Maternal mortality in South Africa – lessons from a case study in the use of deaths reported by households in censuses and surveys

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Abstract: South Africa is unique in being a developing country which has asked questions on pregnancy related deaths in both its 2001 census and 2007 household survey, and monitors maternal and pregnancy related mortality via vital registration and a confidential enquiry into maternal deaths. These sources of data provide a wide range of estimates of maternal mortality for the country. This paper examines these estimates to assess to what extent the differences between them are due to data deficiencies, methodological deficiencies or definitional differences. The results show that maternal deaths, being relatively rare, make it fairly difficult to establish the maternal mortality rate with any great degree of accuracy in a setting where data are less than perfect. They also show that to some extent the differences are due to differences and errors in processing of data but that pregnancy related mortality should not be treated as synonymous with maternal mortality. After adjustment, pregnancy related mortality from vital registration was about double the maternal mortality, and pregnancy related mortality reported by households was about double that from vital registration. None-the-less, all the data indicate an upward trend in maternal mortality that is consistent with the impact of the HIV/AIDS epidemic, and likely contributed to the discrepancies.

Key words: Maternal, mortality, South Africa, census, estimation

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Introduction

The challenge of measuring maternal mortality has been brought into sharp focus by the Millennium Development Goals which include the reduction of maternal mortality as one of the targets to be met by 2015. As has been pointed out by others, e.g. Hill, Stanton and Gupta (2001), maternal mortality, being fairly rare, is difficult to measure accurately. This is particularly true in settings where data are poor, as in many developing countries, including all African countries, where there is no or limited availability of cause of death data from a vital registration system. In such situations researchers and policymakers have to rely largely on indirect measures from surveys or else estimates from models.

The ideal source of data for monitoring trends in maternal mortality is civil registration with good quality certification of cause of death. The review of maternal mortality undertaken by Hill, Thomas, AbouZahr, *et al.* (2007) indicates that even for countries where such data exist, maternal deaths are sometimes under-reported. Alternative sources of data range from household surveys with direct sisterhood questions, specialized studies such as the Reproductive-Age Mortality Studies (RAMOS) that make use of multiple sources including health facility records, to verbal autopsies from Health and Demographic Surveillance Sites (HDSSs). More recently, questions about pregnancy related deaths (i.e. deaths related in time, but not necessarily cause, to pregnancy) reported by household respondents in the census or large surveys have been added to these approaches. Usually in such situations, despite evidence suggesting the contrary (e.g. (Hill, Queiroz, Wong *et al.* 2009; Shahidullah 1995)), the assumption is made (either explicitly, e.g. Hill, Queiroz, Stanton *et al.* (2007), or less clearly, e.g. Garenne, McCaa and Nacro (2007)) that the pregnancy related mortality ratio (PRMR) can be regarded as being synonymous with the maternal mortality ratio (MMR).

United Nation agencies have derived estimates of maternal mortality for 1995, 2000 and 2005 using a variety of methods (Abou-Zahr, Wardlaw and Hill 2001; WHO, UNICEF and UNFPA 2002; WHO, UNICEF, UNFPA *et al.* 2009). While 34% of the countries have vital registration data with “good” attribution of cause, these countries account for only 13% of the global births. For the countries that have no data on maternal mortality, a model was used to estimate the proportions of deaths of women of reproductive age that are maternal (PMDF) based on its associations with selected correlates, which was then applied to the estimate of the number of female deaths in reproductive ages. In the most recent initiative to develop internationally comparable estimates, Hill, Thomas, AbouZahr *et al.* (2007) developed their methodology to take into account the rapid change in adult mortality for countries affected by AIDS. Estimated PMDFs were applied to non-HIV mortality. The modelling approach was used for 36% of countries, accounting for 25% of the global births. The remaining 30% of countries, which accounted for the majority of births (60%), had data from a variety of sources (other than vital registration), all needing some form of adjustment or extrapolation.

Comparative studies to assess the reliability of the different methods used for the majority of births are limited. A large survey conducted in Bangladesh in 2001 was used by Hill, El-Arifeen, Koenig *et al.* (2006) to compare alternative methods for collecting data for estimating pregnancy-related mortality. They contrasted estimates based on the information from a module collecting information on deaths of respondents’ sisters; information about recent household deaths with a time-of-death definition of maternal deaths; and a verbal autopsy instrument. They found that the sisterhood and household death approaches gave similar estimates of all-cause and pregnancy-related mortality, while verbal autopsy gave an estimate of maternal deaths that was about 15% lower than the pregnancy-related deaths.

According to Hill, El-Arifeen, Koenig *et al.* (2006), Graham, Brass and Snow (1989) argue that the sisterhood method gives a reliable estimate of pregnancy-related mortality based on the timing of the deaths relative to pregnancy. However, they report that an investigation by Shahidullah (1995) in Bangladesh found that 20% of pregnancy-related deaths of sisters were not reported as such and Shahidullah suggested that the sisterhood approach might therefore approximate the actual maternal mortality. In an evaluation of data from five countries' censuses, Stanton, Hobcraft, Hill *et al.* (2001) conclude that it is feasible to measure maternal mortality with questions in the census and the method can overcome several of the weaknesses of methods currently in use.

Maternal mortality in South Africa

Despite considerable improvement since 1994, vital registration in South Africa is not yet of sufficient quality to provide accurate direct estimates of maternal mortality rates. There remains considerable uncertainty about the level of maternal mortality. The 1998 South African DHS included questions on sibling survival which also ask whether the sister was pregnant or had given birth in the preceding 42 days of her death. Based on these data, a MMR of 150 per 100 000 births was estimated for the period 1989-1998. The questions were repeated in the 2003 DHS but were too poorly answered to provide useful data. While the institutional-based estimate of MMR from the Confidential Enquiry increased from 73 in 1998 to 152 per 100 000 births for the period 2005-2007, estimates from the 2001 census ranged from 542 per 100 000 derived by Garenne, McCaa and Nacro (2008) to 820 per 100 000 derived by Hill, Thomas, AbouZahr *et al.* (2007), and Stats SA has estimated the rate to be 624 per 100 000 based on the 2007 Community Survey (unpublished estimate) while Garenne, McCaa and Nacro (2009) estimated it to be 700 per 100 000. Model based estimates by WHO and various United Nations agencies for South Africa were 230 per 100 000 in 2000 and 400 per 100 000 in the year 2005 (Hill, Thomas, AbouZahr *et al.* 2007). Bah (2006) investigated the use of multiple cause information from vital registration to assess the trend in the number of maternal deaths. He acknowledged the under-reporting of maternal deaths but highlighted that maternal mortality appeared to be increasing and that the recommendations for reducing maternal mortality identified in the first confidential enquiry were mostly still not yet in place (see Mzolo, Ross, Ross *et al.* (2003)).

South Africa is in the unique situation of having asked questions on pregnancy related deaths in both the 2001 census and the 2007 household survey, in addition to monitoring maternal and pregnancy-related mortality via vital registration as well as the ongoing confidential enquiry into maternal deaths. This paper examines these estimates to assess whether the differences are a result of data deficiencies, methodological deficiencies or definitional deficiencies. Particular attention is paid to the data derived from questions about deaths reported by households from the census and the large household survey.

Definitions

One of the difficulties with comparing various estimates of maternal mortality is the range of different definitions used by researchers, who often do not indicate clearly exactly what measure is being reported on.

Thus, since in part differences are due simply to differences in definition, it is useful to clarify the definitions in common use.

2.1 Maternal death

According to ICD-10, maternal deaths should be divided into two groups:

- *Direct obstetric deaths* – deaths resulting from obstetric complications of the pregnant state (pregnancy, labour and the puerperium), from interventions, omissions, incorrect treatment, or from a chain of events resulting from any of the above.
- *Indirect obstetric deaths* – deaths resulting from previous existing disease or disease that developed during pregnancy and which was not due to direct obstetric causes, but was aggravated by physiologic effects of pregnancy.

Deaths from "accidental or incidental" causes have historically been excluded from maternal mortality. These may be external causes such as road traffic injuries or natural causes such as cancer. However, in practice, it is often difficult to distinguish between *incidental* and *indirect obstetric* causes. To facilitate the identification of maternal deaths under circumstances where cause of death attribution is inadequate, ICD-10 introduced the new category, *pregnancy related death.* This is defined as: *the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death*. Thus *pregnancy related mortality* includes both the direct obstetric and indirect obstetric deaths (i.e. *maternal mortality*) as well as incidental deaths that occur during or just after pregnancy (which are assumed to be a fairly small proportion of the total).

2.2 Measures of maternal mortality

There are three distinct measures of maternal mortality in widespread use: the Maternal Mortality Ratio (MMR), the Maternal Mortality Rate (MM rate), and the Lifetime Risk of Maternal Death. The most commonly used measure is the Maternal Mortality Ratio, which is the number of maternal deaths during a given time period per 100 000 live births during the same time period. This is a measure of the risk of death once a woman has become pregnant.

The Maternal Mortality Rate is the number of maternal deaths in a given period per 100 000 women of reproductive age during the same time period, and reflects the extent to which women are exposed to risk through fertility. The Lifetime Risk of Maternal Death is an accumulated risk of maternal death across a woman's reproductive age. It takes into account both the probability of becoming pregnant and the probability of dying as a result of that pregnancy. It is generally approximated by assuming that probability of dying from maternal causes in each year of the 35 years of reproductive age is equal to the overall maternal mortality rate, that is: Lifetime risk = $1-\left(1-\text{maternal mortality rate}\right)^{35}$. Wilmoth (2009) explores the conceptual and computational issues around the lifetime risk of maternal mortality, and recommends that the calculation take into account competing risks. He also points out that it should ideally be calculated using age-specific maternal mortality rates. However, for practical purposes, he recommends that the international index continue to make use of the crude maternal mortality rate.

In the literature on the estimation of maternal mortality, the proportion of deaths among women of reproductive age that are due to maternal causes (PMDF) is an important metric, as is the Pregnancy-Related Mortality Ratio (PRMR), which is the number of pregnancy-related deaths per 100,000 live births. The data used to estimate the PRMR sometimes includes external deaths (e.g. censuses) and sometimes excludes them (e.g. DHSs).

Methods and datasets

3.1 Confidential Enquiry into Maternal Deaths

In 1997 the South African Minister of Health set up the National Committee for Confidential Enquiry into Maternal Deaths to ensure that all maternal deaths are audited. Compulsory notification is required for every maternal death including a report on the cause of death and factors associated with the death. Provincial assessors review each case with respect to primary and final causes of death, and suboptimal care received. Reports are then sent to the national committee for collation and analysis. A national committee reviews the trends in maternal deaths and issues reports triennially, the first report was for the year 1998 (National Committee for Confidential Enquiry into Maternal Deaths 1999) which has been followed by three further reports (National Committee for Confidential Enquiry into Maternal Deaths 2002, 2006, 2008).

Only a few deaths outside of health facilities are reported annually, as the system does not have a specific mechanism for collecting information about deaths that occur in the home and therefore misses a considerable number of deaths. In addition, such systems are also known to miss many of the maternal deaths that occur through abortions, even if the women attend a health facility, as these women are not treated in the labour wards. Furthermore, such a system may miss women who die in a health facility during the post-partum period but who are not identified in the health facility as having been pregnant in the preceding 42 days. Thus estimates of MMR based on these data may give an indication of trend in the ratio, but they are likely to under-estimate the true MMR.

3.2 Vital Registration

A new death notification form incorporating the International Classification for Diseases (ICD) recommended format for medical certification of cause of death was introduced in South Africa in 1998. The new form allows four lines in Part I for the sequence of conditions that resulted in death as well as another line in Part II for any contributory causes that were not in the causal sequence. The new death notification also introduced an additional question about the pregnancy status of women. The question “If female, was she pregnant 42 days prior to death?” follows the lines for the cause of death details.

When a death is registered the death notification form is submitted to the Department of Home Affairs, and once the forms have been processed and archived, copies are sent to Statistics South Africa for statistical processing. Cause of death information is coded to ICD-10 and the Automated Coding of Medical Entities

(ACME) programme is used to select the underlying cause of death. Unit record data including basic demographic details as well as the underlying cause of death, the cause from each line of the certificate and the pregnancy status are made available once the statistical report has been published. Trends in the maternal deaths as well as the pregnancy related deaths for 1999-2007 are analysed.

Maternal deaths can be identified in two ways:

- the underlying cause is a direct obstetric cause related to pregnancy or childbirth (ICD: O00-O99) , or
- where there is any mention of a direct obstetric cause regardless whether it is identified as the single underlying cause (ICD: O00-O99).

Pregnancy-related deaths can also be identified in two ways:

- the deceased was pregnant up to 42 days prior to the death and the underlying cause was not an injury (which might be assumed to be incidental), or
- the deceased was pregnant up to 42 days prior to the death, regardless of the underlying cause.

Examing the causes of the injury deaths of the deceased who were pregnany suggests that a proportion were possibly failed abortion attemps (such as those classified to the ICD codes of "misadventure from a medical procedure" or "poisoning from a herbal remedy") which could well be considered related to the pregnancy. The Termination of Pregnancy Act of 1996 (South Africa: Republic of 1996) has reduced the extent of abortion related morbity and mortality (Cooper, Morroni, Orner *et al.* 2004). Despite policy changes, there are still barriers such as lack of health care providers willing to perform such services which results in a number of abortions taking place in unsafe circumstances. Since it is not possible to properly distinguish the indirect maternal causes, this analysis will focus on the direct maternal causes as well as the total pregnancy related deaths.

Vital registration data has several other limitations regarding the classification of maternal deaths (e.g. (Hogan, Foreman, Naghavi *et al.* 2010)). Maternal causes can be incorrectly classified and a proportion of maternal and pregnancy related deaths may have been coded as ill-defined or other specific conditions such as disseminated intravascular coagulation (D65), peritonitis (K65), septicaemia (A41, A42), pulmonary embolism (I26), acute and chronic renal failure (N18 and N19), acute abdomen (R10), and hypovolaemic shock (R57.1).23,28,35–37. Furthermore, in South Africa, there is a general concern about the quality of classification of causes of death. Based on data from 1996, the WHO review of quality of cause of death statistics classed South Africa as poor, based in part on the high proportion of ill-defined causes of death (Mathers, Ma Fat, Inoue *et al.* 2005). The proportion of ill-defined deaths has been reduced since then, but there remains concern about the quality of cause of death certification with indications of considerable errors (Burger, Van der Merwe and Volmink 2007; Nojilana, Groenewald, Bradshaw *et al.* 2009). Furthermore, Groenewald *et al*. (2005) has shown that there is considerable misclassification of AIDS as an underlying cause of death.

It is also estimated that not all deaths are registered (Dorrington, Moultrie and Timæus 2004; Statistics South Africa 2009). Thus the data can be used to estimate MMR and PRMR per 1000 live-births using a consistent series of estimates of the births taken from the ASSA2003 projection model (Dorrington, Bradshaw, Johnson *et al.* 2006) but without adjustment for incompleteness these are likely to be underestimates, and if completeness has been increasing over time an upward bias would be introduced into the trend of the ratios over time.

3.3 Deaths in the household reported in the census and community survey

Another approach to estimating maternal mortality has been to include questions in censuses or large national household surveys on the deaths in a household in the preceding 12 months together with broad cause of death information. In South Africa, this approach was used in both the 2001 Census as well as the 2007 Community Survey. Although the phrasing of the questions differed, the structure of the questions allowed for the identification of pregnancy-related deaths including or excluding unnatural/injury deaths.

In the case of the 2001 Census, after asking about the age and sex of the deceased, the following questions were asked: "Did (the person) die from an accident or through violence?"; and if the deceased was a woman<50 years, "Did (the person) die while pregnant or within 6 weeks after delivery?"

The 2007 Community Survey was a national sample including about 247 000 households accounting for slightly less than 2.5% of the population. The questionnaire included questions about deaths in the household in the preceding 12 months. For households that reported a death, questions about the age and sex of the deceased, were followed by: "What caused the death of (the deceased)?" (2 tick box options: unnatural/natural); and "Was (the deceased) pregnant at the time of death or died (sic) within 6 weeks of delivery?" with an instruction to the interviewer to "only ask of women 12-50 at time of death". In addition to questions about the broad cause, the respondent was also asked to provide month and year of death. These data are thus suitable for estimating the PRMR.

The first problem with these sorts of data is that respondents often misjudge the reference period and thus the number of deaths reported by households may be over or under stated. Although one can adjust the number of deaths specifically for this, it is not necessary to do so as the data need to be adjusted for general under or over-reporting of deaths, unless there is reason to suppose that the reference period error is age dependent.

The next problem concerns inconsistencies and non-responses. Both the 2001 and the 2007 data were edited, both logically (to remove pregnancy status from males, and for females aged below 12 and over 50) and by 'hot-decking' to replace non-response to the pregnancy status question. A surprisingly high proportion (27%) of the deaths in 2001 were recorded as being pregnancy related but were males, or females outside the age range 12-50, which calls into question the quality of the data in general. (The comparable figure for the 2007 Community Survey was 15%.) In addition over 4% of all deaths (i.e. nearly 9% of female deaths or nearly 15% of female deaths aged 15-49 or around 22.5% of pregnancy related deaths) in 2001 were imputed to be pregnant by hot-decking. (The comparable figure for 2007 was around 1.5%![1]) Given the uncertainty about the accuracy of responses to this question in the cases where there was a response it is somewhat heroic to assume, as some researchers have, that the adjustment on the basis of the imputation is correct.

[1] It is not clear why there were so many non-responses in 2001. It could be linked to a problem with scanning the last page of the questionnaire which apparently picked up much dirt, or it could be due to deficiencies with training, which were then avoided with the Community Survey.

Garenne, McCaa and Nacro (2008) estimate the extent of exaggeration in the reported number of pregnancy related deaths to be 5.9% in 2001 (slightly over 6% using weighted data) apparently on the basis of the number expected from applying the proportion of deaths at each age that were pregnant in the data not requiring imputation to the total number of reported deaths at that age. However, given that it is more likely for pregnancy status to be left blank where the deceased was known not to be pregnant than it is when the deceased was pregnant without the respondent knowing, it is likely that the exaggeration is much larger than 6%. Probably the best we can do is to accept that the true exaggeration lies somewhere between 0% and 22.5% for 2001.

Data from each of the sources are interrogated in turn in an effort to decide to what extent differences are due to data deficiencies, methodological deficiencies or definitional differences.

Results

4.1 Confidential Enquiry into Maternal Deaths

Nearly 800 maternal deaths were reported through the Confidential Enquiry in 1998 and the number increased to an apparent peak of a little over 1,400 deaths in 2006 before dropping in 2007 (**Error! Reference source not found.**). The large majority of deaths were reported by public sector hospitals with an average of less than 20 deaths per year reported by the private sector.

According to the NCCEMD (2007), the most common cause of death for the period 2005-2007 was non-pregnancy related infections, mainly AIDS (43.7%). This was followed by complications of hypertension (15.7%) and obstetric haemorrhage (12.4%). Compared with the earlier period, complications of hypertension have declined while non-pregnancy related infections increased. There is still a considerable gap in knowledge about HIV status of the women although the proportion tested rose to 59% in the 2005-2007 period from 46% in the previous period. The proportion infected of those tested has remained stable at around 80%.

4.2 Vital Registration

Fig. **1** compares the numbers of registered maternal and pregnancy related deaths alongside the trend in the deaths from the confidential enquiry. It can be seen that the numbers of direct maternal deaths from vital registration are very similar to the number of deaths from the confidential enquiry with the exception of the year 2007 when the number of registered deaths is higher. The numbers with any mention of direct maternal causes are only slightly higher than the number with the maternal cause identified as the underlying cause. As Bah (2006) points out, the trend in the vital registration data with any mention of maternal causes is smoother than either the confidential enquiry or the deaths where it is an underlying cause, although it is not clear why this should be the case. Furthermore, it is impossible to know whether the same maternal deaths are being reported by the two systems or whether they are reporting on different deaths. However, comparing the trends by province (not shown) suggests that there is considerable overlap, although there are bound to be cases in each system that are not being reported by the other system.

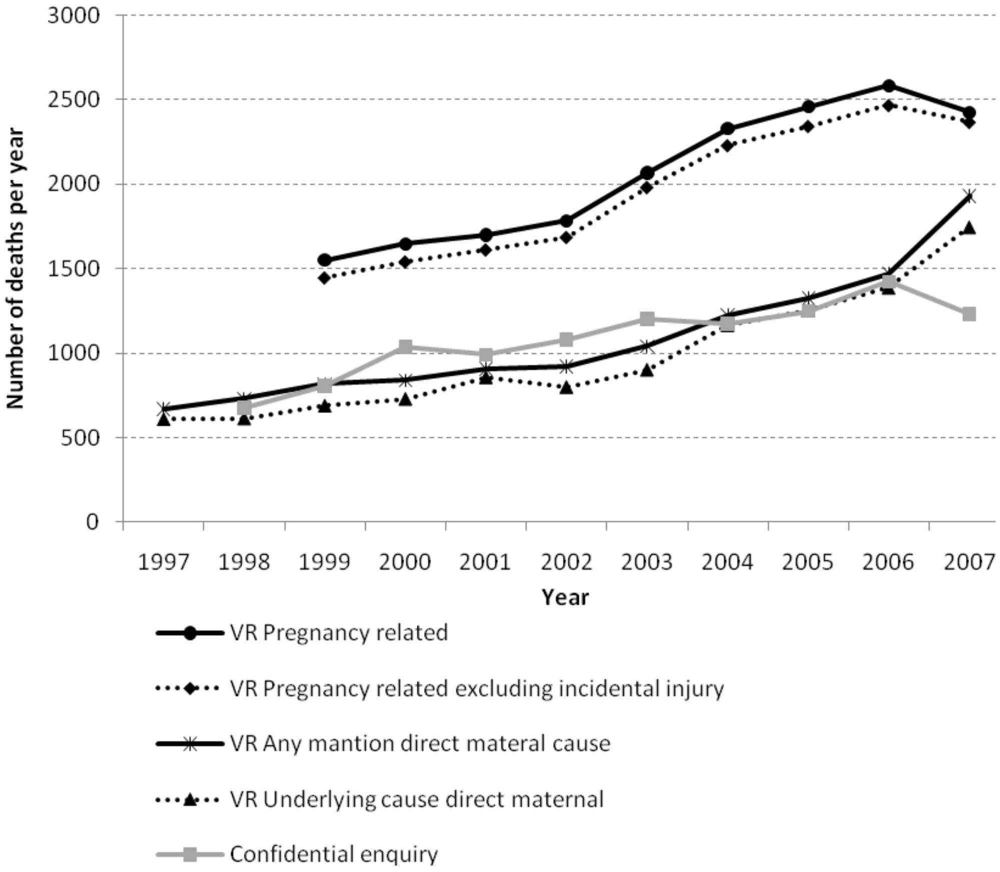

Fig. 1 Reported maternal deaths by year from vital registration and confidential enquiry

The maximum numbers of reported preganancy-related deaths are also shown in Fig. 1. Female deaths with any mention of direct maternal causes or an indication that the deceased was pregnant within 42 days of the death are included, as well as the numbers excluding those who died from injuries, which may well have been incidental to the pregnancy. The trend in the preganancy related deaths follows the pattern of the confidential enquiry deaths with a decrease in 2007 compared to 2006. The reason for the drop in 2007 is not clear but it is possible that there was a change in the coding practice in 2007 with the preganacy question being utalised in the identification of the underlying cause of death.

The MMR and the PRMR are shown in Fig. 2. The PRMR based on the pregnancy question is approximately twice the MMR based on direct maternal causes identified as the underlying cause of death. The trends in these rates are consistent up to 2006, with the confidential enquiry and the PRMR from vital registration indicating a possible drop in 2007.

It should be noted that the trend in the number of deaths and the rates derived from the registered deaths is in reality a little flatter and the level a little higher than depicted in **Error! Reference source not found.**Fig. 2 since these numbers have not been corrected for under-registration. However, since registered adult deaths are estimated to be currently over 90% complete and completeness increased only by about 5% over the period, the impact is considered to be fairly small.

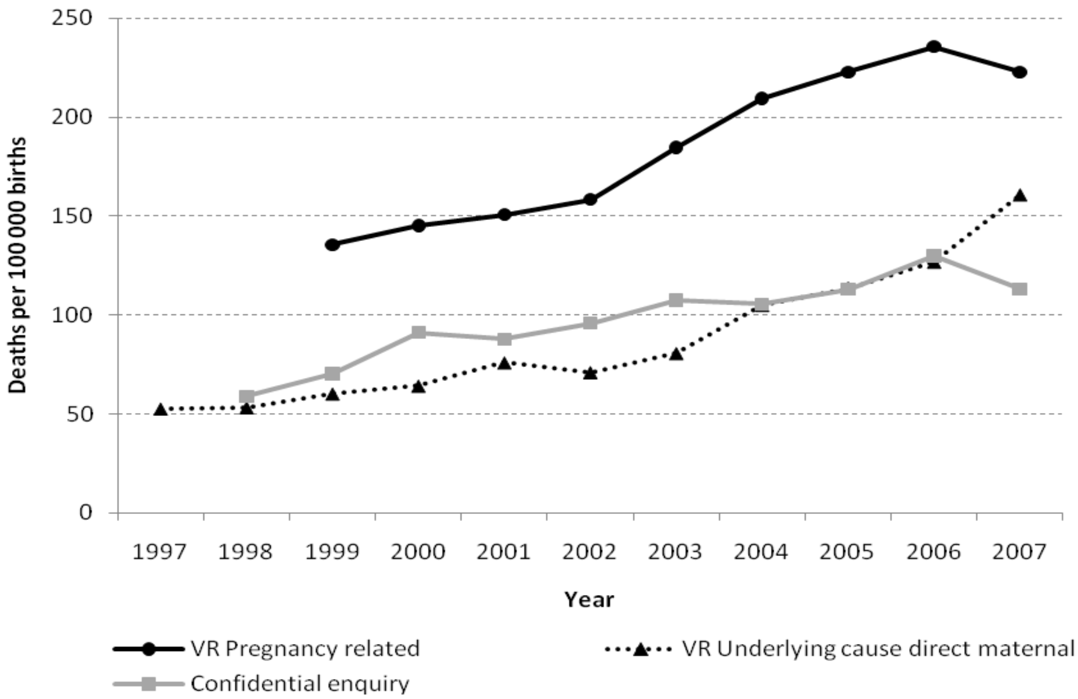

Fig. 2 Maternal mortality ratios by year from vital registration and confidential enquiry

The age distribution of the pregnancy and maternal deaths from vital registration generally peak in the age group 25-29 years and are proportionately very similar. However, the age distribution of deaths of women who were identified as being pregnant which did not have a direct maternal cause has a higher proportion of older women. From Fig. 3, which presents these data as proportions of the total by category, it can be seen that age distribution of the deaths of pregnant women who from an external cause, was younger than the age distribution of the other categories. It is not clear to what extent this reflects the age pattern of injuries in general, and to what extent it may reflect a higher prevalence of attempted abortions among younger women.

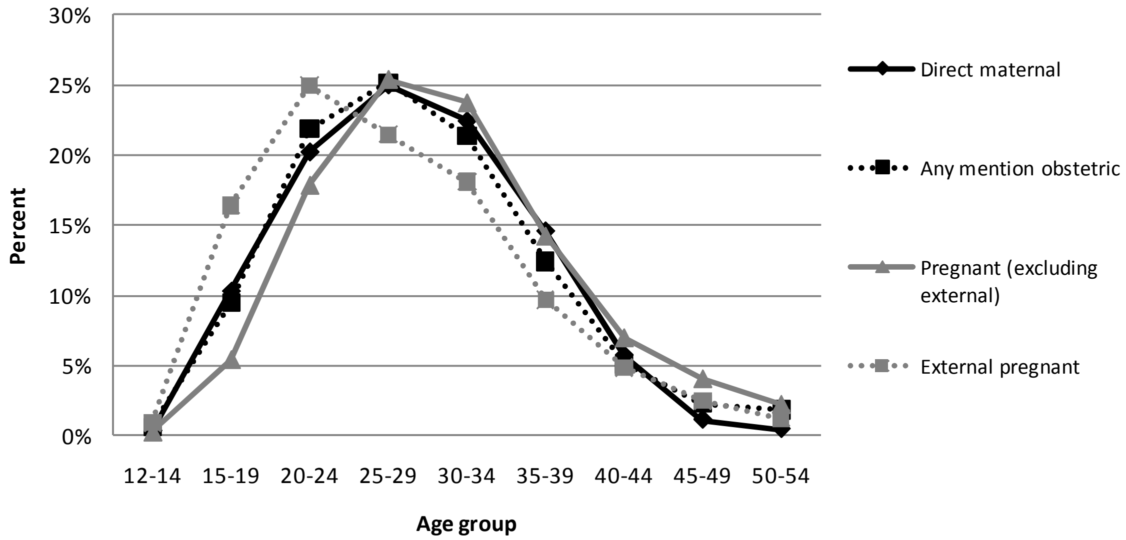

Fig. 3 Proportion of all female deaths due to maternal causes by age and category from vital registration

The proportion of maternal deaths in women of reproductive age (PMDF) is an important parameter in the estimation of maternal mortality. The vital registration data show (Fig. 4) that there has been a shift in the proportion over the period which reflects the rapid changes in mortality from AIDS. In 1999, the PMDF based on the broader category of pregnancy related mortality was 2.3 times higher than the restricted category of direct maternal causes as an underlying cause. The ratio decreased over time to 1.9 times higher, although it displayed variations from year to year. It is interesting to note the distinct age pattern of the PMDF in Fig. 5 and Fig. 6.

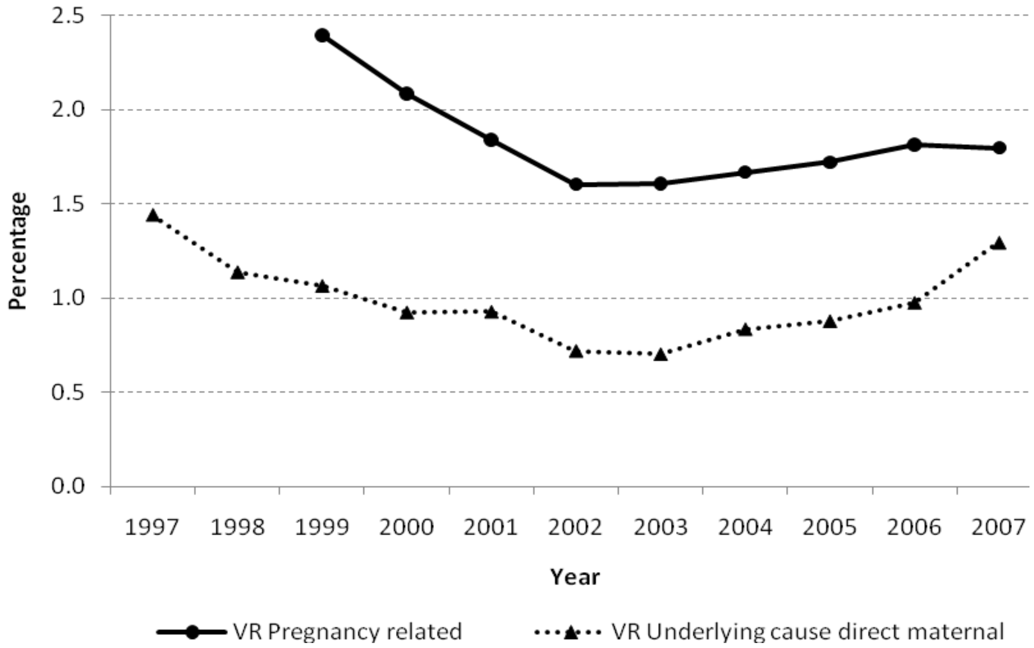

Fig. 4 PMDF (15-49 years) by year from vital registration

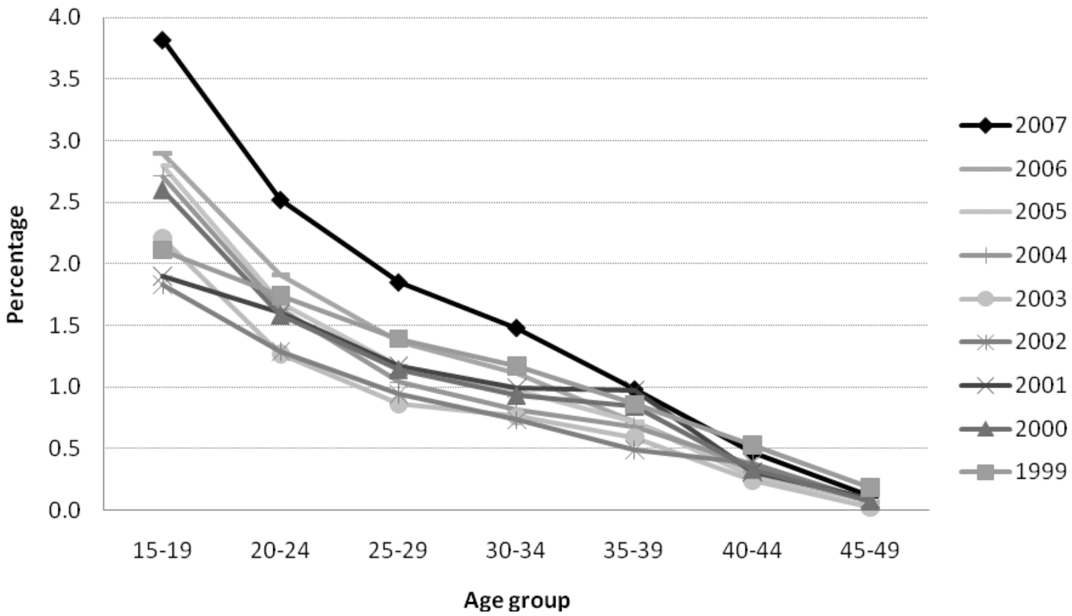

Fig. 5 Age specific PMDF – underling cause direct maternal

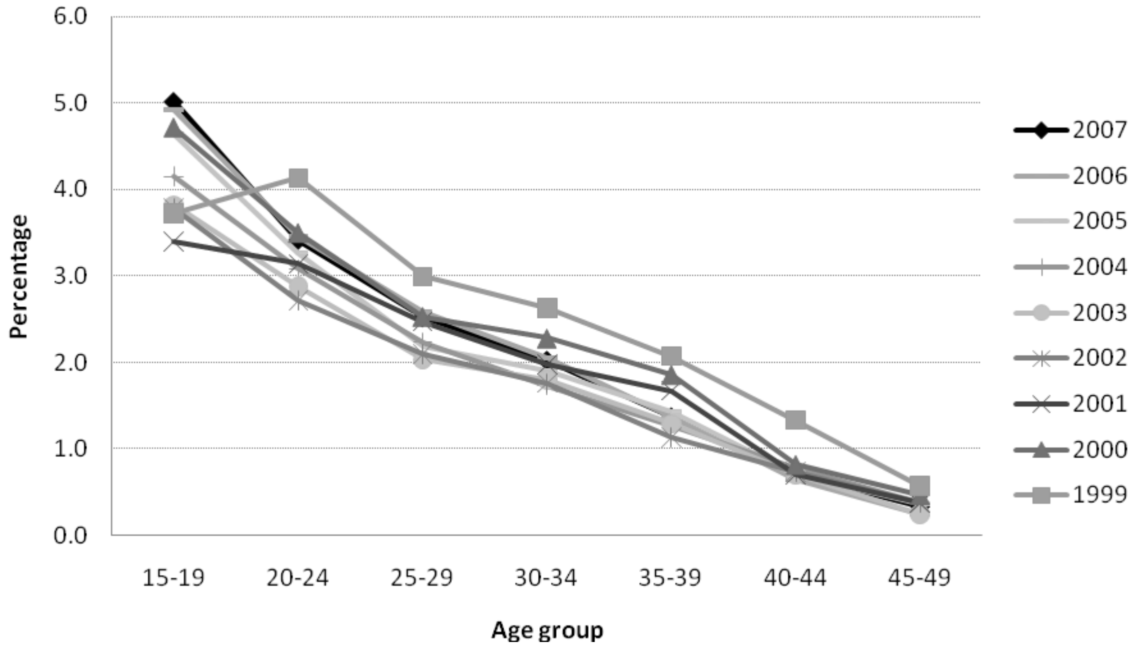

Fig. 6 Age specific PMDF – pregnancy related

4.3 Censuses and surveys

The total number of maternal deaths in 2001, before correcting for under or over reporting, ranged from 4 757 to 6 170[2] depending on the extent to which deaths have been falsely imputed to be pregnancy related. For 2006 the estimate is much higher but the range much narrower, namely 8 017 to 8 142.

The number of deaths needs to be corrected for over or under-reporting of deaths by households in general. Although, as mentioned above, part of this may be due to reference period error it could also be due, as can be seen from Fig. **7**, to over-reporting if a death is reported by more than one household (which appears to be the case for young men and women), under-reporting of deaths due to household disintegration due to the death (which appears to the case at the advanced ages, particularly for women) or it could be due to an inappropriateness of using the household weight for scaling up the deaths. Although not shown here, the completeness of reporting of deaths for men tends to fall less rapidly with age.

[3] These numbers were set to two thirds of the estimate from the survey plus one third of the number estimated by the ASSA projection model for mid-2007.

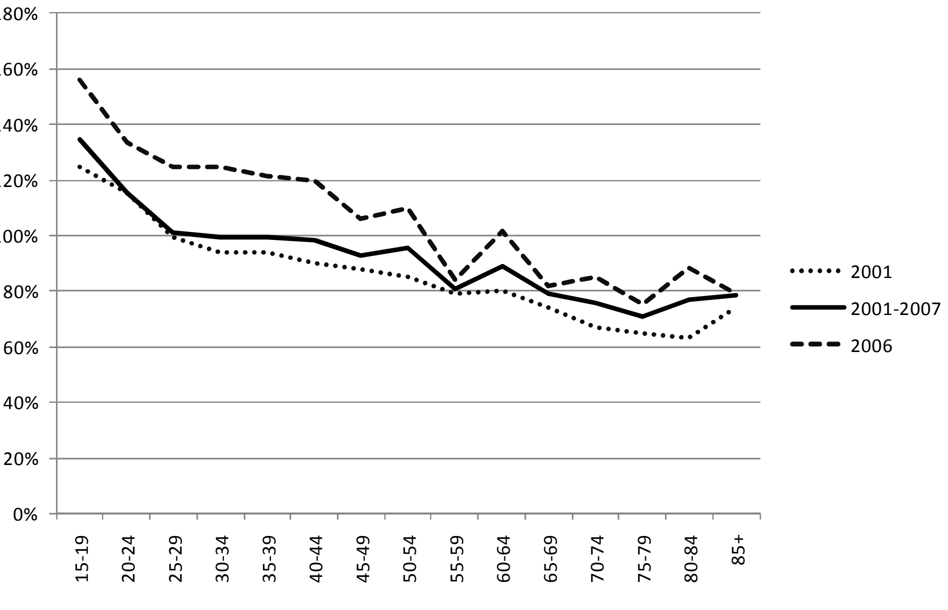

Fig. 7 Completeness of reporting of female deaths by households by age

In order to assess the completeness of reporting one needs to make use of one of the death distribution methods (Bennett and Horiuchi 1981, 1984; Hill 1987) which estimate the completeness of reporting of deaths by comparing them to the number expected on the basis of numbers in the population at the start and end of a period. For our purposes the estimate of the deaths reported by households for the period (5.352 years) between the census in 2001 and the survey in 2007 is derived on the assumption that the number of deaths in each age group grew exponentially between the numbers reported in the 2001 census and those reported in the 2007 survey. In addition the estimate of the numbers in the population one year prior to the census and survey were derived on the assumption that the numbers in the population at each age group grew exponentially from the earlier census at the average annual rate implied by comparisons of the two censuses. Finally, because a comparison of the growth rates over the 2001-2007 period with those of the 1996-2001 period at the older ages suggested that the population numbers estimated from the Community Survey were too high at the older ages (probably due to a degree of age exaggeration or mis-weighting of small numbers) the numbers over age 55 were reduced slightly[3].

The estimates of completeness of the reporting using vital registration data (see Tables 1 to 3, in the appendix) are less variable, more reasonable, and are consistent with previous estimates (Dorrington, Moultrie and Timæus 2004). Thus the estimates of mortality derived from the vital registration data corrected for under-registration might be considered to be reasonably reliable.

Unfortunately the promise shown by the analysis of this sort of data previously (Dorrington, Timæus and Gregson 2006) is not borne out by the analysis of the data from the 2001 census and the 2007 Community Survey. While, as can be seen from Tables 4 to 6 in the appendix, the estimates of completeness of reporting of deaths by households (relative to the estimates of the population from the census and survey) are estimated to be around 70% for all adult ages by the death distribution methods, they are, as shown in Fig. 8, somewhat higher

[3] These numbers were set to two thirds of the estimate from the survey plus one third of the number estimated by the ASSA projection model for mid-2007.

(98%, 102% and 123% for 2001, 2001-2007 and 2006 respectively), particularly in the case of 2006, for the age range 15-49 when compared directly with the number of deaths estimated using the data from the vital registration. Thus correcting for under registration in the vital registration provides the ‘gold standard’ estimates of ${}_{35}q_{15}$ for women of 27% and 37% for 2001 and 2006 respectively, correcting for completeness of reporting of deaths by households in the census and Community Survey on the basis only of the census and survey data, produces estimates of 37% and 52% for 2001 and 2006, respectively.

Although not shown here, the data on deaths reported by households from the census and survey for males produced estimates of completeness that were higher than those for females, and hence closer to that estimated by a comparison with the estimate of complete number of deaths from the vital registration but nonetheless also suffered from the same problem.

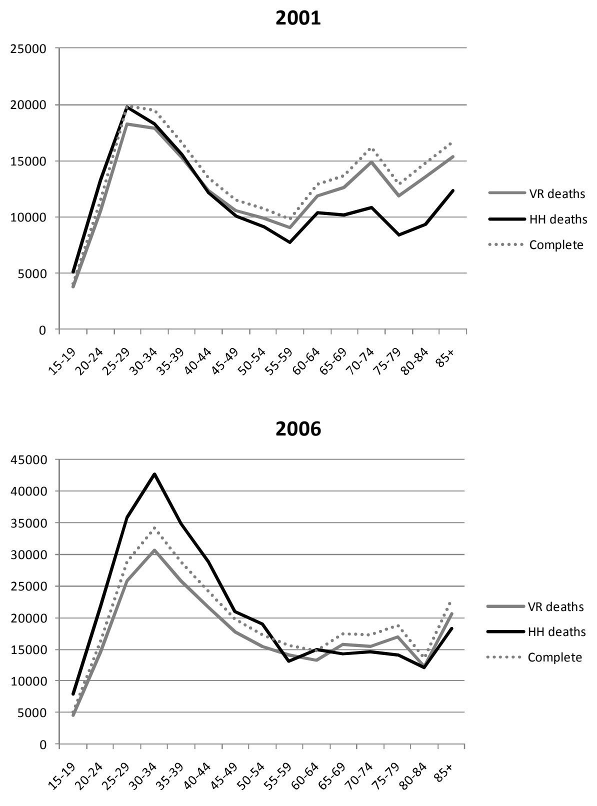

Fig. 8 Reported and complete deaths by age for the periods 2001, 2001-2007 and 2006

On the assumption that deaths aged 15-49 reported by households were 98% complete in 2001 and 123% complete in 2006 and that the numbers of births per annum were 1.152 million in 2001, and 1.082 million in 2006[4], the estimate of the PRMR ranges from 421 to 547 in 2001 and 602 to 612 in 2006, depending on what proportion of the imputed pregnancy related cause of death one takes into account. If we further assume that the estimate for 2006 is the mid-point of the range (607) and that the PRMR of women infected with HIV is 6.2 times higher than those not infected (Bicego, Boerma and Ronsmans 2002; Black, Brooke and Chersich 2009), this would suggest that the PRMR for 2001 was 543 (and that the non-HIV PRMR was 290) since the increase in prevalence of women aged 15-49 over the period was about 4.25%. If, on the other hand, we assumed the

[4] As estimated by the ASSA2003 projection model (www.actuarialsociety.org.za).

multiple to be the maximum of 11.4 (Bicego, Boerma and Ronsmans 2002; Black, Brooke and Chersich 2009) then the estimate of PRMR for 2001 would be 523 (and that of the non-HIV women, 191).

4.4 Estimates of maternal mortality

As can be seen from the Fig. 9 there is a great deal of disparity between various estimates. Estimates of the MMR from vital registration (VR) data show an increase since 1999 reaching a level of 126 per 100 000 births by 2006. Parallel to this, the estimates of PRMR from VR increased to 226 per 100 000 births. The Confidential Enquiry shows a similar trend with rates falling between the two VR based estimates. Census based estates for 2001 have ranged from 542 per 100 000 derived by Garenne, McCaa and Nacro (2008) to 820 per 100 000 derived by Hill, Thomas, AbouZahr *et al.* (2007). Stats SA have reported a figure of 624 per 100 000 based on the 2007 Community Survey (unpublished estimate), while Garenne, McCaa and Nacro (2009) put the estimate at 700. Estimates for South Africa from the model used by WHO and various United Nations agencies were 230 per 100 000 in 2000 and 400 per 100 000 in the year 2005 (Hill, Thomas, AbouZahr *et al.* 2007). The recent estimates by (Hogan, Foreman, Naghavi *et al.* 2010) were 155 per 100 000 in 2000 and 237 per 100 000 in 2008.

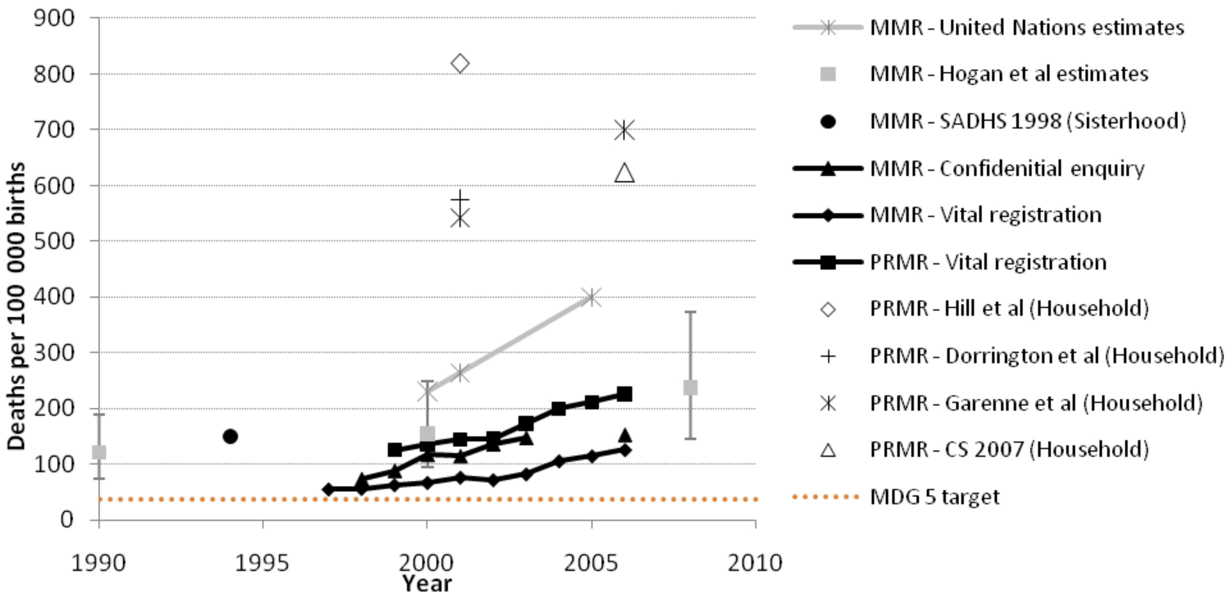

Fig. 9 Various estimates of Maternal and Pregnancy Related Mortality Ratios for South Africa

It can be seen from Fig. 9 that the estimates from the Confidential Enquiry are higher than the estimates from registered deaths with a maternal cause as the underlying cause. The estimate is, in turn, lower than the estimate based on the registered deaths from all natural causes where the woman was pregnant or had given birth in the previous 42 days. Since there is under-registration of deaths, and a proportion of the deaths are classified to ill-defined causes due to lack of information on the underlying cause, it is likely that the numbers of maternal and pregnancy-related deaths are actually higher, and that these rates understate the MMR and PRMR respectively.

On the other hand the estimates derived from the census and community survey may well exaggerate the true ratio due to imputation and possible inclusion of non-natural causes, as well as incorrect adjustment for incompleteness of the death reporting. Considering the estimates based on the 2001 census data, Dorrington, Moultrie and Timaeus (2004) questioned the reasonableness of the estimate they derived, both because of its magnitude (relative to the estimate of 150 per 100 000 from the 1998 SADHS) as well as the extent of imputation of the pregnancy related death data in the 2001 census. Garenne et al (2008) cite a number of supposedly independent estimates as corroboration of the reasonableness of their estimate, however, their argument fails to convince. In addition, they make no adjustment for completeness, other than to reduce the number of deaths for excess of deaths reported for October relative to other months. Further, the only adjustment they make for imputation is to allow for its impact on the age distribution of deaths. Finally, their estimate of the number of births is 10-20% lower than those estimated by applying the estimates of fertility (Dorrington, Bradshaw, Johnson *et al.* 2006; Dorrington, Timæus, Moultrie *et al.* 2004; Moultrie and Dorrington 2004) to the numbers of women of reproductive ages.

The PRMR estimate by Hill *et al* (2007) is much higher than the others derived from the household deaths reported in the 2001 census. To a large extent the difference between their estimate and that of Dorrington *et al* (2004) is explained by their estimate that households report only 55% of all deaths. Estimates by Dorrington *et al* of the completeness of reporting of deaths by households relative to those expected on the basis of vital registration (corrected for under-registration) suggest that reporting is about 85% complete, with some evidence of an impact of dissolution of households on the reporting of deaths of the women (and possible over-reporting of deaths in young adults). The reason for this discrepancy is not clear at this stage but as discussed by Dorrington, Timaeus and Gregson (2006) estimating completeness of reporting of deaths over the most recent 12 months as reported by households may well not produce an accurate estimate when one has only one census reporting deaths and the immediately preceding census is 10 years earlier.

4.5 Narrowing the gap between various estimates for 2001 and 2006

Thus using our estimates of the PRMR from the census and survey, estimates for 2001 range from a minimum of 76 (MMR based on VR maternal mortality) to a maximum of 547 (PRMR (including external causes) from deaths reported by households). For 2006 the range is 126 to 612. Of this range the estimates from the census/survey question, as described in section 4.3 range from 421 to 547 (mid-point = 484) in 2001 (or 356 to 461 (409) excluding external causes) to 602 to 612 (607) in 2006 (or 501 to 509 (505) excluding external causes). The question is whether one can narrow these ranges of estimates.

First, the vital registration data should be adjusted for under-reporting of deaths, estimated to be 9% incomplete in 2001 and 8% incomplete in 2006. Next the number of maternal and pregnancy related deaths in the vital registration can be increased by a proportion (estimated to be about 17% in 2001 and 16% in 2006) that may have been classified as ill-defined natural. These adjustments increase the estimate of the MMR (including indirect causes) to 102 in 2001 and 169 in 2006, which are very similar to the estimates from the confidential enquiry. The PRMR (including external causes) increases to 195 in 2001 and 300 in 2006 (i.e. still around double the MMR).

Alternatively if we assume that the estimate of 150 (of PRMR excluding external deaths) from the siblinghood data in the 1998 SADHS is correct and that the ratio of the MMR of mothers infected with HIV to that of non-infected mothers is in the range 3.6 to 11.4 estimated by Black, Brooke and Chersich (2009) then given estimates of the prevalence of HIV in women 15-49 (namely, 2.5%, 16.75% and 21% for 1994, 2001 and

2006 respectively[5]) the estimates of PRMR (excluding external deaths) could range from 171 to 411 in 2001, and 184 to 478 in 2006. However, the lower bounds would imply that the ratio of the PRMR of infected to uninfected mothers would have been at the highest possible in 1994 and to have fallen to the lowest possible in 2006, which seems quite unlikely, and more realistic lower bounds would be to assume a multiple of 3.6 throughout which gives 202 and 218 for 2001 and 2006 respectively.

A final approach would be to derive a national estimate using the deaths recorded in institutions reported by the confidential enquiry together with an estimate of the proportion of maternal deaths in rural areas occur in institutions. According to the report of the Confidential Enquiry (National Committee for Confidential Enquiry into Maternal Deaths 2008) Graham and Newell (2009) estimated the proportion of rural deaths occurring in institutions to range between 20% and 66% and thus the MMR to range between 181 and 382 for the period 2005-2007.

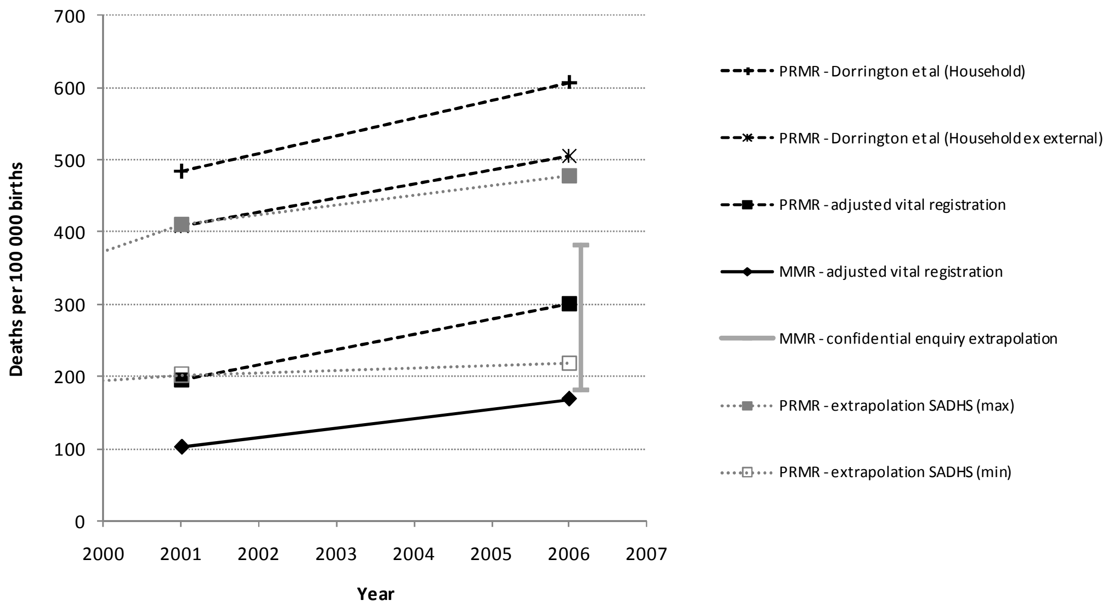

Fig. 10 Estimates of MMR and PRMR for 2001 and 2006 from various sources

The adjusted estimates are presented in Fig. **10**. From the comparison the following is apparent:

- The estimates from the PRMR from the census/survey are about double those from the vital registration data.
- The range of estimates of MMR from Graham and Newell (2009) suggest that the true MMR could be double that recorded in the vital registration data.
- Deaths of pregnant women due to unnatural causes contribute 16-17% to the deaths of pregnant women reported by households. However, only about 5% of deaths of pregnant women in the vital registration data are reported to be due to unnatural causes, for both 2001 and 2006. Since one can probably assume that all deaths of pregnant women from external causes would be correctly documented in the vital registration (through autopsy) it would appear that data captured by the census exaggerates the proportion of deaths due to non-natural causes by at least 10%.

[5] Derived from the ASSA2003 AIDS and Demographic projection model (www.actuarialsociety.org.za).

- There appears to be a consistent increase in rates between 2001 and 2006. The increase is consistent with an increase that would result from the HIV prevalence increasing from 25% to 29% and the observation that the MMR and PRMR of mothers infected with HIV is about 6 times higher than that of uninfected mothers (Bicego, Boerma and Ronsmans 2002; Black, Brooke and Chersich 2009).
- Although the adjusted estimates still indicate considerable uncertainty in the MMR (ranging from 181 to 478 per 100 000 births in 2006) MMR in South Africa in 2006 was probably of the of the order of 300 per 100 000 births[6].

Discussion

While it is probably clear that the country is not on track to meet the MDG 5 target of reducing the Maternal Mortality Ratio by three-quarters (if we take the 1998 DHS estimate as base value) by 2015, and that the data suggests an upward trend over time, it must be acknowledged that there is much uncertainty about the actual level of MMR. However, whichever measure is considered, the increase between 2001 and 2007 appears to be consistent with the increase in the prevalence of HIV among pregnant women, suggesting access to anti-retroviral therapy may be expected to reduce maternal mortality in future.

Although it is possible the results produced above are unique to the South African data or situation (e.g. poor field work and training which has resulted in recent censuses having to be corrected for significant undercounting identified by the post enumeration surveys (Statistics South Africa 1998, 2004) or in some demographic questions, such as those on child mortality in the 2001 census, being rendered useless (Dorrington, Moultrie and Timæus 2004)) it does appear that there are some more general conclusions that can be reached from this research. The first is that one cannot assume that deaths reported by households are 100% complete (or that the incompleteness of reporting of deaths by household is similar to the incompleteness of reporting of births) and hence it is necessary to assess the level of completeness of reporting of deaths by households (and estimate the number of births as accurately as possible). However, efforts to assess completeness of reporting of deaths suggest that while it may be possible to derive reasonable estimates of completeness for an intercensal period from two censuses the same cannot be said of a single census. In addition, even where it is possible to produce a reasonable estimate of the overall level of completeness of reporting of adult deaths it is possible that there could be, *inter alia*, over-reporting of the deaths of young women where significant numbers of them might be considered to be part of more than one household (e.g. before formal marriage).

In addition, it appears that small sample surveys are probably not reliable enough to be used to estimate pregnancy related mortality – not only are estimates of completeness of reporting highly variable depending on the age range used to derive the estimates but there is also uncertainty of the age distribution and completeness by age of the population.

However, even being able to correct for these problem (by, for example, comparison with the overall number of deaths estimated from complete vital registration), still leaves us with the conclusion that the numbers of deaths that are reported by households as being pregnancy related grossly over estimates the level of the

[6] Roughly the mid-point of the range of the estimates based on (a) the vital registration adjusted for under-registration and ill-defined deaths; (b) projections from the SADHS 1998 estimate allowing for the possible impact of HIV; and (c) the Confidential Enquiry allowing for maternal deaths outside facilities, bearing in mind that this is an underestimate since it excludes maternal deaths in facilities but outside labour wards.

PRMR. Further research is needed to assess to what extent this is particular to the Southern African context, where estimates of PRMR from the censuses appear to be extraordinarily high (Hill, Queiroz, Stanton *et al.* 2007), or if it is a more general feature of this question, which is simply magnified in Southern African censuses due to extremely high HIV mortality.

In addition to this the question appears to exaggerate, significantly, the number of deaths due to external causes that occurred within 42 days of the women being pregnant. This could be the result of poor fieldwork or training, either in properly identifying whether the cause was unnatural, or identifying recent pregnancy correctly. Also, where data have been edited it is necessary to investigate the impact of the various edits thoroughly. Where details on which data are edited and the type of edits which were carried out are not available, as is the case in most sub-Saharan African countries, the estimates need to be treated with a high degree of skepticism.

It is necessary to be more definite with our definitions, at least in terms of the indices used to measure and compare maternal mortality. As we see it, indices could be based on one of four definitions, namely, mortality due to direct obstetric causes; maternal mortality due to both direct and indirect causes; pregnancy related deaths excluding unnatural causes; and all cause pregnancy related deaths. In addition, it is desirable, at least for comparative purposes, that a standard age range (e.g. 15-49) be used.

Further there is the need to develop vital registration systems if we want to measure maternal mortality at all accurately. In this regard the addition of the question on pregnancy on the death certificate appears to be useful. Finally, since one is attempting to estimate a relatively rare event it is necessary to understand the data perhaps more thoroughly than for many other estimates, often making it difficult for those without a significant understanding of how the data were produced and the local context to be able to produce reliable estimates.

The census question cannot be relied upon to produce accurate estimates of the maternal mortality ratio. First, it estimates the pregnancy related mortality ratio which is somewhat higher, even after excluding deaths from unnatural causes, than the maternal mortality ratio, even if one includes indirect maternal causes. Second, even ignoring the difficulty of estimating the completeness of reporting of deaths by households, households appear to exaggerate, considerably, the number of pregnancy related deaths. Third, and most important for the purpose of this paper, it appears as if the violation of the assumption that completeness of deaths reported by households is the same for all ages is such as to undermine one's confidence in any estimates produced using death distribution methods without further correction for the excess of reporting of young adults and the disintegration of households on death. While it is probable that the effect of under-reporting of older deaths due to disintegration of households is more extreme in South Africa than in other countries (particularly including the effect of higher level deaths which occur in old-age homes which are not captured as part of households), it is likely that similar effects will be found in other African countries. It may be possible to correct for this bias by making use of census information on the proportion of women living in households where they are either the head of household or sole breadwinner, but this will require further research.

In terms of South Africa, we reiterate Graham *et al* (2008) who emphasise the importance of ownership of the data – making the point that "what you count is what you do". The introduction of the confidential enquiry into maternal deaths indicates that South Africa has gone some way to making this commitment. However, our investigation suggests that reliable measurement of progress in reducing maternal mortality is unlikely to be achieved through this approach and thus that it will be necessary to further strengthen the vital registration and statistics system.

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Appendix: Estimates of completeness of reporting of deaths of females

Table 1 Estimated completeness (%) vital registration 2001: GGB/SEG

End age / Start age	65	70	75	80	85
5	93/95	95/97	102/92	92/94	101/91
15	96/91	99/95	96/89	90/93	106/89
30	79/86	90/95	84/86	94/93	92/89

Table 2 Estimated completeness (%) vital registration 2001-2007: GGB/SEG

End age / Start age	65	70	75	80	85
5	122/100	120/89	104/88	93/89	91/89
15	124/89	107/86	94/83	87/85	87/86
30	105/85	91/79	83/80	84/83	85/85

Table 3 Estimated completeness (%) vital registration 2006: GGB/SEG

End age / Start age	65	70	75	80	85
5	115/92	105/89	88/91	100/89	94/92
15	107/90	89/85	90/89	93/87	87/91
30	87/84	75/83	90/82	86/86	91/90

Table 4 Estimated completeness (%) household deaths 2001: GGB/SEG

End age / Start age	65	70	75	80	85
5	66/67	66/68	72/64	64/66	69/65
15	65/63	68/66	66/62	62/66	73/65
30	55/60	63/67	58/60	65/66	64/64

Table 5 Estimated completeness (%) household deaths 2001-2007: GGB/SEG

End age / Start age	65	70	75	80	85
5	96/78	92/70	81/68	71/69	70/73
15	92/70	80/66	71/65	65/68	66/69
30	77/66	70/61	63/63	64/66	67/69

Table 6 Estimated completeness (%) household deaths 2006: GGB/SEG

End age / Start age	65	70	75	80	85
5	89/74	79/70	70/73	78/74	75/77
15	72/68	64/68	68/72	69/72	68/77
30	60/66	58/68	69/71	69/71	75/78