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Maternal mortality in South Africa: an update from the 2007 Community Survey

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Abstract The 2007 Community Survey conducted in South Africa included questions on maternal deaths in the previous 12 months (pregnancy-related deaths). The Maternal Mortality Ratio (MMR) was estimated at 702 per 100,000 live births, some 30% more than at the 2001 census. This high level occurred despite a low proportion of maternal deaths (4.3%) among deaths of women aged 15–49 years, which is even lower than the proportion of time spent in the maternal risk period (7.6%). The high level of MMR was due to the astonishingly high level of adult mortality, which increased by 46% since 2001. The main reasons for these excessive levels were HIV/AIDS and external causes of death (accidents and violence). Differentials in MMR were very marked, and similar to those found in 2001 with respect to urban residence, race, province, education, income, and wealth. Provincial levels of MMR correlated primarily with HIV/AIDS prevalence. Maternal

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mortality defined as 'pregnancy-related death' appears no longer as a proper indicator of 'safe motherhood' in this situation.

Keywords Maternal mortality · Pregnancy-related deaths · Case definition · Census · Socio-economic correlate · South Africa

Introduction

Some time ago, we completed an analysis of maternal mortality in South Africa using the 2001 census microdata available from IPUMS-International: https://international.ipums.org/international (Garenne et al. 2008; Minnesota Population Center 2009). The paper discussed the relevance of the demographic definition of maternal mortality (pregnancy-related deaths) in the context of a severe HIV/AIDS epidemic. The main findings were that the level of maternal mortality was much higher than previously estimated in South Africa, and that its relationship with obstetric care became very weak. Indeed, maternal mortality counted as any death during the maternal risk period (pregnancy, delivery, 6 weeks postpartum) included many deaths which were most probably due to chronic infectious diseases (e.g. HIV/AIDS and PTB: Pulmonary Tuberculosis) or to external causes (accident and violence), and had little to do with obstetric causes of death, the medical definition of maternal mortality. This study also revealed very marked gradients of maternal mortality by area of residence, province, population group (race), education, income and wealth. At the provincial level, maternal mortality was primarily correlated with the prevalence of HIV/AIDS and with the proportion of external causes, and less with development indicators: income, wealth, urbanization. Surprisingly, the correlation with the proportion of home deliveries was negative. In this context, the 'pregnancy-related death' case definition lacked specificity and appeared misleading.

We repeated the analysis of maternal mortality using the 2007 Community Survey microdata also available from IPUMS-International. This survey included similar questions on maternal deaths and on external deaths in the past 12 months. This paper presents the new findings, and compares them with the findings from the 2001 census microdata. Here, we do not focus as much on case definitions and on the reliability of the estimates, but rather on the similarities with, and changes since, the 2001 census. Note that our estimates are not official estimates, and readers should refer to Statistics South Africa (Stat-SA Statistics South Africa: www.statssa.gov.za) and to estimates made at CARE (Center for Actuarial Research): www.commerce.uct.ac.za/care (University of Cape Town) for final values of mortality indicators.

Data and methods

The 2007 Community Survey was a large-scale demographic survey conducted in South Africa, from 7 February to 7 March 2007, by Statistics South Africa. It used a

questionnaire similar to a census questionnaire, and was designed to substitute for the census that had been scheduled to be conducted 5 years after the 2001 census. The sample size was very large, and corresponded to a 1 per 43 sample of a full census. Its methodology is described in detail in other documents (Stats SA 2007). In brief, a large nationally representative sample of households was drawn in two stages: enumeration areas (stratified by type of municipality) updated from the 2001 census, and dwelling units, also drawn from updated lists. Some 21.5% of enumeration areas and 10.9% of dwellings were selected, each dwelling having equal chances of being selected. Almost all enumeration areas were visited, and the non-response rate among selected households was small (6.1%). The complete sample of both integrated and non-harmonized variables is available free of charge from the IPUMS-International website.

The questionnaire used for the 2007 Community Survey was very similar to that of the 2001 Census. In addition to classic census questions on individuals and housing, it included questions on past fertility and mortality. The fertility module focused on women aged 12–50 years, and included cohort fertility (children living in the household, children living elsewhere, and children who died, by sex), and questions on the last birth (date of last birth, sex of last birth, survival of last birth). The fertility module started with a question on whether the woman ever had a live birth, to avoid problems in coding infertile women as happened in previous censuses. The mortality module included questions on survival of mother and father, and a question on deaths in the past 12 months in the household, with date of death (month and year), sex and age at death, whether the death was due to external causes (non natural), and, for women aged 12–50 years, whether the death occurred during the maternal period. The precise question reads: 'Was the deceased person pregnant at time of death, or died within 6 weeks after delivery?', which is basically the same question as that asked at the 2001 census. This question defines maternal mortality as 'pregnancy-related death', and includes direct causes (obstetric conditions), indirect causes (infectious and non-communicable diseases) and fortuitous causes.

The 2007 Community Survey microdata were analysed with straightforward demographic methods, as was done with the 2001 Census microdata. Fertility rates were calculated from births last year (February 2006 to January 2007), and corrected for twins with a coefficient = 1.014 since the census provided only the number of women who delivered last year, and not the total number of births. Mortality rates were calculated from deaths last year (since 1 February 2006): all deaths in the file were included, and a correction factor of 0.948 was applied to account for the inclusion of deaths during the month of the survey (February 2007): this ratio is simply the ratio of 12 months to the total number of months included in the calculations, including the month of the survey (12.66). Person-years lived in the past 12 months were calculated from the population by single year of age at time of survey, and included the person-years lived by those who died, assumed to have lived only half of the year. Life tables were constructed, by single year of age and by 5-year age groups, and compared with UN General model life tables for developing countries (United Nations 1982). Maternal mortality was calculated as the ratio of pregnancy-related deaths in the past 12 months to the number of births in the past 12 months, expressed per 100,000 births. Multivariate analysis was conducted the

same way as for the 2001 census microdata, using a binary logistic regression model. Independent variables were the same: level of education (measured as the number of years of schooling), urban residence, population group (race) and province of residence. The boundaries of some provinces changed somewhat between 2001 and 2007, so we used the 2001 definition for analysing the 2007 Community Survey. An absolute wealth index was computed the same way as in 2001, from housing characteristics and goods and amenities owned (see also Garenne and Hohmann 2003; Hohmann and Garenne 2009).

Results

Sample size

The 2007 Community Survey included a fairly large sample of 354,170 households, of which 246,618 were private households eligible for final analysis, after excluding institutions, recreational areas and other special cases. This represents about a quarter of the 10% sample of the 2001 Census: 949,105 persons, and 265,945 women age 15–49 (Table 1). The crude birth rate calculated from births last year was 24.0 per 1,000; the general fertility rate was slightly higher than that measured in 2001 by about 5%, suggesting a modest increase in fertility. The crude death rate calculated from deaths last year was 15.3 per 1,000, a 64% increase from the 2001 estimate. The maternal mortality analysis was based on 168 maternal deaths, a sample large enough for a number of detailed investigations, although smaller than the 508 maternal deaths in the 2001 census 10% sample.

Imputations

There were a number of issues with imputations in the 2001 census data, well detailed in our first paper. It did not seem to be the case in the 2007 Community Survey: only two maternal deaths (1.2%) were imputed by Hot-Deck procedures, a percentage even lower than for non-maternal deaths of women aged 15–49 (2.6%). Only a few deaths had a date imputed (1.8%) or an age imputed (0.8%), which indicates that the reliability of 2007 survey data was high.

Mortality level and pattern

The main feature of the 2007 sample was the major rise in overall mortality within the 5 years separating the two surveys (Table 2). From life table estimates, the death rate for children under age 15 ($_{15}q_0$) increased by 26% in 5 years, and was 1.8 times higher than model life table values with the same life expectancy at age 60 (United Nations General Pattern for developing countries). The death rate for young adults from age 15 to 59 ($_{45}q_{15}$) increased by 46% for both sexes, and more so for women (+57%) than for men (+38%). In 2006, the death rate of young women was 4.5 times higher than that of model life tables, and that of men was 3.2 times higher. In contrast, mortality above age 60 hardly changed, with a life expectancy around

Table 1 Main characteristics of the two samples, South Africa

Characteristics	Census 2001 10% sample	Community Survey 2007	Ratio 2007/2001
Mean date	2001.8	2007.1	
Population			
Number of households	991,543	246,618	
Number of persons	3,725,655	949,105	
Mean household size	3.76	3.85	1.02
Fertility			
Number of women 15–49	1,048,824	265,945	
Number of births last year	84,520	22,397	
GFR	0.081	0.085	1.06
Time in maternal period %	7.1%	7.6%	1.06
Mortality			
Number of deaths last year	36,267	15,304	
Number of female deaths 15–49	7,934	3,924	
Number of maternal deaths	508	168	
Proportion maternal (%)	6.4%	4.3%	0.67
Raw estimates			
Death rate 15–49	0.0076	0.0140	1.85
MMR (per 100,000)	542	702	1.29
CBR (per 1,000)	0.0228	0.0240	1.05
CDR (per 1,000)	0.0093	0.0153	1.64

Community survey: private households only; birth rates and death rates corrected for minor errors (see text for details)

GFR gross fertility rate, *MMR* maternal mortality ratio, *CBR* crude birth rate, *CDR* crude death rate

21 years for women and around 17 years for men, which correspond roughly to 73 and 67 years of life expectancy at birth in model life tables. This outstanding pattern of adult mortality is primarily due to HIV/AIDS and PTB, two raging epidemics in South Africa, and to the very high mortality from external causes.

Level of maternal mortality (pregnancy-related death)

The extremely high value of young adult mortality explains the very high values of maternal mortality, as already noted in our first paper, but with even higher values due to the rise in mortality. The raw estimate of maternal mortality was 702 per 100,000 live births (95% CI = 603–816), a value higher than any other estimate for South Africa and than most estimates for other developing countries (Boerma 1988; Dorrington et al. 2005; Dickson-Tetteh and Rees 1999; Fauveau et al. 1988; Fawcus et al. 2005; Khan et al. 2001; Koenig et al. 1988; Moodley and Pattinson 2003; Moodley 2003; NCCEMD 1988; Van Coeverden de Groot 1979, 1986). This estimate of maternal mortality was 29% higher than the value estimated from the

Table 2 Changes in mortality from 2001 to 2007, South Africa

Age group	Indicator	Community Survey (CS) 2007	Census 2001	Model life table	Mortality increase 2007/2001	Ratio CS 2007/MLT
Both sexes						
0–14	$_{15}q_0$	0.099	0.079	0.055	1.26	1.8
15–59	$_{45}q_{15}$	0.553	0.380	0.151	1.46	3.7
60+	$e^o(60)$	18.3	19.8	18.6		
Males						
0–14	$_{15}q_0$	0.100	0.086	0.063	1.17	1.6
15–59	$_{45}q_{15}$	0.606	0.440	0.190	1.38	3.2
60+	$e^o(60)$	15.5	17.3	17.0		
Females						
0–14	$_{15}q_0$	0.099	0.072	0.047	1.38	2.1
15–59	$_{45}q_{15}$	0.501	0.320	0.112	1.57	4.5
60+	$e^o(60)$	20.5	21.8	20.1		

Model life table: General model for developing countries; life expectancy: 67 for males and 73 for females (approximately same life expectancy at age 60)

Indicators are: $_{15}q_0$ = mortality quotient between age 0 and 15; $_{45}q_{15}$ = mortality quotient between age 15 and 60; $e^o(60)$ = life expectancy at age 60

2001 census data ($P < 0.004$). However, from 2001 to 2007, the proportion of maternal deaths among deaths of women aged 15–49 decreased from 6.4 to 4.3%. The increase in maternal mortality ratio seems therefore primarily due to the increase in mortality from all causes combined.

Attributable risk

We computed an expected number of maternal deaths assuming that there was no increased risk associated with pregnancy and delivery, in order to estimate a risk attributable to the maternal period. Details of the computations are displayed in Table 3. The maternal period is fixed at 46 weeks (40 weeks of pregnancy and 6 weeks postpartum), and the expected number of deaths during the maternal risk period is simply the product of population times the proportion of time spent in the maternal period times the death rate. Results show that a total of 294 deaths were expected during the maternal risk period, as compared with 168 observed at the survey. This means that, statistically speaking, there was no excess risk associated with the maternal risk period: on the contrary, the maternal risk period appeared as protective for survival. This is obviously due to a selection effect: the women who deliver are not the same as the women who die of HIV/AIDS or of external causes. Numerous selection effects could be operating. First, women with full-blown AIDS tend to have very low fertility. Secondly, women who are at risk of HIV/AIDS or of external causes are likely to have a life style different from that of women who are in stable unions and who deliver. It should be noted that this situation is very new, and due to the major demographic changes induced by HIV/AIDS. It differs

Table 3 Estimation of mortality risks attributable to the maternal period, South Africa, Community Survey 2007 (events of past 12 months)

Age group	Population (Person-years lived)	Fertility rates (ASFR)	Time spent in maternal period (%)	Mortality rates (ASDR)	Maternal deaths (%)	Pregnancy-related deaths	
						Expected	Observed
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
12–14	31,593	0.0040	0.4	0.0015	0.0	0	0
15–19	51,674	0.0729	6.5	0.0032	7.3	11	12
20–24	48,358	0.1329	11.8	0.0093	7.6	53	34
25–29	39,333	0.1315	11.6	0.0187	5.8	86	43
30–34	35,898	0.1091	9.7	0.0242	4.6	84	40
35–39	33,048	0.0701	6.2	0.0209	3.6	43	25
40–44	30,463	0.0292	2.6	0.0192	1.5	15	9
45–49	26,163	0.0065	0.6	0.0164	1.2	2	5
Total	296,529	0.0768	6.8	0.0134	4.2	294	168

Expected number of deaths (7) = product of population (2) by time spent in maternal period (4) by death rate (5). Observed number of deaths (8) = product of population (2) by death rate (5) by proportion maternal (6)

markedly from the situation prevailing in the pre-AIDS era. For instance, in Niakhar, Senegal, in the 1980s, maternal deaths accounted for 25% of deaths of women aged 15–49, and the ratio of maternal deaths to that expected during the maternal period was 1.25 (Garenne and Fontaine 1988). In Matlab, Bangladesh, despite lower fertility, maternal deaths accounted for 26% of all deaths, and the ratio of maternal deaths to that expected during the maternal period was 1.77 (Khlat and Ronsmans 2000). Both values revealed the excess risk during the maternal period, and are very different from the 0.57 ratio found in South Africa.

Socio-economic correlates

We investigated maternal mortality differentials according to a variety of socio-economic correlates, by calculating a risk ratio of a given category to the national average, and compared the risk ratio with that found in 2001 (Table 4). Results show a high consistency in the two differential univariate analyses: higher risks for rural areas, for selected provinces (in particular Eastern Cape and Kwazulu-Natal), lower risk for selected population groups (Indian/Asian and White/European), decreasing risk with level of education, and a complex relationship with income and wealth, as already noted in the 2001 Census analysis (higher risks for the very poor and for middle classes). Only a few differences in relative risks were notable and statistically significant, in particular the lower risk associated with high education in 2007. Increases in maternal mortality from 2001 to 2007 were significant only for selected categories: rural areas (+47%), the Eastern-Cape (+74%), Black/African (+28%), middle income (48,00–28,800 ZAR) (+97%). These differences are probably related with increasing HIV/AIDS in high risk areas, and possibly with better treatment of HIV/AIDS for more highly educated groups.

Table 4 Comparison of risk factors between 2001 Census and 2007 Community Survey, South Africa (univariate analysis)

		Community Survey 2007		Census 2001	
Variable	Category	Nb deaths	RR	Nb deaths	RR
	Total	168	1.00	508	1.00
Residence	Urban	69	0.77	249	0.92
	Rural	99	1.27	259	1.10
Province	Western Cape	4	0.25	22	0.44
	Eastern Cape	47	1.76	88	1.29
	Northern Cape	5	0.73	7	0.75
	Free State	11	1.23	34	1.19
	Kwazulu Natal	46	1.30	152	1.40
	North-West	13	0.91	57	1.36
	Gauteng	23	0.79	70	0.72
	Mpumalanga	7	0.59	37	0.94
	Limpopo	12	0.63	41	0.63
Race	Black/African	161	1.12	478	1.11
	Coloured	7	0.44	24	0.52
	Indian/Asian	0	0.00	3	0.36
	White/European	0	0.00	3	0.12
Education	0–4 years	79	1.42	52	1.63
	5–8 years	44	1.00	121	1.37
	9–11 years	31	0.85	183	1.09
	12 + years	11	0.37	152	0.69
Income	None	15	1.26	142	1.18
	< 2,400 Rd	43	0.91	181	1.07
	< 4,800 Rd	54	1.10	96	1.22
	< 9,600 Rd	34	1.18	52	0.87
	< 28,800 Rd	20	1.01	25	0.52
	> 28,800 Rd	2	0.18	12	0.38
Wealth	0	5	1.88	12	1.63
	1	9	1.23	23	0.95
	2	11	0.96	37	0.97
	3	17	1.32	38	0.90
	4	14	1.22	51	1.22
	5	16	1.39	46	1.18
	6	18	1.53	49	1.36
	7	13	1.05	43	1.26
	8	18	1.39	40	1.19
	9	8	0.58	41	1.20
	10	16	1.05	29	0.87
	11	7	0.39	29	0.82
	12	11	0.74	36	0.92

Table 4 continued

Variable	Category	Community Survey 2007		Census 2001	
		Nb deaths	RR	Nb deaths	RR
	13	5	0.79	23	0.64
	14	0	0.00	10	0.45
	15	0	0.00	1	0.09

Risk ratios (RR) are computed as the ratio of the maternal mortality in a category to the national average, for each survey

Table 5 Comparison of correlation coefficients between maternal mortality level and selected indicators at provincial level, South Africa

Indicator	Community Survey 2007	Census 2001
Crude death rate	+0.754	+0.892
Violence death rate	+0.664	+0.798
HIV seroprevalence	+0.592	+0.730
Household size	+0.308	+0.368
Birth rate	+0.240	+0.240
Urbanization	−0.254	−0.315
Education	−0.396	−0.400
Average income	−0.458	−0.495
Average wealth	−0.638	−0.490
Proportion of deliveries in institutions	NA	+0.293

Provincial differences

Provincial differences in maternal mortality are large in South Africa. We compared the correlations of MMR with the provincial characteristics, and found correlations similar to those found in the 2001 census (Table 5). Largest positive correlations were with overall level of mortality (+0.754), with death rate from external causes (+0.664), and with HIV prevalence (+0.592), and largest negative correlations were with education (−0.396), income (−0.458) and wealth (−0.638). No recent survey providing the proportion of deliveries in institutions at provincial level in 2007 was available to compare with results from the 2001 census.

Discussion

The level of maternal mortality measured by all deaths during the maternal risk period (the 'pregnancy-related death' demographic definition) is abnormally high for a country like South Africa, and obviously due to a lack of specificity of the case definition. By including many deaths which are most likely to be due to HIV/AIDS, PTB, accident and violence, it gives an exaggerated measure of the risk assumed to

be due primarily to obstetric conditions. However, even if a fraction of these pregnancy-related deaths is due to obstetric causes, maternal mortality in South Africa appears still higher than in developed countries, as shown by the comparison with Sweden, and deserves attention from health professionals.

We further validated the results from the 2007 Community Survey by comparing with vital registration data. In 2006, there were 145,381 deaths of women aged 12–50 registered in South Africa, which is consistent with the extrapolated census estimates, given the possible undercount. Among these, the pregnancy status of the deceased woman was known in 25% of the cases, and among those whose status was known, 6.5% occurred in the maternal risk period (pregnancy, delivery, 6 weeks postpartum). Assuming that this number is representative of the whole population, it would lead to an MMR even higher than that found in the 2007 Community Survey. However, if one assumes that, among the remaining 75% of women, 3.6% were pregnant, then the numbers provided by the two sources become compatible. We ran a simple hot-deck procedure, based on province of residence, marital status and occupation, to impute missing values in the 2006 vital registration data. Results show that 4.3% of deaths of women aged 15–50 were pregnancy-related, a proportion basically identical to that found in the 2007 Community Survey. Furthermore, according to vital registration data, some 1.1% of deaths of women aged 12–50 were obstetric deaths (medical definition of maternal mortality), defined by an underlying cause in the 'pregnancy, childbirth and puerperium' category (ICD-10 code O00 to O99). This leads to about 1,800 obstetric deaths a year in South Africa, which is about 1 in 4 pregnancy-related deaths. These numbers appear compatible with the excess mortality among young adults found in South Africa, and suggest that obstetric deaths are not much in excess given the underlying level of mortality discounting for outstanding causes (HIV/AIDS, PTB, external causes). However, compared with 1950 Sweden, a country with similar female life expectancy at age 60 (18.3 years) and known to have a low maternal mortality, the obstetric MMR still appears higher in South Africa (obstetric MMR = 87 per 100,000 in 1950 Sweden).

The fact that maternal mortality increased rapidly from 2001 to 2007 is not surprising given the major rise in adult mortality over this period. This is mostly due to HIV/AIDS and PTB, and to external causes, which continue to account for a large and constant proportion of all deaths (about 14%).

Emerging diseases and conditions such as HIV/AIDS and external causes are changing mortality patterns to an extent never seen before. At a given level of mortality, regional model life tables provide a range of variations which is largely exceeded by emerging patterns such as those seen in South Africa. And this is reflected here in the abnormally high level of pregnancy-related maternal mortality.

Furthermore, HIV/AIDS may be an underlying cause of maternal deaths, especially in the postpartum period. Numerous accounts of unexpected deaths during the few weeks following delivery have been reported among HIV-positive women in South Africa. A cohort study of HIV positive women and their children reported a very high postpartum death rate of 2,265 per 100,000 in South Africa within 36 weeks of delivery (Chopra 2008).

HIV/AIDS is also changing the patterns of mortality differentials by socio-economic status. If the relationship with education remains as expected, the relationship with income or wealth is not monotonic: it reveals two modes, one for the very poor, and one for the middle income classes. This is probably due to the fact that the risk of sexually transmitted infections is due to a balance between sexual behaviour (more partners associated with higher socio-economic status), and prevention (more care associated with higher socio-economic status). These relations deserve more investigation, and require more specific data than those provided by a census.

The lower risk of mortality associated with the maternal risk period may seem counter-intuitive to readers not familiar with South Africa. Our findings suggest that selection for pregnancy is very pronounced in this country, and probably due to both the effect of HIV/AIDS on fertility and to different attitudes and behaviours associated with pregnancy. This last point deserves more research. Women who choose to have a baby must behave very differently from others in order to have a much lower risk of dying.

There is no doubt that the census is the best tool to measure maternal mortality in the absence of complete vital registration, at least because of the large sample size required to reach statistical significance (Graham 2002; Hill et al. 2006; Ronsmans and Graham 2006; Stanton et al. 2001; United Nations 2001, 2008a, b). However, in the context of HIV/AIDS and high death rates from external causes, it is necessary to include causes of death in order to focus on obstetric causes. This is the only way to measure progress in 'safe motherhood'. This can be done using verbal autopsies in absence of medical causes (Fauveau et al. 1988; Fortney et al. 1986; Fottrell et al. 2007; Garenne and Fontaine 1988). One could imagine and test a strategy where pregnancy-related deaths are identified in a census and where causes of death are later investigated by a special team. This could be done by a physician or a nurse living in the area and trained for this purpose, or by conducting a special verbal autopsy survey after the census on the sample of pregnancy-related deaths previously identified. Given the small number of cases at country level, this would induce only a small marginal cost to that of the census.

The increasing level of maternal mortality is a matter of serious concern, especially when compared with international public health targets such as the Millennium Development Goals: www.un.org/millenniumgoals/maternal.shtml. (United Nations 2000; Rosenfield et al. 2006) Even if this increase seems to have little to do with obstetric care, it deserves more research, and calls for specific actions to reduce overall mortality, with the main focus on treatment of HIV/AIDS and PTB, which is already occurring since 2007, and on the prevention of external causes.

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References

Boerma, J. T. (1988). The magnitude of the maternal mortality problem in sub-Saharan Africa. *Social Science and Medicine, 24*(6), 551–558.

Chopra, M. (2008). Prevention of mother to child transmission of HIV in Africa. Operational research to reduce post-natal transmission and infant mortality. Acta Universitatis Upsaliensis. In *Digital comprehensive summaries of Uppsala Dissertations from the faculty of medicine*. Uppsala.

Dickson-Tetteh, K., & Rees, H. (1999). Efforts to reduce abortion-related mortality in South Africa. In M. Berer & T. K. S. Ravindran (Eds.), *Safe Motherhood Initiatives: Critical Issues. Reproductive Health Matters* (pp. 190–197). London: Blackwell Sciences Limited.

Dorrington, R., Moultrie, T. A., & Timaeus, I. M. (2005). Estimation of mortality using the South African census 2001. Care Monograph No 11, University of Cape Town.

Fauveau, V., Koenig, M. A., Chakraborty, J., & Chowdhury, A. I. (1988). Causes of maternal mortality in rural Bangladesh: 1976–1985. *Bulletin of the World Health Organization, 66*(5), 643–651.

Fawcus, S. R., de Groot, H. A., & Isaacs, S. (2005). A 50-year audit of maternal mortality in the Peninsula maternal and neonatal service, Cape Town (1953–2002). *BJOG: An International Journal of Obstetrics and Gynaecology, 112*, 1257–1263.

Fortney, J. A., Susanti, I., Gadalla, S., Seleh, S., Rogers, S. M., & Potts, M. (1986). Reproductive mortality in two developing countries. *American Journal of Public Health, 76*(2), 134–138.

Fottrell, E., Byass, P., Ouedraogo, T. W., et al. (2007). Revealing the burden of maternal mortality: A probabilistic model for determining pregnancy-related causes of death from verbal autopsies. *Population Health Metrics, 5*(1), 1–9.

Garenne, M., & Fontaine, O. (1988). Assessing probable causes of deaths using a standardized questionnaire. A study in rural Senegal. In J. Vallin, S. D'Souza & A. Palloni (Eds.), *Measurement and analysis of mortality*. (Reprinted as a Public Health Classic, in *Bulletin WHO* 2006*, 84*(3), 248–253.

Garenne, M., & Hohmann, S. (2003). A wealth index to screen high risk families: Application to Morocco. *Journal of Health, Population and Nutrition, 21*(3), 235–242.

Garenne, M., McCaa, R., & Nacro, K. (2008). Maternal mortality in South Africa, 2001: From demographic census to epidemiological investigation. *Population Health Metrics, 6*(4), 1–13.

Graham, W. J. (2002). Now or never: The case for measuring maternal mortality. *Lancet, 359*(9307), 701–704.

Hill, K., El-Arifeen, S., Koenig, M., Al-Sabir, A., Jamil, K., & Raggers, H. (2006). How should we measure maternal mortality in the developing world? A comparison of household deaths and sibling history approaches. *Bulletin of the World Health Organization, 84*, 173–180.

Hohmann, S., & Garenne, M. (2009). Absolute versus relative measures of poverty: Application for DHS African surveys. Paper presented at the IUSSP conference, Marrakech, Sep.

Khan, M., Pillay, T., Moodley, J. M., & Connolly, C. A. (2001). Maternal mortality associated with tuberculosis-HIV-1 co-infection in Durban South Africa. *AIDS, 15*(14), 1857–1963.

Khlat, M., & Ronsmans, C. (2000). Deaths attributable to childbearing in Matlab, Bangladesh: Indirect causes of maternal mortality questioned. *American Journal of Epidemiology, 151*(3), 300–3030.

Koenig, M. A., Fauveau, V., Chowdhury, A. I., Chakraborty, J., & Khan, M. A. (1988). Maternal mortality in Matlab, Bangladesh: 1976–1985. *Studies in Family Planning, 19*(2), 69–80.

Minnesota Population Center. (2009). *Integrated public use microdata series—international: Version 5.0*. Minneapolis: University of Minnesota.

Moodley, J. (2003). Saving mothers: 1999–2001. *South African Medical Journal, 93*(5), 364–366.

Moodley, J., & Pattinson, R. C. (2003). Maternal deaths in South Africa. *South African Medical Journal, 93*(5), 354.

National Committee for the Confidential Enquiry into Maternal Deaths (NCCEMD). (1988). *Interim report on the confidential enquiry into maternal deaths in South Africa*. Pretoria: Department of Health.

Ronsmans, C., & Graham, W. J. (2006). Maternal mortality: Who, when, where, and why. *Lancet, 368*, 1189–1200.

Rosenfield, A., Maine, D., & Freedman, L. (2006). Meeting MDG-5: An impossible dream? *Lancet, 368*(9542), 1133–1135.

Stanton, C., Hobcraft, J., Hill, K., et al. (2001). Every death counts: Measurement of maternal mortality via a census. *Bulletin of the World Health Organization, 79*(7), 657–664.

Statistics South Africa (Stat-SA). (2007). *Community Survey 2007: Methodology, processes and highlights of key results*. Report No. 03-01-20. Pretoria: Statistics South Africa.

United Nations. (1982). *Model life tables for developing countries*. New York. Sales No. E.81.XIII.7.

United Nations. (2000). *United Nations Millennium Declaration*. Resolution A/RES/55/2. New York.

United Nations. (2001). Paragraph 125. In *Handbook on population and housing census editing*. New York.

United Nations. (2008a). Paragraph 2.196. In *Principles and recommendations for population and housing censuses*, Revision 2. New York.

United Nations. African Center for Statistics. (2008b). Africa addendum to the United Nations. In *Principles and recommendations for population and housing censuses*, Revision 2 (Draft, dated March 2008).

Van Coeverden de Groot, H. A. (1979). Trends in maternal mortality in Cape Town, 1953–1977. *South African Medical Journal, 56*(14), 547–552.

Van Coeverden de Groot, H. A. (1986). Maternal mortality in Cape Town, 1978–1983. *South African Medical Journal, 69*(13), 797–802.