	106%	117%	129%	133%	128%	124%	119%	117%	114%	113%	110%	106%	105%	102%
KZN	53%	51%	55%	58%	61%	64%	68%	66%	65%	64%	64%	62%	61%	57%	57%	54%	53%
NW	68%	67%	74%	81%	88%	95%	105%	108%	111%	113%	117%	117%	118%	118%	116%	115%	115%
GP	109%	104%	109%	114%	119%	124%	128%	125%	121%	117%	115%	111%	107%	100%	98%	88%	82%
MP	57%	55%	59%	64%	67%	72%	76%	75%	75%	74%	74%	73%	72%	68%	68%	66%	66%
LM	32%	34%	39%	45%	52%	58%	65%	68%	71%	74%	77%	79%	87%	85%	84%	81%	80%
SA	**62%**	**62%**	**66%**	**71%**	**76%**	**80%**	**85%**	**85%**	**85%**	**85%**	**85%**	**84%**	**84%**	**80%**	**79%**	**76%**	**75%**

Table 14 Completeness of Vital Registration, under-five

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
WC	99%	91%	92%	95%	96%	97%	107%	106%	105%	106%	105%	98%	96%	92%	91%	89%	88%
EC	30%	31%	34%	36%	40%	43%	48%	49%	51%	53%	54%	52%	53%	52%	53%	53%	54%
NC	122%	115%	119%	126%	131%	136%	142%	138%	135%	134%	132%	121%	117%	111%	108%	104%	102%
FS	80%	80%	88%	98%	107%	116%	120%	116%	113%	111%	108%	103%	104%	104%	98%	98%	97%
KZN	52%	51%	53%	57%	59%	61%	62%	61%	60%	59%	59%	54%	52%	50%	49%	44%	43%
NW	64%	64%	69%	77%	82%	88%	96%	98%	99%	102%	108%	106%	102%	97%	95%	97%	98%
GP	102%	93%	97%	101%	108%	114%	111%	108%	105%	95%	93%	104%	100%	94%	92%	85%	80%
MP	49%	49%	54%	62%	67%	71%	75%	74%	74%	74%	72%	67%	66%	63%	62%	56%	56%
LM	32%	34%	41%	47%	54%	62%	69%	74%	77%	81%	86%	82%	89%	88%	89%	88%	86%
SA	**58%**	**57%**	**62%**	**66%**	**71%**	**75%**	**79%**	**79%**	**79%**	**79%**	**79%**	**77%**	**75%**	**73%**	**72%**	**70%**	**70%**

Table 15 Completeness of Vital Registration, 25+

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
WC	100%	102%	104%	105%	107%	107%	108%	109%	109%	110%	110%	109%	108%	109%	112%	110%	111%
EC	73%	74%	75%	75%	76%	79%	79%	79%	79%	79%	80%	79%	78%	79%	80%	78%	78%
NC	96%	98%	100%	101%	102%	102%	102%	102%	102%	102%	102%	101%	100%	100%	102%	101%	101%
FS	94%	95%	95%	96%	96%	96%	95%	95%	94%	93%	93%	91%	89%	89%	90%	88%	87%
KZN	78%	80%	82%	83%	84%	85%	86%	87%	87%	88%	88%	88%	87%	88%	90%	88%	89%
NW	73%	74%	76%	77%	77%	77%	78%	78%	78%	78%	78%	77%	76%	77%	78%	77%	77%
GP	104%	106%	108%	110%	111%	112%	113%	114%	114%	115%	115%	114%	111%	109%	110%	108%	109%
MP	91%	92%	93%	93%	93%	93%	92%	92%	91%	90%	90%	88%	86%	88%	89%	89%	89%
LM	87%	89%	91%	92%	93%	94%	95%	95%	96%	96%	96%	95%	95%	95%	98%	97%	97%
SA	86%	87%	89%	90%	91%	91%	92%	93%	93%	93%	93%	92%	92%	92%	94%	92%	92%

Table 16 IMR implied by NPR data

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
WC	0.021	0.022	0.024	0.021	0.022	0.021	0.021	0.021	0.019	0.018	0.018	0.016	0.017	0.015	0.016	0.016	0.015
EC	0.059	0.054	0.055	0.058	0.064	0.060	0.053	0.050	0.051	0.037	0.041	0.033	0.030	0.030	0.033	0.030	0.026
NC	0.036	0.034	0.033	0.032	0.039	0.032	0.030	0.029	0.035	0.031	0.033	0.030	0.029	0.037	0.039	0.034	0.039
FS	0.057	0.063	0.069	0.062	0.064	0.062	0.057	0.054	0.060	0.050	0.046	0.041	0.032	0.032	0.033	0.032	0.032
KZN	0.057	0.066	0.065	0.064	0.057	0.065	0.060	0.055	0.055	0.049	0.046	0.036	0.036	0.040	0.034	0.032	0.027
NW	0.051	0.054	0.060	0.055	0.054	0.056	0.058	0.059	0.058	0.045	0.037	0.029	0.024	0.027	0.030	0.028	0.027
GP	0.035	0.041	0.047	0.042	0.042	0.042	0.038	0.034	0.034	0.031	0.026	0.023	0.023	0.023	0.021	0.022	0.022
MP	0.050	0.044	0.059	0.060	0.054	0.058	0.050	0.051	0.048	0.042	0.039	0.031	0.030	0.030	0.031	0.029	0.027
LM	0.034	0.033	0.038	0.038	0.036	0.038	0.041	0.044	0.044	0.040	0.032	0.024	0.028	0.025	0.027	0.028	0.024
SA	0.045	0.048	0.052	0.050	0.049	0.050	0.047	0.044	0.044	0.038	0.034	0.028	0.027	0.028	0.027	0.026	0.024

Table 17 U5MR implied by NPR data

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
WC	0.029	0.032	0.037	0.032	0.033	0.030	0.026	0.026	0.024	0.022	0.022	0.020	0.021	0.020	0.020	0.019	0.018
EC	0.079	0.081	0.083	0.091	0.103	0.092	0.077	0.073	0.076	0.058	0.063	0.052	0.050	0.048	0.053	0.044	0.037
NC	0.046	0.047	0.044	0.042	0.051	0.043	0.042	0.037	0.046	0.040	0.043	0.042	0.039	0.049	0.054	0.045	0.050
FS	0.079	0.089	0.099	0.090	0.092	0.089	0.083	0.078	0.088	0.072	0.068	0.058	0.045	0.045	0.045	0.042	0.042
KZN	0.076	0.086	0.090	0.090	0.087	0.095	0.087	0.082	0.081	0.073	0.068	0.057	0.062	0.062	0.055	0.055	0.047
NW	0.069	0.078	0.088	0.083	0.082	0.083	0.087	0.090	0.088	0.071	0.057	0.042	0.037	0.044	0.050	0.041	0.041
GP	0.046	0.057	0.066	0.061	0.058	0.056	0.053	0.048	0.048	0.046	0.040	0.030	0.029	0.029	0.028	0.028	0.028
MP	0.073	0.073	0.092	0.087	0.078	0.085	0.075	0.075	0.071	0.062	0.062	0.050	0.052	0.048	0.050	0.048	0.045
LM	0.056	0.060	0.062	0.061	0.057	0.057	0.060	0.061	0.060	0.055	0.045	0.035	0.042	0.036	0.037	0.037	0.032
SA	0.063	0.070	0.076	0.074	0.073	0.073	0.067	0.064	0.064	0.056	0.051	0.041	0.042	0.041	0.041	0.038	0.035

Table 18 Adult mortality implied by NPR data

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
WC	0.29	0.29	0.29	0.28	0.27	0.27	0.26	0.27	0.27	0.25	0.24	0.24	0.23	0.23	0.22	0.23	0.23
EC	0.49	0.52	0.57	0.61	0.64	0.63	0.63	0.62	0.60	0.58	0.55	0.53	0.49	0.47	0.44	0.44	0.43
NC	0.47	0.47	0.48	0.51	0.53	0.53	0.54	0.49	0.49	0.49	0.51	0.48	0.47	0.45	0.44	0.45	0.44
FS	0.50	0.53	0.55	0.58	0.60	0.61	0.62	0.62	0.61	0.61	0.58	0.55	0.49	0.46	0.44	0.44	0.43
KZN	0.51	0.54	0.57	0.60	0.61	0.63	0.62	0.60	0.58	0.55	0.51	0.47	0.44	0.40	0.36	0.36	0.35
NW	0.42	0.46	0.50	0.52	0.54	0.56	0.57	0.61	0.58	0.58	0.54	0.48	0.45	0.43	0.42	0.40	0.40
GP	0.33	0.33	0.34	0.36	0.35	0.35	0.34	0.32	0.31	0.28	0.27	0.26	0.25	0.24	0.23	0.22	0.21
MP	0.40	0.45	0.48	0.51	0.52	0.54	0.54	0.53	0.52	0.50	0.48	0.45	0.42	0.39	0.37	0.35	0.34
LM	0.32	0.35	0.38	0.42	0.44	0.47	0.49	0.49	0.47	0.45	0.42	0.39	0.38	0.35	0.34	0.33	0.31
SA	0.41	0.44	0.46	0.49	0.49	0.50	0.50	0.49	0.47	0.45	0.42	0.40	0.37	0.35	0.33	0.32	0.31

Table 19 NMR per 1000 live-births

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
WC	0.007	0.008	0.009	0.009	0.009	0.009	0.008	0.008	0.007	0.008	0.007	0.006	0.007	0.007	0.007	0.007
EC	0.015	0.013	0.016	0.017	0.018	0.015	0.014	0.011	0.019	0.020	0.022	0.024	0.021	0.025	0.024	0.019
NC	0.011	0.013	0.011	0.011	0.009	0.010	0.010	0.011	0.010	0.011	0.009	0.009	0.011	0.009	0.014	0.014
FS	0.016	0.014	0.015	0.015	0.013	0.014	0.015	0.015	0.013	0.015	0.013	0.012	0.011	0.011	0.012	0.012
KZN	0.019	0.018	0.020	0.020	0.017	0.020	0.019	0.018	0.016	0.017	0.015	0.012	0.014	0.014	0.017	0.018
NW	0.016	0.014	0.015	0.015	0.013	0.015	0.015	0.016	0.014	0.014	0.011	0.009	0.009	0.009	0.009	0.011
GP	0.012	0.011	0.014	0.014	0.011	0.013	0.013	0.012	0.010	0.011	0.009	0.008	0.009	0.008	0.010	0.010
MP	0.017	0.013	0.015	0.016	0.013	0.015	0.013	0.014	0.012	0.013	0.010	0.009	0.011	0.010	0.010	0.012
LM	0.012	0.009	0.010	0.010	0.008	0.008	0.010	0.010	0.012	0.013	0.011	0.011	0.011	0.012	0.013	0.015
SA	0.015	0.013	0.015	0.015	0.013	0.014	0.013	0.013	0.013	0.014	0.012	0.011	0.011	0.012	0.013	0.013

Table 20 **MMR per 100 000 live-births**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
WC	46	64	56	49	71	49	68	89	99	126	103	66	64	69	63	55
EC	158	202	209	244	294	301	334	328	322	429	384	258	188	247	231	200
NC	137	176	193	113	68	139	148	251	285	202	217	141	96	137	139	171
FS	190	251	214	237	330	372	311	440	442	478	403	301	194	165	242	218
KZN	175	226	188	201	239	234	258	333	319	298	277	225	167	145	151	129
NW	178	188	173	176	267	253	250	380	386	397	379	257	252	232	260	218
GP	147	181	160	134	163	185	190	228	233	253	192	164	135	133	146	136
MP	165	147	121	182	185	212	221	298	321	342	316	240	225	146	160	138
LM	139	100	112	138	131	143	185	235	222	237	215	171	200	151	176	166
SA	151	175	159	171	203	210	225	278	276	295	258	195	164	152	163	145