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Maternal Mortality in South Africa in 2001:

From Census to Epidemiology

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Abstract

The 2001 census of South Africa included a question on deaths in the previous 12 months in the household, and for these deaths two questions on external causes and maternal mortality. The census offers therefore a range of opportunities to assess levels and differentials in maternal mortality, in a country severely affected by high death rates from HIV/AIDS and from external causes. The level of the Maternal Mortality Ratio in 2001, MMR = 646 per 100,000 live births, appeared much higher than anticipated, and much higher than previous estimates dating from pre-HIV/AIDS times. This high level occurred despite a relatively low proportion of maternal deaths (6.4%) among deaths of women aged 15-49 years, and was due to the outstandingly high level of adult mortality, some 4.7 times higher than expected from mortality below age 15 or above age 50. The main reasons for these outstanding levels were HIV/AIDS and external causes of deaths. Levels were found to be consistent with other findings in the Cape Town area, and with the Agincourt DSS. The gradients of differentials in MMR were considerable: 1 to 9.1 for population groups (race), 1 to 3.1 for provinces, and 1 to 2.1 for levels of education. Relationship with income and wealth were complex, with highest values for middle income and middle wealth index. The effect of urbanization was small, and reversed in a multivariate analysis. Higher risks in some of the provinces were not necessarily associated with lower income or lower education, but correlated with prevalence of HIV/AIDS. These results have many implications for public health: maternal mortality seems to have increased dramatically over the past 10 years, most likely because of HIV/AIDS and tuberculosis; indirect causes of maternal mortality appear much more important than direct obstetric causes; the MMR appears not longer a reliable measure of the quality of obstetric care in this type of situation.

Keywords: Maternal mortality, Differentials, Risk factors, HIV/AIDS, Indirect causes, External causes, South Africa

Introduction

Maternal mortality is an important element of the health transition, and in developed countries the decline in maternal mortality indicators has been dramatic during the 20th century. Beyond the number of maternal deaths, which remains small compared to the number of deaths for all causes combined, maternal mortality bears a strong symbolic value, since these deaths occur "while giving birth". Interest in maternal mortality in developing countries has been gaining momentum in the 1980's with the "Safe Motherhood Initiative", and more recently with the "Millennium Development Goals" (MDG) and the IMMPACT project [Rosenfield and Maine, 1985; Rosenfield et al., 2006; United Nations, 2000; Graham, 2002]. A recent collection of articles, published in the Lancet in 2006, summarizes the demographic and public health debates around maternal mortality [Ronsmans et al. 2006].

A recurrent issue with assessing maternal mortality levels in developing countries has been the source of data, especially in situations where vital registration is deficient, which is the case for most of Africa [Boerma, 1988]. Many attempts were tried over the past 50 years to overcome this lack of information. For instance, some of the demographic sample surveys conducted by INSEE in the 1950's and 1960's in Africa included a question on maternal deaths among other questions on deaths in past 12 months. This was the case at the survey conducted in Burkina Faso in 1960-1961 (Haute Volta at that time), and again later in the same country at the 1991 demographic survey. These surveys were often based on fairly large samples (50,000 to 100,000 households), and produced some reliable estimates. With the WFS and DHS programs in vogue since the mid 1970's, the focus became on smaller surveys, based on 5,000 to 10,000 households, and a new technique was developed for measuring maternal mortality: the "sisterhood method", with its two variants, the indirect and the direct estimates [Graham et al., 1989; Rutenberg and Sullivan, 1991]. The sisterhood method measures maternal deaths among the sisters of the respondent, which can therefore increase significantly the number of cases in populations with high fertility. However, if the sample size is small, the number of cases recorded this way is still small, with wide confidence intervals. These are even wider when the indirect estimation is used [Garenne & Friedberg, 1997]. Furthermore, the sisterhood methods produce estimates for several years before the survey, with imprecise dating in case of the indirect method. When applied with care, both types of retrospective data provide similar estimates, as shown in a case study in Bangladesh (Hill et al., 2006).

An alternative is to use a full scale population census, and to investigate maternal deaths in the past 12 months (or 2 to 3 years), to get rid at the same time of the issue of sample size and of the issue of time reference. Only a few examples are available in Africa: Benin (1992), Madagascar (1993), and Zimbabwe (1992), which have already been reviewed [Stanton et al. 2001], and the South Africa 2001 census, which is investigated in this study.

Note that The United Nations “Principles and Recommendations for Population and Housing Censuses, Revision 2” recognize the importance of using censuses to measure maternal mortality for countries that lack complete and reliable civil registration and vital statistics systems, but also note that census information in general is a poor substitute for complete and reliable vital registration data. In addition, they present cautionary statements about the collection of this information in a census, which thus implies the need for countries to build and maintain complete and reliable vital registration systems. They recommend two follow-up questions in cases where the household being interviewed reports that there was a death during the past 12 months. After ascertaining the name, age and sex of the deceased person and date of death, the two additional questions concerning cause of death should be asked as follows: 1) Was the death due to an accident, violence, homicide or suicide? 2) If the deceased was a woman aged 15 to 49, did the death occur while she was pregnant or during childbirth or during the six weeks after the end of pregnancy? [United Nations, 2006].

In addition to demographic information, many studies have tried to capture maternal mortality from hospital based studies. Of course, these studies have numerous biases, and they may either over-estimate maternal mortality when hospital function well and attract most of the complicated obstetric cases, or under-estimate maternal mortality, when the population has low access to the health infrastructure.

The aim of this paper is to investigate the results of the 2001 census of South Africa, which included the recommended questions on maternal deaths. In addition to the estimation of maternal mortality levels and age patterns, the paper also shows the ability of the census to provide information on maternal mortality differentials, and the opportunity for multivariate analysis, analogous to a case / control study, to investigate epidemiological risk factors.

Definition of maternal deaths

The World Health Organization (WHO) definition has been stable over the past 30 years: “A maternal death is the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and the site of the pregnancy, from any cause related to- or aggravated by- the pregnancy or its management, but not from accidental or incidental causes” (ICD-10, volume 2, page 134). The WHO definition also distinguishes between the “direct obstetric” causes, resulting from natural obstetric complications or from obstetric interventions, and the “indirect obstetric” causes, resulting from previously existing diseases, or diseases that developed during pregnancy independently from obstetric causes. The ICD-10 makes a special provision for HIV/AIDS and obstetrical tetanus (normally coded among the infectious and parasitic diseases), and recommends to include them among the maternal deaths. In theory, HIV/AIDS should be included in the “indirect cause” category, and the obstetrical tetanus in the “direct cause” category, but this is not explicit in the ICD-10. The ICD-10 manual recommends to publish separately direct causes and indirect causes, however this is rarely done in practice in demographic surveys, and more generally in developing countries, except when the source of data are medical certificates or special hospital investigations. The WHO definition therefore includes deaths that result from communicable and non-communicable diseases that could have occurred even if the woman had not been pregnant or delivering. However, the WHO definition does exclude external causes which are not related to pregnancy or delivery.

Khlat & Ronsmans [2000] have shown how difficult it is to assess an attributable risk of maternal mortality from the WHO definition. In fact, during the maternal risk period (40 weeks of pregnancy and 6 weeks post partum), women appear at the same time at increased risk of death from the direct causes, and at lower risk of death from indirect causes for a variety of reasons. A simple way of investigating the possible biases is to compare the proportion of deaths due to maternal causes to the proportion of time spent by women in the maternal risk period between age 15 and 49, which depends primarily on the Total Fertility Rate (TFR). If the first proportion is much higher than the second, then most likely the direct causes are overwhelming; however, in the case where both are equivalent, positive and negative effects of pregnancy are compensating. We will see such a case when analyzing the 2001 census of South Africa.

Data and Methods

The IPUMS sample

The 2001 census conducted in South Africa included a question on deaths that occurred in the past 12 months in the household, that is between October 10, 2000 and October 10, 2001. Deaths were recorded by month and year and by age and sex. Furthermore, for each death in the past 12 months, two questions on cause of death were asked: whether it was due to accident or violence, or whether it was a maternal death. Maternal deaths fitted the World Health Organization (WHO) definition, that is any death of a woman in their reproductive ages (in this case under age 50), either pregnant, delivering, or within six weeks after delivery.

The census also included a number of questions which could be used for the analysis of maternal mortality differentials: area of residence (urban/rural), province of residence, level of education, citizenship (nativity), population group (race), ethnicity (defined by the language spoken at home), and religion. In addition, several characteristics of the dwelling unit were also available in the census form (type of living quarters and housing unit, number of rooms, tenure status, source of water, toilet facility, energy or fuel used mainly for cooking, heating, and lighting), as well as a number of household goods (radio, refrigerator, television, telephone, computer, cell-phone). The questionnaire also included an item on annual gross income for each household member, coded in 12 categories, presented as multiples of 4800 ZAR per year, coefficients being 2^n, with n= 1 to 12.

A 10% sample of the census was made available to the IPUMS project by Stats-SA, the statistical institute of South Africa, and this dataset was the basis for the analysis. The sample included most questions on the questionnaire. However, in the IPUMS file, the question on survival of mother and father was not included, and furthermore the row number of the surviving mother was not included, which did not permit a direct match of infants to their mother.

Calculation of maternal mortality levels

The three classic indexes of maternal mortality are used in this paper. The maternal mortality ratio (MMR) was calculated as the number of maternal deaths to the number of births in the past 12 months. The number of births in the past 12 months was calculated as the number of infants surviving at time of census backward projected in past year. The probability of surviving was calculated directly from the data ($_1L_0/S_0$), by calculating the infant death rate (deaths age 0 in past 12 months divided by the infant population at time of census), and applying a separation coefficient ($_1a_0$) of 0.315, derived from model life tables. This calculation was repeated for each group in the differential analysis.

The maternal death rate (MDR) was calculated as the number of maternal deaths divided by the female population age 15-49 at time of census.

The maternal mortality quotient (MMQ), or lifetime risk of dying from maternal causes, was calculated by reconstructing the life table for maternal mortality, by single year of age, from age 12 to age 51 years. Yearly quotients were calculated as the ratio of maternal deaths to the female population at risk, that is the surviving women plus the deaths in the past 12 months.

Socio-economic factors

Most socio-economic variables were used as recoded in the IPUMS sample, which was equivalent to the coding on the census sheet in most cases. Income was given as the mean of the class (for instance 2400 ZAR for the class ranging from 1 to 4800 ZAR, etc.), with the exception of the last open class (2,457,601+ ZAR) coded as the bottom value of the class.

The differential analysis presents maternal mortality ratios by socioeconomic characteristics taken at the household level, since details at the level of individual maternal deaths were not available. For some factors the definition of socio-economic characteristics was straightforward, since it applied to all members of the household (place of residence, province). For other characteristics, the corresponding value for the head of household was considered (race, ethnicity, nativity). For level of education, we took the highest level in the household, whoever it was (other codings were tried: level of education of the household head, level of education of women in their reproductive ages, but the highest level in household gave the highest correlations). For income, we cumulated all incomes in the household, and divided by the number of household members, to obtain an income per capita.

We also defined a “wealth index” on the model used by other authors (Garenne & Hohmann, 2003). This index is the sum of 10 dummy variables indicating modern goods in the household or its modern status. The variables selected were: ownership of dwelling, piped water, electricity, sewage, toilets in dwelling, telephone, cell-phone, television, refrigerator, and radio.

Matching cases and controls

In the multivariate analysis, cases (maternal deaths) were matched with controls (women who delivered and survived). Controls were defined as women living in the households who had a surviving infant at time of census. The identification of the controls was done by selecting women most likely to be mothers of the infants in the census file. In more than half of the cases, this was easy since only one woman aged 12-50 years was living in the household. In other cases, we took the woman aged 12-50 preceding the child in the list of household members. The choice of the woman selected for controls in a household did not matter for the multivariate analysis, since only the characteristics of the household were considered. This choice could have been crucial for the estimation of the effect of age at delivery, and was therefore ignored for the case control study. However, we present below an estimation of age effects based on an independent estimation of the age pattern of fertility derived from DHS data (see below).

Results

Death registration

The IPUMS 10% sample of the 2001 census of South Africa included 36,267 deaths out of a total of 3,725,655 persons enumerated, and 76,292 surviving infants, corresponding to 78,702 births in the past 12 months, with a survival probability of newborns from birth to the census date equal to 0.970. This corresponds to a crude birth rate (CBR) of 21.1 per 1000 and a crude death rate (CDR) of 9.7 per 1000, which are values consistent with other estimates for this period in South Africa. The distribution of deaths by month and year was quite regular, with an average of 2790 deaths per month, and a marked seasonality with excess mortality from June to September. However, the month of October was probably over-estimated, since the 21 days of year 2000 included 2641 deaths and the 10 days of year 2001 included 2137 deaths, whereas one would have expected 3133 deaths in total from the number recorded in the previous and next two months. This suggests that mortality in the previous 12 months could have been overestimated by some 4.7%, because of including too many deaths in October 2000 (instead of only from October 10 to October 31) and in October 2001 (instead of only from October 1 to October 10). We did not attempt to correct for this minor bias in the final estimates.

Maternal mortality level

The IPUMS sample of the 2001 census of South Africa included 508 maternal deaths, out of 1,048,824 women aged 15-49 years. Straightforward calculations give a maternal mortality ratio (MMR) of 646 per 100,000 live births, a maternal death rate (MDR) of 48.4 per 100,000 women, and a life-time risk (MMQ) of 1681 per 100,000 (Table 1). Matching the MMR and MMQ corresponds to a total fertility rate (TFR) of 2.62, which is basically equal to the TFR expected from the trends in TFR at the two previous DHS surveys (TFR= 4.58 at the 1988 DHS for the 1985-1988 period, and TFR= 3.10 at the 1998 DHS for the 1995-1998 period predict a TFR of 2.60 in 2001). These estimates are therefore internally consistent.

The value of the MMR may appear high for a country such as South Africa. However, the total number of deaths of females age 15-49 in the 12 months preceding the survey was 7934, so that the proportion of these deaths classified as maternal deaths was only 6.4%. With a TFR of 2.62 children per woman, some 6.6% of the time of women age 15-49 is spent in the maternal risk period (40 weeks of pregnancy and 6 weeks after delivery out of 35 years), which means that the observed proportion of maternal deaths is equivalent to that expected from the level of mortality in the population, and therefore that the deaths attributable to obstetric causes must be compensated by the lower risk of pregnant women from indirect causes, for a variety of reasons that remain to be explored. In conclusion, it is because female adult mortality is extremely high in South Africa that the MMR also appears very high.

The female mortality quotient between ages 15 and 50 years (${}_{35}q_{15}$) calculated from the 2001 census data was 0.2471, which corresponds to a life expectancy of 49.7 years in the UN model life table system for developing countries (general pattern). This is obviously much lower than the observed female life expectancy in the census data (e°(0)= 64.4 years). This discrepancy is due to the fact that mortality in young adult ages is much higher than that at other ages, in particular because of the high burden of HIV/AIDS and of external causes. Mortality before age 15 (${}_{15}q_0$) was 0.072, which corresponds to a life expectancy of 68.1 years in model life tables. Life expectancy above age 50 was 30.65 years, which corresponds to a life expectancy of 77.1 years in model life tables. Taking an average of 72.6 years as a reference value for life expectancy, adult female mortality in the census appeared as 4.7 times higher than expected from model life tables based on other age groups (expected ${}_{35}q_{15}$ = 0.05237). If this coefficient is applied, the MMR would be only 137 per 100,000.

The 2001 census estimates for the Shangaan living in rural areas of the Limpopo province could be compared with the Agincourt DSS, a population from the same ethnic group living in the same province, and which accounts for about 7% of the total Shangaan living in Limpopo (Tollman, 1999; Tollman et al., 1999). The MMR for the 2000-2002 period in Agincourt was 305 per 100,000 live births (15/4912), not significantly different from the MMR among the Shangaan from rural Limpopo at the 2001 census (MMR= 382 per 100,000; P= 0.593). Note that the two populations were also comparable in birth rates (24 per 1000 in both cases, P= 0.970), and in life expectancy at birth for men (e°= 58.7 and 57.1 respectively, P= 0.251). However, female mortality in 2000-2002 was higher in Agincourt than at the census (e°= 64.3 and 72.9 respectively, P< 0.001), and this was true for all adult age groups. This is probably due to a higher level of HIV/AIDS infection among women in Agincourt than among the Shangaan of Limpopo on the average, since female life expectancy averaged also 72 years in 1992-1994 in Agincourt, before HIV/AIDS became an important cause of death.

In-depth studies and long term trends of maternal mortality were conducted in the Cape Town Peninsula, from births and deaths data recorded in hospitals [van Coeverden, 1979 and 1986; Fawcus et al. 2005]. Results show first a marked decline in MMR from 301 per 100,000 in 1953 to 31.2 per 100,000 in 1987-1989, followed by a marked increase reaching 112 per 100,000 in 2002. These data are not strictly comparable to the census data, since they apply to the most developed part of the province, and are based on hospital data. However, they indicate firstly that even in the most advanced part of the country, MMR was already high (112 versus 306 for the whole province at the 2001 Census), and secondly, that the MMR has been multiplied by 3.6 in the recent years, mostly because of indirect causes, in particular HIV/AIDS, and to a lesser extent to hypertension and pregnancy related sepsis.

Another element corroborating the MMR estimates is given by hospital statistics on induced abortion. Dickinson and Rees (1999) report that “425 women died in hospitals each year from complications of unsafe, clandestine abortions”. The confidential enquiry on maternal deaths (1998) estimated that out of 133 cases of maternal deaths investigated, 12 were due to septic abortion, out of which 7 were due to induced abortion outside of health services. Even if these data apply to a time when the “Termination Of Pregnancy act” was just passed, it gives an order of magnitude of the number of maternal deaths from other causes consistent with the 508 deaths found in the 10% sample.

Maternal mortality differentials

South Africa is a complex society, with outstanding gradients by race and level of economic development. Some groups are living on European standards, whereas others are closer to those living in remote place of other parts of sub-Saharan Africa. As a consequence, mortality differentials are usually very large, and this applies as well to maternal mortality. In addition to living standards, mortality levels and trends are also compounded by the raging HIV/AIDS epidemic and by the high mortality from accident and violence, both groups of causes of death which maintain a complex relationship with socio-economic status, often different from that with other causes of death such as other infectious and parasitic diseases, and non-communicable diseases. We present here only differentials in the MMR, since the relationships with the other maternal mortality indicators were the same (Table 2).

The MMR was only marginally higher in rural areas (691 per 100,000) than in urban areas (605 per 100,000). This is probably due to the balance between diverging forces: more HIV/AIDS and more external causes in urban areas, and less access to medical services in rural areas (Table 2).

The gradient by province was very marked, from 3.0 to 1 between the province with highest maternal mortality (Kwazulu-Natal, 933 per 100,000) and the province with the lowest MMR (Western-Cape, 306 per 100,000) (Figure 1-e). South African provinces vary very much in their ethnic composition, as well as in their level of development. Kwazulu-Natal is the most populated, has the highest HIV seroprevalence rates and the lowest life expectancy, but fares better for education, income and wealth. On the other side of the spectrum, Western Cape has the lowest HIV seroprevalence rates, the highest life expectancy, the highest level of education, the highest wealth index, and the next-highest income. The wealthiest province (Gauteng) has a MMR below average, but still somewhat higher than the MMR in the poorest province (Limpopo). These two contrasting provinces have similar life expectancy (67.6 and 66.4 respectively), similar levels of female adult mortality at age 15-49 (0.155 and 0.172 per 1000), but Gauteng has higher HIV infection rates (29.8%) than Limpopo (14.5%), which probably explain the differences in maternal mortality, since the death rates from external causes was about the same.

The gradient by population group (race) was even more marked, with a range from 9.1 to 1 from Black/African (717 per 100,000) to White/European (79 per 100,000), the two other groups being in an intermediate situation: Coloured: 348 per 100,000, and Indian/Asian: 231 per 100,000 (Figure 1-b).

The gradient by ethnicity, measured by the language spoken at home, reflects at the same time the race, the urbanization, and the location. As could be anticipated, the range of variation was also considerable, from 1 to 7.5 (Figure 1-f). The two groups speaking European languages appear in a more favorable situation: speakers of English (122 per 100,000) and Afrikaans (287 per 100,000). Among the speakers of African languages, the levels of MMR were much higher, with a range from 469 per 100,000 (SiSwati) to 910 per 100,000 (IsiZulu), with the exception of the TshiVenda (93 per 100,000), a group in which only 2 maternal deaths were recorded, therefore with a huge confidence interval (23 to 372 per 100,000), although still significantly lower than the next lowest African group, the SiSwati (P= 0.034).

The gradient by level of education was small, compared to gradients by province, primarily because of the high level of education in the country, even in remote rural areas (Figure A-a). The range was from 1 to 2.1 between 12+ years of education (MMR= 461 per 100,000) and less than 5 years of education (MMR= 963 per 100,000).

The gradient by level of income was complex, with two peaks, one for the very poor, who declared no monetary income (MMR= 743 per 100,000), and the other for the intermediate category (4800-9600 ZAR per capita), with the same MMR (Figure 1-c). The differences between contiguous categories for groups above the intermediate category were statistically significant (P= 0.015 between III and IV, and P= 0.036 between IV and V), whereas differences between contiguous categories for groups below the intermediate were not (P= 0.267, P= 0.538 and P= 0.737 respectively). However, it was clear that maternal mortality was not increasing with lower income below the intermediate category. This seems to be due to the complex relationships between area of residence, income, HIV/AIDS and level of mortality from all causes.

The gradient by level of wealth, measured by the wealth index was even more striking than the income gradient (Figure 1-d). The relationship had an inverse U-shape, with lower levels of MMR for the second poorest (MMR= 556 per 100,000) and the wealthiest (MMR= 311 per 100,000), and the maximum for the intermediate category (5 items), with an MMR= 867 per 100,000.

The correlations between the MMR and the various variables at the level of the province revealed the key factors. Correlation between the MMR and any indicator of mortality was very high, and reached -0.91 with life expectancy, and was also high (+0.73) with the prevalence of HIV in the province. Correlations with indicators of socio-economic status were average: -0.42 with education; -0.49 with income, -0.49 with wealth, -0.32 with urbanization. Relationships with racial composition were complex: negatively related with the proportion of White/European (-0.53) and Coloured (-0.58), but positively related with the proportion of Black/African (+0.58) and Indian/Asian (+0.45), the last being explained by the concentration of Indian/Asian in Kwazulu-Natal. Correlations with fertility (+0.14) and with population density (-0.15) were very small. Correlation with the proportion of home delivery was positive, as expected, but of small magnitude (+0.29), underlying again the importance of indirect causes in maternal mortality levels in South Africa.

Age effect

The effect of age at delivery could not be assessed directly from the census data, due to the lack of link of births to mothers, but could be approached by comparing the distribution of maternal deaths by age to that expected from age specific fertility rates in the 1998 DHS survey, standardized with the estimated TFR in 2001. Results show a regular increase of MMR with age from adolescent years (12-19) to age 39, and a major increase above age 40 (Figure 2). This is probably due to two factors: the age at HIV infection, which peaks around age 30 (age effect), and the fact that older women are much more likely to deliver at home (cohort effect). The National Committee for the Confidential Enquiry into Maternal Deaths (1998) already noted the high vulnerability of older women, attributed to obstetric causes and to heart complications in case of pre-existing valvular heart disease.

5) Multivariate analysis

Because of the complex social fabric of South Africa, the multivariate analysis is particularly difficult, and potentially misleading. A series of Linear-Logistic regression models were ran on cases (maternal deaths) versus controls (surviving women), which provide not only odds ratios, but also absolute risks since controls cover the whole population. However, it should be noted that the analysis is not strictly equivalent to a formal case / control study, since individual characteristics are not known for women who died, but only the characteristics of their household. In addition to household characteristics, we have added, in a second model, some of the characteristics of the province (community variable) likely to have an effect on maternal mortality ratios, namely the HIV seroprevalence rate in 2001, the proportion of home delivery, and the female death rate from external causes at age 15-49 years.

Considering first the household characteristics reveals some interesting features, when controlling for urban residence, education, race, wealth, and province (Table 3). Firstly, the effect of urban residence changed, with higher levels of MMR in urban areas (+27% instead of -14% in the univariate analysis) when other factors were taken into account. Secondly, the effect of the level of education became even smaller, with a net effect of -15% for one standard deviation (2.9 years of schooling). Relationship with income or wealth was not linear, and their net effect in the logit-linear regression were not significant. As seen above in the univariate analysis, the relationship with wealth was quadratic, and better seen as a peak for medium values of wealth (5-items). We therefore coded a "wealth distance" as the absolute difference between the number of items in the household and the medium value. Taken this way, the effect of wealth was significant, but remained relatively small, and of similar magnitude to that of education. The ranking of the four racial groups was maintained in the multivariate analysis. Large differences were also seen within provinces, keeping basically the same relationships as in the univariate analysis. The difference between Limpopo and Western Cape even disappeared in the multivariate analysis, because the small difference noted in the univariate analysis was compensated by the effect of large differences in income and education. The case of Limpopo deserves further investigation, not only for maternal mortality, but also for overall levels of mortality, which appear lower than expected from its situation in socio-economic development. Note that the Agincourt DSS, located in Limpopo, confirms these findings.

In order to better approach the large differences between the provinces, further controls were added: the HIV prevalence in the province, taken from the published values by the Ministry of Health for 2001 (sentinel sites of pregnant women), the death rate at 15-49 from external causes, calculated from the 2001 census data, and the proportion of home deliveries, taken from the 1998 DHS survey. Results confirmed the probable role of HIV/AIDS and violent deaths in the overall level of maternal mortality: both effects were positive and significant (Table 4). The effect of the home delivery variable, however, was not significant, and even somewhat negative, contrary to what was expected. This indicates that indirect causes (and in particular HIV/AIDS and external causes) are the most important factors for determining MMR levels, and that conversely direct causes play a much smaller role in the differentials.

Discussion

The census has a great potential for monitoring levels, trends and differentials in maternal mortality. By definition, the census provides a complete picture of the whole population, and therefore ignores the issues of representativeness which often hamper estimates based on medical statistics. The census also provides large numbers and small confidence intervals, which limit the value of estimates from demographic sample surveys. It also permits precise point estimates, which is not the case for estimates derived from the survival of sisters, an important issue in situations where changes are rapid. The census also allows for a variety of univariate and multivariate analyses at the household level, which can reveal the source of major differentials in a country. Even if less precise than formal case / control studies investigating the effect of individual characteristics on maternal mortality, and if the list of variables is small and imposed by the census, the lessons learned may still be very informative for public health professionals.

Levels for MMR in 2001 South Africa appear much higher than previous estimates (Moodley and Pattinson, 2003; Moodley, 2003). The 1998 DHS estimate (150 per 100,000 live births) covered a different period (1992-1997), when HIV/AIDS was not yet a major cause of death, and was based on a tiny sample (19.2 deaths after sampling weights were applied) which produce a large confidence interval, to which should be added the variance due to the sampling technique, and another variance due to the sisterhood method. At the 2001 census, the MMR was 4.3 times higher, the MDR was 3.3 higher, and the GFR was 0.77 times lower. Even taking into account the large confidence intervals at the 1998 DHS, there is no doubt that maternal mortality has been increasing dramatically in South Africa over the past 10 years, which is confirmed by local studies in Cape Town and in Agincourt.

The proportion of maternal deaths among deaths of women in their reproductive ages is obviously different from that observed in other countries, even with similarly high levels or MMR. For instance, in Niakhar, Senegal, the MMR was 519 per 100,000 in 1983-1989, with a proportion of maternal deaths equal to 26.3% [Garenne & Fontaine, 1988]. In Nouna, Burkina Faso, the MMR was 389 per 100,000, and the proportion of maternal deaths was

24.1% [Garenne et al. 1997]. In Matlab, Bangladesh over the 1976-1985 period, the MMR was 551 per 100,000, with a high proportion of 37.3% of all deaths of women aged 15-44 years [Koenig et al. 1988]. In the case of South Africa, the proportion of maternal deaths was only 6.6%, not different from the proportion of time spent in the maternal risk period. Assuming that half of the maternal deaths were due to direct causes implies that women are at a 50% lower risk from indirect causes during the maternal risk period. Of course, a proper investigation of direct and indirect causes should be done to better understand these phenomenon, and in particular by considering separately cases of premarital fertility (very young women), middle age women, and older women, who have very different obstetric risks, and are differentially affected by HIV/AIDS and by tuberculosis [Khan et al., 2001].

Maternal mortality differentials appeared quite different from classic differentials observed elsewhere in Africa or Asia. Above all, the ethnic/racial and provincial differences were overwhelming in South Africa, even after controlling for socio-economic status. Furthermore, relationships with income and wealth were far more complex than elsewhere. This has also been observed in Agincourt, where mortality from infectious diseases other than HIV/AIDS were negatively linked to socio-economic status, but where mortality from chronic diseases, from accident and violence, and from HIV/AIDS and PTB were either inversely related, or had a U-shape relationship. Lastly, relationship with urbanization was also different from expected, with a small gradient, that was even reversed in the multivariate analysis. A similar observation was made in the hospitals of Kwazulu-Natal (Moodley et al. 1996). All these patterns should be understood within the framework of the complex social fabric of the country, and its recent history.

The magnitude of the changes noted in maternal mortality in South Africa is simply outstanding, and calls for a careful monitoring of trends and patterns. The vital registration has been improving dramatically in South Africa from 1992 to 2001, so that trend analysis is difficult. However, its coverage is becoming high and stable for adults, and it can now be used for monitoring trends in maternal mortality in the coming years. This will provide at least trends in direct causes, the most likely to be picked up in the medical certificates.

Another important finding of this study is the major role played by indirect causes. This makes the analysis of MMR using the demographic definition of maternal mortality more difficult than before. The main aim of the MMR was to target the obstetric causes, with the idea to improve the safety of pregnancies and deliveries. We could now be in a situation where direct causes continue to decrease while indirect causes increase, so that trends in

MMR reflect primarily trends in indirect causes. This changes totally the interpretation of the MMR, and its implication for monitoring progresses in safe motherhood.

One of the Millennium Development Goals (MDG) is to reduce maternal mortality by three fourth by 2015. In order to monitor progresses made in obstetric care, new tools are needed, since the MMR using the demographic definition is unlikely to be appropriate in cases where emerging diseases and external causes play an increasing role. There is therefore a need to go beyond the demographic numbers, and to look more carefully at trends in maternal causes of death in developing countries. If the census provides the numbers, it should be complemented with cause of death information. This can be done by full scale verbal autopsies, detailing the timing of the death (early pregnancy, late pregnancy, delivery, post-partum period, induced abortion), the leading obstetric causes (hemorrhage, eclampsia, obstructed labor, pulmonary embolism, post-partum infections, etc), the leading indirect causes (HIV/AIDS, PTB, hepatitis, etc.), and the leading external causes (road traffic accidents, household accidents, homicide, suicide, etc.). Verbal autopsies have been used with success for a long time for investigating maternal deaths, and are likely to add immensely to the whole picture (Fortney et al., 1986; Garenne & Fontaine, 1988; Fauveau et al. 1988, Fottrell et al. 2007).

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Table 1: Maternal mortality indicators estimated from the 2001 census (10% sample), South Africa

Maternal mortality indicators	Value	95% confidence interval Min - Max	
Maternal mortality ratio (MMR), per 100,000 live births	646	592	705
Maternal death rate (MDR), per 100,000 person-years lived	48.4	44.4	52.8
Life time risk of maternal mortality (MMQ) per 100,000 women at age 12	1681	1541	1833

Table 2: Differentials in maternal mortality ratio, South Africa 2001 census.

Variable	Category	Nb maternal Deaths	MMR, per 100,000	95% Confidence interval		Relative risk
				Min	Max	
Total	Total	508	645	591	704	
Residence	Rural	259	691	612	780	1.14
	Urban	249	605	534	685	1.00
Province	Kwazulu Natal	152	933	796	1094	3.05
	North-West	57	824	636	1068	2.69
	Eastern Cape	88	795	645	980	2.60
	Free State	34	763	545	1068	2.49
	Mpumalanga	37	581	421	802	1.90
	Gauteng	70	485	384	613	1.58
	Northern Cape	7	465	222	975	1.52
	Limpopo	41	393	289	534	1.28
	Western Cape	22	306	201	465	1.00
Race	Black/African	478	717	656	784	9.08
	Coloured	24	348	233	519	4.41
	Indian/Asian	3	231	75	716	2.92
	White/European	3	79	25	245	1.00
Language	IsiZulu	183	910	787	1052	7.46
	IsiXhosa	114	788	656	947	6.46
	SeSotho	47	757	569	1008	6.20
	SeTswana	50	717	543	946	5.88
	IsiNdebele	8	653	327	1306	5.35
	XiTsonga	22	522	344	793	4.28
	SePedi	39	488	357	668	4.00
	SiSwati	12	469	266	826	3.84
	TshiVenda	2	93	23	372	0.76
	Afrikaans	24	287	192	428	2.35
	English	5	122	51	293	1.00

Table 2 Cont./…

Education	0-4 years	52	963	734	1264	2.09
	5-8 years	121	841	704	1005	1.82
	9-11 years	183	714	618	825	1.55
	12+ years	152	461	393	540	1.00
Income	None declared	142	743	630	876	3.18
	< 2400 Rd	147	652	555	766	2.79
	2400-4800 Rd	95	707	578	864	3.02
	4800-9600 Rd	73	745	592	937	3.18
	9600-28800 Rd	38	459	334	631	1.96
	28800 Rd	13	234	136	403	1.00
Wealth index (nb items)						
	1	24	660	442	985	0.76
	2	53	596	455	780	0.69
	3	74	732	583	919	0.84
	4	68	797	628	1011	0.92
	5	72	867	688	1092	1.00
	6	59	694	538	896	0.80
	7	55	654	502	852	0.75
	8	55	561	431	731	0.65
	9	40	403	296	549	0.46
	10	8	311	156	622	0.36

Table 3: Risk factors of maternal mortality at household level, South Africa, 2001 (from Linear Logistic regression)

Household characteristics	Beta	St. Error	Net effect	Relative risk	P-value	Signif.
Urban	0.23904	0.10867	475	1.27	0.028	*
Black/African			374	1.00		
White	-1.88565	0.58328	57	0.15	0.001	*
Indian/Asian	-1.23909	0.58595	109	0.29	0.034	*
Coloured	-0.43246	0.25164	243	0.65	0.086	
Education	-0.05248	0.01385	321	0.95	0.000	*
Wealth distance	-0.11891	0.03533	319	0.89	0.001	*
Western Cape			374	1.00	0.000	*
Eastern Cape	0.73675	0.27245	779	2.09	0.007	*
Northern Cape	0.31594	0.43583	513	1.37	0.469	
Free State	0.60283	0.30319	682	1.83	0.047	*
KwaZulu-Natal	0.93274	0.26747	946	2.54	0.000	*
North West	0.73027	0.28681	774	2.08	0.011	*
Gauteng	0.27466	0.27578	492	1.32	0.319	
Mpumalanga	0.40365	0.30333	559	1.50	0.183	
Limpopo	-0.00212	0.30594	373	1.00	0.994	
Constant	-4.80018	0.29671	374	0.01	0.000	*

N.B. Reference categories: Race =Black/African, Province = Western Cape. Net effects are calculated for dummy variables, and for one standard deviation for quantitative variables (education and wealth). Education is counted in number of years schooling. Wealth distance is counted as the distance in the wealth index from the average (5 items).

Table 4: Risk factors of maternal mortality at household and provincial level, South Africa, 2001 (from Linear Logistic regression)

Household characteristics	Beta	St. Error	Net effect	Relative risk	P-value	Signif.
Provincial level						
HIV prevalence	0.01798	0.00821	740	1.02	0.029	*
Violence d. rate	0.04040	0.00879	852	1.04	0.000	*
Home delivery	-0.01031	0.00850	590	0.99	0.225	
Household level						
Urban	0.20986	0.09994	788	1.23	0.036	*
Black/African				1.00		
White	-1.88793	0.58333	97	0.15	0.001	*
Indian/Asian	-1.22527	0.58413	189	0.29	0.036	*
Coloured	-0.46607	0.23724	402	0.63	0.049	*
Education	-0.05214	0.01384	549	0.95	0.000	*
Wealth distance	-0.11382	0.03508	549	0.89	0.001	*
Constant	-5.70372	0.31478	639			*

Figure 1: Maternal Mortality differentials, South Africa, 2001 Census

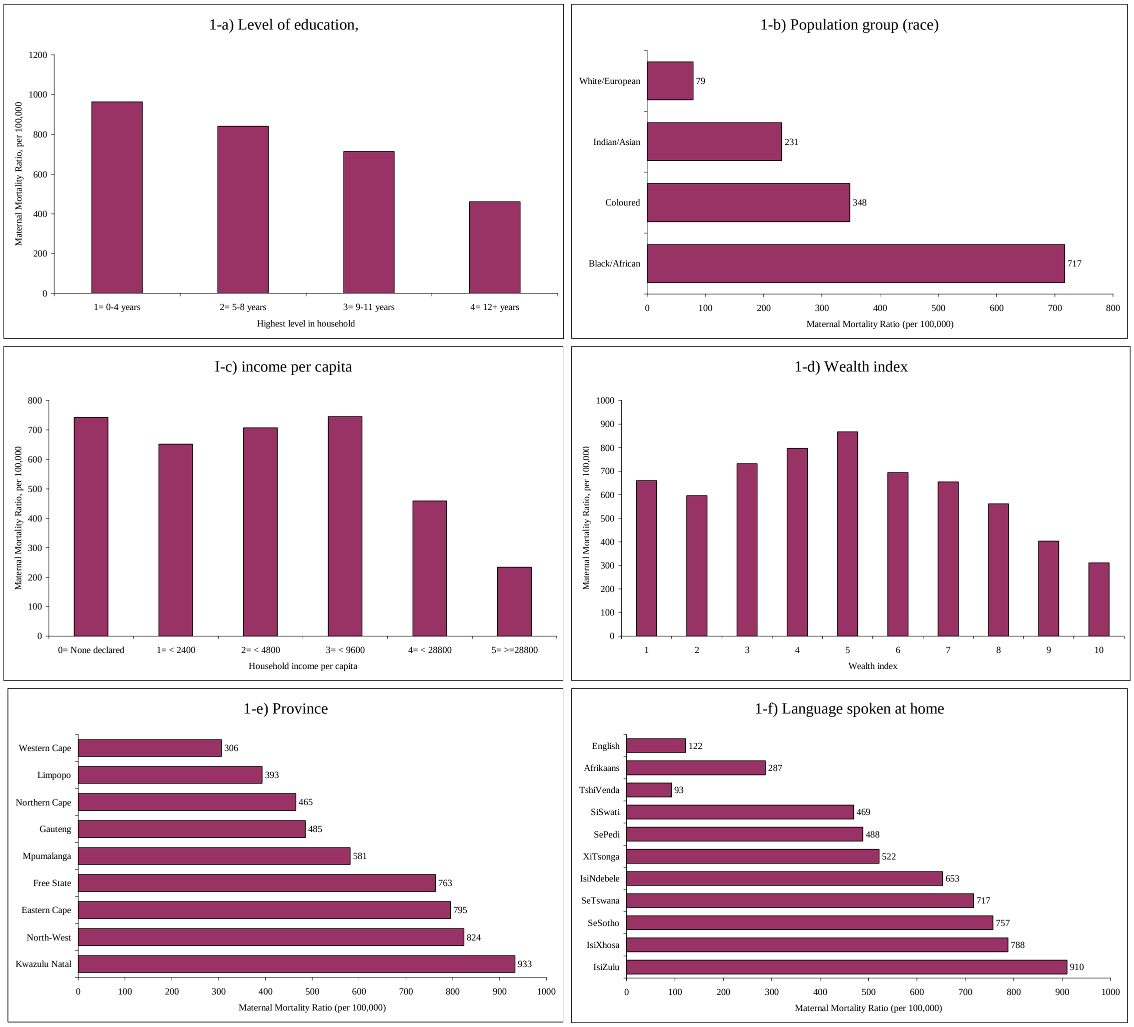

Figure 2: Age pattern of maternal mortality, South Africa, 2001