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Progress in Safe Motherhood in Tanzania during the 1990s: findings based on NSS/AMMP monitoring

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Summary and key findings

Maternal mortality has been monitored through a sentinel demographic and mortality surveillance system in Tanzania. The surveillance included more than 77,000 women of reproductive age (15 to 49), and prospective monitoring of mortality in a densely populated urban location, a wealthy rural district, and a poor rural district. The time period of observation was mid-1992-1999 for rural areas, and 1993-1999 for Dar es Salaam. The proportion of deaths to women of reproductive age due to maternal causes (PMDFs) ranged from 0.063 to 0.095, Maternal Mortality Ratios (MMRs) ranged from 591 to 1,099, and maternal mortality rates ranged from 43.1 to 123.0 per 100,000 women of child bearing age. MMRs in the areas under surveillance were substantially higher than estimates from official, facility-based statistics. Maternal mortality in 1999 was substantially lower than in 1992 in all areas, although trends during the period were statistically significant at the 90% level only in Dar es Salaam. A 1-year increase in education of household heads was associated with 62% lower maternal mortality after controlling for variables such as proportion of home births and occupational class at the community level. Although maternal mortality may be dropping, it remains high in these areas of Tanzania. Education seems to be a major contributor to its decline. Sentinel registration areas may be a cost-effective way for developing countries to accurately monitor rates and causes of mortality including maternal mortality

- The Safe Motherhood goal of a 50% reduction in maternal mortality by 2000 has probably been accomplished in urban Tanzania. Substantial declines were observed in rural areas as well.
- A 1-year increase in average education of household heads was associated with 62% lower maternal mortality at the community level.
- Despite apparent declines, population-based monitoring of maternal deaths over a 7½-year period has shown very high maternal mortality rates and ratios—much higher than official regional estimates based largely on hospital data.
- In rural areas, adequate prenatal and obstetric services could prevent up to 62% of maternal deaths.
- Maternal deaths represent less than 13% of deaths in women of childbearing age in the project populations, so other causes of death need to be addressed as well.
- Monitoring progress toward the goals of the Safe Motherhood Initiative requires information that has not been readily available in sub-Saharan Africa. Sentinel registration areas may be a cost-effective way for such countries to accurately monitor rates and causes of mortality including maternal mortality.

Introduction

The Safe Motherhood Initiative (SMI) was launched in 1987 by the World Bank, the World Health Organization, and the United Nations Fund for Population Activities in response to the huge burden of maternal mortality in developing countries (*1*). Its global goal was a reduction in maternal mortality by at least one half by the year 2000. WHO's preferred indicator for measuring progress toward this goal is the maternal mortality ratio (MMR) (*2*), which is expressed as the number of maternal deaths per 100,000 live births. In 1997 Tanzania formally stated its strategy for accomplishing this goal (*3*). This included raising the status of women, increasing health education, and improving access to family planning and emergency obstetric services.

In this paper we examine the indications of progress toward achieving the goal for SMI in one urban area and two rural districts in Tanzania during the 1990s. The analysis deepens our previous consideration of six-year cause-specific mortality (which included maternal mortality) in adults aged 15 to 59 (*4*). Here we focus on proportional mortality, rates, trends, and causes of maternal deaths observed prospectively over a 7½-year period among 77,464 women aged 15 to 49 years in a total population of 313,183. We also examine the relationship between maternal mortality, place of delivery, education, and occupational class at the community level. Lastly, we propose that a platform of 'sentinel districts' for mortality and demographic surveillance may be a cost-effective way of charting progress toward many population health goals, including SMI.

Several recent papers to the *Bulletin* have discussed concerns over the use of mortality indicators in measuring or evaluating progress in safe motherhood (*5-7*). Hill et al., for example, propose the use of the proportion of mortality among women of reproductive age due to maternal causes (PMDF) as a new standard comparator for maternal mortality. A better mortality indicator such as PMDF in combination with process measures like proportion of deliveries with trained attendants, can contribute to an evaluation strategy for SMI, particularly if the evaluation objectives are thought through well in advance (*8*). Here we employ the PMDF and maternal death rates as the main measures of interest. Progress in reducing maternal mortality is measured in terms of changes in the maternal death rate (i.e. deaths per 100,000 due to maternal causes), as trends in proportional mortality can be difficult to interpret. In order to allow our findings to be comparable with the majority of the literature on the topic, however, we also report MMR.

Methods

The Ministry of Health of Tanzania is establishing a national sentinel system (NSS) for monitoring cause-specific mortality. The system is based on demographic and mortality surveillance in several districts. The first three sentinel districts were established in 1992 under the Adult Morbidity and Mortality Project (AMMP) in order to determine rates and causes of mortality in adults with a view to the later introduction of cost-effective interventions. All-cause and cause-specific mortality information for all ages has been collected continuously since then. This type of surveillance is finding an increasingly important role in the context of evidence-based health reform in developing countries (*9*). The total population participating in surveillance between 1992 and 1999 amounted to over 1% of the Tanzania mainland population.

Data Collection

The urban surveillance area is in Dar es Salaam, the country's largest city. The population resident in the surveillance area as of the mid-period date (31 March 1996) was 64,024, of whom 18,638 (29.1%) were women aged 15 to 49 years. In 1987 the MRR reported for Dar es Salaam was 44 per 100,000 total births (*10*), although more recent estimates quote figures of 220 and 399 per 100,000 live births for 1992 and 1993 respectively (*11*). The two rural surveillance areas are in Hai District (Kilimanjaro Region), and Morogoro District (Morogoro Region). Hai District lies on the south-western slopes of Mount Kilimanjaro and has an economy based on the production of cash crops, mainly coffee. The project surveillance area, which includes 51 of 61 villages in the district, had a mid-period population of 145,822 of whom 34,449 (23.6%) were women 15 to 49 years of age. Kilimanjaro region is one of the most developed rural areas of the country. In 1987 the MMR was reported as 105 per 100,000 total births (*10*) and estimates for 1992 and 1993 were 42 and 47 per 100,000 live births respectively (*11*). Morogoro District is situated 180 km to the west of Dar es Salaam. The population is comprised mostly of subsistence farmers or workers on sisal plantations. The NSS covers 61 of 215 villages in the district. The mid-period population was 103,337 of whom 24,377 (23.6%) were women aged 15 to 49 years. In 1987 the reported regional maternal mortality ratio was 155 per 100,000 total births. Official estimates for 1992 and 1993 were 264 and 172 per 100,000 live births respectively (*11*). In Tanzania, rural districts are sub-divided into administrative units of divisions, wards, and villages. In Dar es Salaam, we refer to the unit of the 'branch' to correspond to a geographically contiguous area of similar population to a typical rural ward. AMMP surveillance covers 3 branches in Dar es Salaam, 14 wards in Morogoro District, and 8 wards in Hai District. These ward-branch units had a wide variation in size, with an average mid-period population of 10,637 (SD 6,967).

Methods of population enumeration and cause of death attribution in these project areas have been described elsewhere (*12*, *13*). Briefly, the populations of the surveillance areas are determined by census update rounds (twice yearly in Dar es Salaam and annually in the two rural areas). Community development workers and health and education personnel conduct the census updates. Mortality surveillance is conducted using an active reporting system based on a network of respected individuals within each community. Cause of death is determined through administration of a 'verbal autopsy' interview to family members of the deceased. These individuals make regular reports to a team of verbal autopsy supervisors. The teams consist of clinical officers from the District Health Management Teams in each area. In all cases of death among women aged 15 to 49 relatives are routinely asked if the deceased had been pregnant, and if so, the time during pregnancy or weeks postpartum at which death occurred. Verbal autopsies are usually conducted within two to four weeks of death. A panel of physicians codes the completed verbal autopsy forms according to a classification system based on the Tenth Revision of the International Classification of Diseases (ICD-10) (*14*). The village- and neighbourhood-based system of active reporting of deaths is well established in the sentinel areas, and we believe the enumeration of adult mortality events to be thorough and complete.

The identification of cause of maternal death has been a principal use of the verbal autopsy technique (*15, 16*), and verbal autopsy can be expected to perform well in identifying direct obstetric causes in particular (*17*). We are therefore confident that our ascertainment of probable cause of death is thorough and that our cause of death attribution is as reliable as that used in many other community-based studies of maternal mortality employing verbal autopsies. It should be noted, however, that verbal autopsies have limitations in terms of sensitivity and specificity in determining precise causes of death in many instances. The particular strength of the technique, however, is its ability to accurately describe the cause structure of mortality in settings where vital registration systems are non-functioning or moribund — not in the determination of cause of death on an individual basis (*18, 19*).

Analysis

We analysed all deaths (N=31,940) recorded in Morogoro and Hai Districts from July 1992 to December 1999, and from January 1993 to December 1999 in Dar es Salaam. Cause of death attribution was made using methods previously described (*13, 20*). We also conducted a detailed review of all verbal autopsy forms coded as 'maternal death' (N=441), restricting analysis to women aged 15 to 49. Denominators for calculations were derived as described above. Following the ICD-10 (*14*), a maternal death was defined as the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and the site of pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes. PMDFs and maternal death rates were calculated in the conventional manner, and trends in death rates were analysed using the Cox and Stuart test for trend.

MMRs were based on estimates of numbers of births for the three project areas ('NSS / AMMP' estimates) calculated from the demographic surveillance system after allowing for missed infant deaths and mis-reporting of ages of infants (from age 0 to 2 years). We also calculated an 'official' estimate of numbers of births using the 1991 / 1992 official Tanzanian crude birth rate of 43 per 1,000 population (*21*). For comparison with the official rate and ratio estimates and to assess the number of observed events, we used the official maternal mortality ratios to obtain an estimate of the expected number of maternal deaths in each project area during the period. Because the NSS districts using AMMP demographic surveillance focus on cause-specific mortality surveillance, the parity and pregnancy status of resident women are not routinely tracked. In order to examine the relationship between age and risk of maternal mortality, therefore, an estimate of the number of pregnant women in each age group was derived from the 1994 Tanzania Knowledge, Attitudes and Practices (TKAP) survey (*22*). Although more recent data are available, the 1994 data are closer to both the mid-period date (1996) and the dates of other official estimates (1991 / 1992). The number of pregnant women expected in each age group in the project populations was calculated using the age-specific proportions found in the TKAP. The number of "expected" maternal deaths in each 10-year age-group was calculated by multiplying the proportion of pregnancies in that age-group by the total number of maternal deaths observed, and thus assumed no difference in maternal mortality ratios between age groups. The ratio of observed-to-expected deaths was then estimated.

For analysis of specific causes, maternal deaths were sub-divided into 'direct' and 'indirect' obstetric deaths. A direct obstetric death was defined as 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. An indirect obstetric death was defined as resulting from previous existing disease which progressed during pregnancy or which was not due to direct causes, but which was aggravated by the physiological effects of pregnancy.

Finally, we have analysed the effect of education and occupational class of household head and place of delivery on risk of maternal death at the ward level. While these variables may serve as rough proxies for relative socio-economic advantage or disadvantage, they do not measure poverty *per se*. In order to analyse the data at the ward level, we adapted the spatial aggregation model of Breslow and Clayton (*23*). We assumed that the number of maternal deaths in each ward can be modeled as conditionally independent Poisson variables, with means (μ_i) that are a function of the number of women of childbearing age in the ward (W_i), the percentage of household heads in the ward who are engaged in work for which they receive a cash income (O_i), the average educational attainment of household heads within the ward[4] (E_i), and the percentage of home births (H_i). Formally, the model has the following structure:

$$D_i \sim Poission(m_i)$$
$$\log m_i = \log W_i + b_i + a_1 E_i + a_2 O_i + a_3 H_i$$
$$b_i \mid b_{j \in \aleph_i} \sim N\left(\bar{b}_{j \in \aleph_i}, t / n_i\right)$$

The set $\aleph_i$ defines the neighbouring wards of ward i, and n_i is the number of neighbouring wards for ward i. This is the conditional autoregressive prior of Besag et al (*24*), which allows the modelling of spatially smoothed random effects. To fully specify this Bayesian model, we introduced non-informative vague priors for the a coefficients (i.e. we assume that $a_{i,i=1,..3} \sim N(0,00001)$), and that $t \sim Gamma(2,2)$). The model also included terms for area of residence and ward population size. The model was fit using the BUGS software package (*25*) with a burn-in period of 20,000 iterations and data collected from the subsequent 30,000 iterations.

The analysis provides 95% predictive intervals (i.e. a range of values that are 95% certain to contain the true value) for both the true value of the maternal death rate at the ward level during the period of observation, and quantifying the effect of each covariate on maternal death rates after controlling for the effects of all the others.

Results

Trends

Maternal mortality rates were substantially lower in 1999 compared with 1992 (Table 1, Figures 1a-c). The Cox and Stuart test, however, confirmed strong evidence for a decline in maternal mortality only in Dar es Salaam at the 90% significance level (p=.005859). Changes in maternal mortality over time in Hai (p=0.290527) and Morogoro Districts (p=0.387207) were not statistically significant, despite the apparent downward trends portrayed in Figures 1b and c.

Ratios and rates

Of all 31,940 total deaths recorded in the surveillance areas, 31.4% were in women 15 years and above (2,030 in Dar es Salaam, 3,759 in Hai, and 4,257 in Morogoro District). In Dar es Salaam 73.8% of the adult female deaths occurred in women 15 to 49 years, a substantially higher proportion than in either Hai (46.2%) or Morogoro Districts (55.4%). Maternal deaths (including both direct and indirect obstetric deaths) accounted for 8.8% (107) of deaths in this age-group in Dar es Salaam, 8.1% (110) of deaths in Hai District and 12.1% (224) in Morogoro District. Table 2 shows PMDFs and MMRs in sentinel demographic surveillance areas (with 95% confidence intervals); 'official' regional estimates of MMR derived from government sources for 1992-93(*11*); the number of births expected in the NSS/AMMP populations assuming the official birth rate estimate of 43 per 1000 population (*21*); and the number of maternal deaths expected on this basis (the 'Official' estimate).

Estimated death rates due to maternal causes per 100,000 population for the entire period of observation were 77.2 for Dar es Salaam (SD 8.668), 43.1 for Hai District (SD 4.216), and 123.0 for Morogoro (SD 9.147). NSS/AMMP estimates of MMRs were 591, 348 and 1,099 per 100,000 live births in Dar es Salaam, Hai District, and Morogoro District respectively. Observed deaths were much higher than expected numbers derived by the method described above, with observed-to-expected ratios of 1.7, 5.3, and 3.1. Using the lower NSS/AMMP estimates for numbers of births (based on crude birth rates derived from NSS census data in each sentinel area), and the number of maternal deaths expected from the official 1992/93 maternal mortality ratios, the ratio of observed-to-expected deaths was even higher.

Timing and place of maternal death

There was no clear relationship between age and risk of maternal death. Half (50.1%) of the 441 maternal deaths recorded occurred to women in their 20s. In each area, both the proportion of maternal deaths and the maternal mortality rates were highest for the age groups 20 to 24 years and 25 to 29 years, although no consistent relationship was observed. The available data did not allow analysis by parity. Table 3 shows the timing and place of maternal death. Patterns in the timing of maternal death were similar in Dar es Salaam and Morogoro District, where the highest proportion of deaths occurred in the postpartum period. In Hai District, more deaths occurred during pregnancy than in labour and delivery or during the postpartum period (due to the importance of unsafe abortion there as a cause of death). In Dar es Salaam and Hai District, over 70% of deaths occurred in hospital, while in

Morogoro District fewer than half of all maternal deaths were in a health facility.

Specific causes

In Dar es Salaam, direct causes accounted for 67.3% of maternal mortality. Three direct causes (hypertensive disorders, postpartum haemorrhage, and sepsis) accounted for 42.0% of deaths. Anaemia, which caused just over 10% of the mortality, was the most significant indirect cause. In Hai District, 79.1% of maternal mortality was due to direct causes. Induced abortion was the leading cause of maternal mortality (22.7%); hypertensive disorders and postpartum haemorrhage were also significant, and together accounted for more than 23% of observed death. In Morogoro District, 87.9% of maternal mortality was due to direct causes, with postpartum haemorrhage alone accounting for 29.0% of maternal death. Spontaneous and unspecified abortion, and complications of labour and delivery were responsible for another 29.0% of maternal mortality.

In the absence of confirmatory evidence about the serostatus of deceased women, the verbal autopsy cannot adequately describe the full role of HIV/AIDS in maternal mortality in NSS/AMMP areas. Only those deaths to women who exhibited clinical signs and symptoms of advanced HIV disease or AIDS and who otherwise fit the criteria for a maternal death contributed to the proportions under 'HIV/AIDS' in Table 4. Accordingly, the role of AIDS as a main or underlying cause of maternal death appears small relative to other specific causes.

Socio-economic disadvantage and maternal mortality

The effects on maternal mortality of the covariates of interest are shown in Figure 2. The model shows that education is strongly protective of maternal mortality. In two districts where the average educational attainment of household heads differs by one year, and other factors in the model are held constant, the maternal mortality rate in the more educated district will be 38% that of the less educated district. This effect is multiplicative; i.e. if two regions differed by two years in average educational level, the maternal death rate in the more educated district would be 14% (38% x 38% x 100%) that of the rate in the less educated district. As Figure 4 indicates, a 10% change in either the proportion of household heads with an income or in the proportion of home births showed no significant relationship with maternal mortality.

Possible limitations

In the sentinel demographic surveillance system used by NSS/AMMP inconsistent determination of residency status is a possible source of error in the calculation of all mortality rates, including those for maternal mortality. Given annual and six-monthly census update rounds in the surveillance areas and measures taken to refine attribution of residency status in enumeration, we believe our population denominators to be accurate.

We can be less certain that the reporting of pregnancies and births is as complete as our mortality enumeration, both in terms of missed events and errors of recall in relating the timing of the states/events of interest (pregnancy, birth, and maternal death). Based on comparisons with Tanzanian Demographic and Health Surveys (*26, 27*), it was felt that fertility rates observed in the rural sentinel areas were too low. If unadjusted this under-counting of births would have tended to bias the estimate of MMRs upward, but would not have affected other measures of maternal mortality. We adjusted estimates of fertility used in MMR calculations using the methods described in the body of the paper.

Conclusions

From the evidence presented here it appears that in Dar es Salaam, at least, the goal of a 50% reduction in maternal mortality during the 1990s has probably been accomplished. Major reductions may be in train in the rural sentinel areas, but a longer period of observation is required to determine whether they are statistically significant. (Other Key Messages are summarised in Box 1.) This accomplishment may be tempered somewhat by observing that the reduction in maternal mortality in Dar es Salaam has still left it with rates somewhat higher than those in Hai District. Dar es Salaam is home to most of the country's gynaecologists and since liberalisation of health care, private medical facilities have sprung up throughout the city. Presumably, residents of Dar es Salaam should enjoy the easiest access to obstetric care in the country. It is also noteworthy that 6.5 % of maternal deaths in Dar es Salaam were due to HIV/AIDS.

Data are not available from the sentinel system to examine the reasons behind these trends, and we are unable to assess the role played by the Tanzanian government's four key strategies in implementing SMI. We do note, however, that during the 1990s the city of Dar es Salaam engaged in a major re-organization and renovation of the public health delivery system through implementing the Dar es Salaam Urban Health Project funded by the Swiss Agency for Development and Co-operation. The trends observed are unlikely to be due any secular declines in mortality among women; total mortality appears to have remained stable or increased for most women in the sentinel area since 1992 (analysis not shown). Fertility decline, which has been the trend in Tanzania since at least 1991, should be contributing somewhat to the decline in maternal mortality as smaller proportions of women are at risk of maternal death under such conditions.

In NSS/AMMP areas PMDFs for most of the 1990s were less than 0.13. This is within the bounds of proportional maternal mortality for countries in Africa south of the Sahara previously estimated to range between 0.093 and 0.33 (*11*, *28-32*). By comparison, Hill et al reported age-standardised PMDFs ranging from 0.14 to 0.34 for 18 African countries, with a figure of 0.26 for Tanzania (*5*).

The commonest cause of death in women of reproductive age in the three surveillance areas during the 1990s, however, was HIV/AIDS (with or without tuberculosis). By 1999, AIDS accounted for 35 to 45% of all deaths to adult women in AMMP areas. In Hai District, acute febrile illness including malaria, injuries (intentional and unintentional) and cancer all accounted for higher proportions of deaths than maternal deaths. In Morogoro District, acute febrile illness including malaria was the second commonest cause of death after HIV/AIDS, and diarrhoeal diseases accounted for 10.4% of mortality in women, nearly as great a proportion as maternal causes. Given both the apparent direction of maternal mortality during the 1990s and the frequency of maternal mortality relative to other preventable causes of death, it may be helpful to reaffirm priorities in addressing the health needs of adult women living in similar circumstances in Tanzania. National policy makers may wish to balance efforts aimed at bringing high maternal death rates still lower against the resources required to address other preventable and treatable causes of death among women.

The risk of maternal death is generally considered to be higher in teenagers/for first and second pregnancies, and after the fifth pregnancy/in women over the age of 40 years (*33*). In these sentinel areas of Tanzania, however, the highest mortality was among women between 20 and 29 years of age—the most fertile ages. We wish to stress that our analysis of the relationship between age and risk of maternal death, however, relied on estimates of the proportion of pregnant women in each age group from a national survey, and were not based on surveillance data. Nevertheless, no clear relationship between age and risk of maternal death was found. Lack of adequate data on parity made it impossible to investigate the relationship between parity and risk of maternal death.

According to the WHO, 72% of maternal deaths globally are due to five main causes: haemorrhage, sepsis, obstructed labour, eclampsia and unsafe abortion (*34*). Taken together, causes of maternal death preventable by adequate prenatal and obstetric care accounted for 47.9% of maternal deaths in Dar es Salaam, 66.3% in Hai, and 71.6% in Morogoro. In Dar es Salaam, it should be noted, indirect causes accounted for nearly a third of maternal deaths. It has been estimated that almost 70,000 women around the world die each year as a result of unsafe abortion (*34*). Data on the contribution of unsafe abortion to maternal deaths are particularly difficult to obtain (*35*), especially from countries such as Tanzania where voluntary abortion is illegal (*36*). Despite this possible negative influence on reporting, 23% of maternal deaths were attributed to induced abortion in Hai District. These data suggest that a re-emphasis within the health sector on providing basic family planning and obstetric services and removing obstacles to their use may aid in achieving still further reductions in maternal mortality.

The debates about the use of MMR as a standard indicator and the costs and complexities of its measurement are discussed briefly below, but remain unresolved. Maternal mortality ratios in all three areas exceeded official regional estimates, the greatest discrepancy being in Hai. Discrepancies arose partly because official maternal death reporting systems include only hospital deaths (*3*). Such discrepancies point to the potential value of community-based sentinel surveillance in deriving accurate mortality estimates.

The range of MMRs for sentinel areas under AMMP surveillance (591-1,099) is within the range reported in other population-based studies in sub-Saharan Africa from the 1980s-1990s (241-2,362) (*37*), comparable to UNFPA estimates for Africa (878) and the East African region (1,061) (*38*), but above the nationally reported figure for 2001 (530)(*39*).

The estimates for Dar es Salaam and Hai are low compared with the Hill et al's adjusted estimate of 1,059 for Tanzania as a whole. This figure is nearly twice our MMRs for Dar es Salaam and Hai District, although the MMR reported here for Dar es Salaam is similar to other recent estimates (*40*).

Of the three sentinel areas, Morogoro District was already known to have the highest adult mortality rate (*12*); it also had the highest maternal mortality rate in 1995 (*13*). Its position in this regard has not changed relative to the other sentinel areas. Using the sisterhood method, Font et al estimated a 1985 MMR of 448 for an area contiguous with the Morogoro District sentinel area (*41*). In comparing the 1995 NSS/AMMP estimate of MMR with their own, Font et al expressed concern that the difference in ratios may be due to the fact that our previous method for estimating MMR did not rely on observed fertility. The current analysis corrects this shortcoming, and yields an even higher estimate of MMR for Morogoro District within relatively narrow confidence limits. Furthermore, Hill et al found that sisterhood surveys in general have generated implausible and inaccurate estimates of mortality, and found it necessary to adjust the MMR for Tanzania based on sisterhood estimates upward from 529 to 1,059. This revised estimate is very close to the NSS/AMMP estimate for Morogoro. The difference in rate estimates from neighbouring areas produced by Font et al and by the AMMP team here may be less surprising (if still concerning) given findings from research in Bangladesh. Even using the same denominator population enumerated through a demographic surveillance system, three different methods of lay reporting of maternal deaths yielded large disparities in the levels and causes of maternal mortality (*15*). Given the importance of the issue and the varying performance of methods to measure maternal mortality, it will be necessary to explore, validate, and disseminate cost-effective options that yield reliable results.

Elsewhere we reported preliminary indications that education was strongly related to total, maternal, and under-five mortality (*42*). The results of the present analysis have shown a dramatic relationship between increased education among household heads and lower risk of maternal death at the community level, after controlling for other factors. Much more research would be required to establish a causal link between increasing education and lower maternal mortality. Nevertheless, this finding complements findings from elsewhere in Africa that better educated women in rural areas receive better obstetric care (*43*) and the well-documented influence of increased education among both males and females in lowering fertility. Much has been spoken and written about medical means by which maternal mortality might be reduced (*44, 45*) and it is clear from this surveillance activity that most deaths could be prevented by adequate medical care. It is nevertheless questionable whether medical means alone will be sufficient to reduce maternal mortality in the context of severe poverty and limited education. This issue will become increasingly important to understand given the increasing weight placed on process measures such as the proportion of deliveries by trained attendants (*6*) and the lack of a demonstrated association between proportion of home births and maternal mortality in the Tanzanian data reported here.

Implications for the cost-effective measurement of maternal mortality

The Tanzanian government's strategy paper on reproductive health and child survival (*3*) encapsulates the dilemma facing the evaluation of SMI's impact on mortality: it embraces an ambitious goal for reducing maternal mortality while also acknowledging the lack of accurate and readily available information for measuring progress toward this objective. In particular, the paper decries the weakness of facility-based information sources and the lack of community-based statistics. This situation is acute in other low-income countries as well.

On the face of it, reducing mortality seems an appropriate choice of indicator for measuring 'safe motherhood.' This has, however, not been the case. Despite the fact that maternal mortality is often pointed to as the indicator that reflects the greatest disparities among women in poor and rich countries (*46*), it is still a rare enough event even in poor countries that measuring it repeatedly and reliably is costly and complicated. The concern about using maternal mortality as an indicator for measuring progress in SMI rests mainly on this observation. Arguing in favour of retaining the MMR, Stanton et al (*7*) recommend that national censuses can be appropriately modified to do the job. However, in their five-country sample both births and deaths had to be adjusted by factors of 1.0 to 3.0 and the results of the exercise were not subject to standard tests of significance. It may be reasonably asked, then, whether mortality should be the first choice as the impact indicator (*47*)? The fact that maternal death is relatively uncommon compared to debilitating and non-fatal consequences of poor maternal health and health care has led some to conclude that mortality should, in fact, not be the prime indicator (*6*). The prevention of death, it has also been argued, is too 'distal' an effect of most programs to serve as a good outcome indicator (*48, 49*).

Even if we consider maternal mortality measurement necessary (if not sufficient) to assessing progress toward goals, existing knowledge of levels and causes are too often estimates based on indirect measures such as sisterhood or demographic and health surveys, or on unrepresentative hospital-based data (*33, 50-52*). The concern over reliable repeated measurements of maternal mortality globally has been bolstered by a recent meta-analysis (*5*). Hill et al. reveal that shortcomings in data quality and availability make the measurement of MMR too difficult to be useful for monitoring the impact of programs. Even under 'optimal' data conditions, MMRs are underestimated by as much as 50% and indirect techniques commonly used in data-scarce environments (especially 'sisterhood methods') can under-estimate MMRs by an order of magnitude.

It is also important to note that the contribution of maternal deaths to all-cause mortality in women of childbearing years remains poorly understood (*5, 53, 54*). This may be due, in part, to a focus on using the MMR, which relates deaths to births rather than to other causes of death or total mortality among women. Thus a global reliance on measuring progress in Safe Motherhood in terms of MMR may, unintentionally, have led to the impression that maternal mortality is the major health problem in women in developing countries. This could divert attention from other important and preventable causes of death and from non-fatal maternal and reproductive conditions.

The criterion of cost effectiveness is increasingly applied to the choice of health intervention, but is rarely discussed in relation to options for monitoring and evaluating those interventions. We believe such a discussion is overdue. A common impression is that the establishment and maintenance of 'sentinel surveillance' as described in this paper is too expensive for poor countries. This may not be the case, assuming that some form of focussed monitoring is essential, and once alternatives have been assessed. What is needed is a comparative assessment of options for monitoring and evaluation based on evidence. Current discussions about maternal mortality monitoring methods need to be more explicit about costs and outputs.

We have estimated that in 1995 (excluding start-up costs for the purchase of motor-cycles, computers, software, etc.), the recurrent costs of conducting regular censuses, combined with added costs for districts carrying out continuous monitoring of mortality, ranged from US$30,000 to US$34,000 per area. This represented a per capita annual running cost of US$0.20 to US$0.48 for the complete demographic surveillance system and US$0.06 to US$0.12 per capita for the mortality surveillance component alone. The capital equipment needed to conduct surveillance in a population of about 100,000 should not exceed US$40,000 even in a sparsely populated district. By comparison, a nationally representative Demographic and Health Survey in Tanzania costs approximately US$1,500,000, or US$82 per completed interview.

Each of these data collection methods has its comparative advantages and disadvantages. Demographic surveillance systems can make a unique contribution to a monitoring a wide range of population health and development issues and indicators. In terms of maternal mortality monitoring, sentinel demographic surveillance has the potential to meet all the criteria of an ideal methodology (*7, p658*). Initiatives like the INDEPTH network of demographic surveillance sites (http://www.indepth-network.org) are seeking ways to address concerns raised by Stanton et al about the representativeness and generalisability of demographic surveillance at a regional and international level. Through projects and institutions like AMMP, the Tanzanian Ministry of Health is addressing these questions at a national and sub-national level. It is only with careful monitoring with the most cost-effective tools that the success of programmes designed to reduce the burden of disease due to maternal mortality and other causes can be adequately assessed over the long term.

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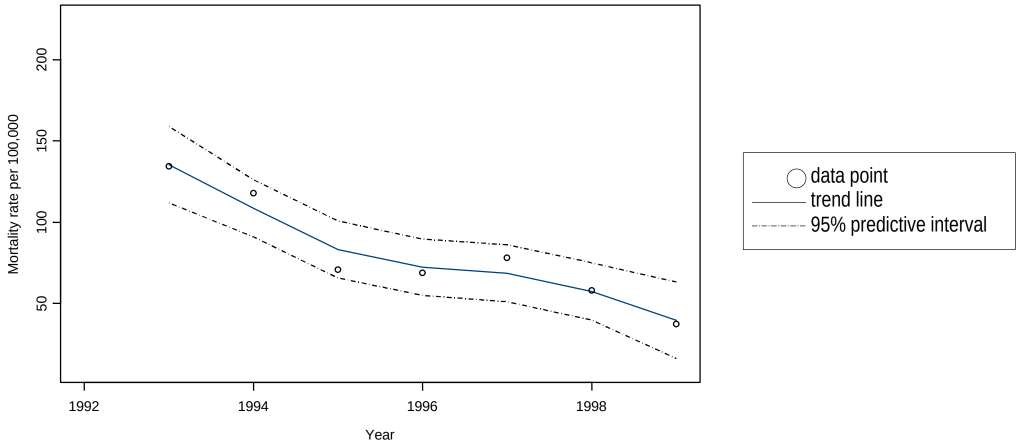

Figure 1a. Maternal mortality trend and 95% predictive intervals in Dar es Salaam (p<.01)

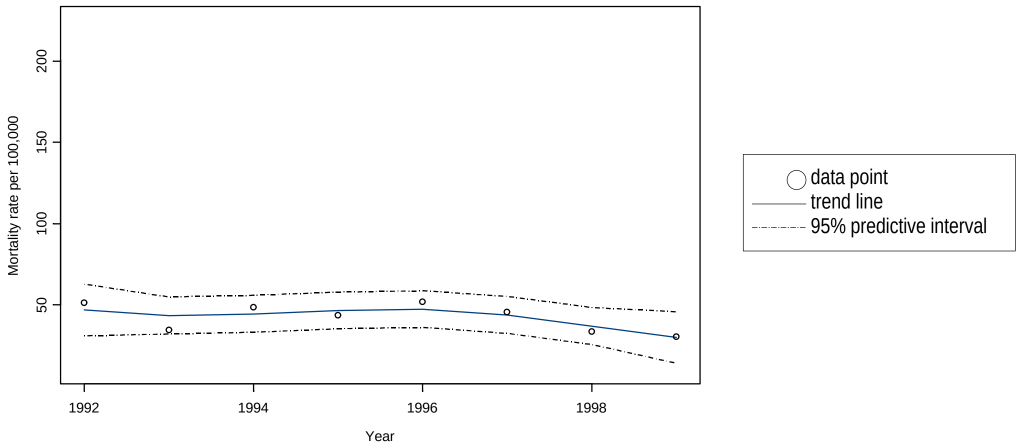

Figure 1b. Maternal mortality trend and 95% predictive intervals in in Hai District (p>.01)

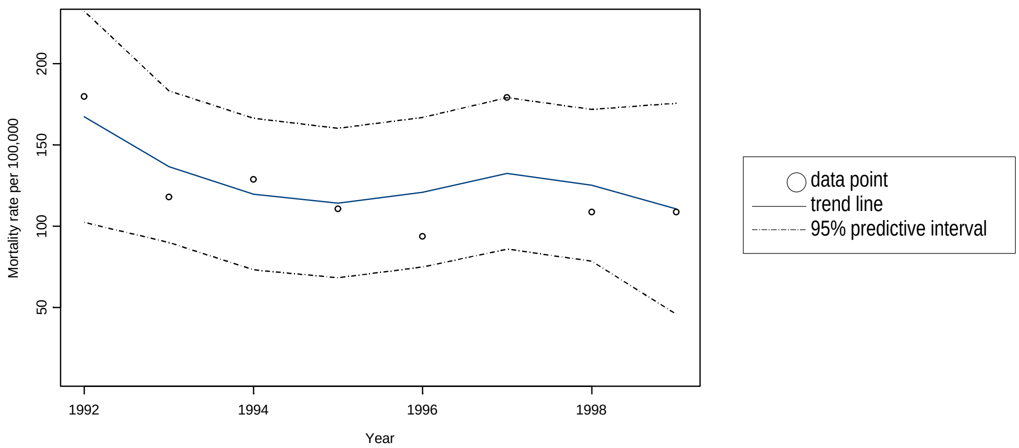

Figure 1c. Maternal mortality trend and 95% predictive intervals in Morogoro District (p>.01)

Table 1. change in maternal mortality rates in NSS/AMMP areas (1992 and 1999)

	1992	1999	% Change
Dar es Salaam (from 01/1993)	134	37	-72.3
Hai District	51	30	-40.8
Morogoro District	179	108	-39.5

Table 2. PMDFs, maternal mortality rates, MMRs, and numbers of maternal deaths observed and expected, NSS/AMMP areas (1992-1999)

	PMDF†	Maternal mortality rate per 100,000 (SD)	MMR‡	Estimated births ('92-'99)	Expected Maternal Deaths (N)	Observed Maternal Deaths (N)	Observed/Expected*
Dar es Salaam							
NSS/AMMP (95% CI)¶	0.071(0.065-0.078)	77.2 (63.3-92.5)	591(489-714)	18,090	56	107	1.9
Official§	-		310	20,648	64	-	1.7
Hai District							
NSS/AMMP	0.063(0.057-0.069)	43.1 (35.3-51.4)	348(289-420)	31,578	14	110	7.9
Official	-		44	47,028	21	-	5.3
Morogoro District							
NSS/AMMP	0.095(0.089-0.101)	123.0 (107.5-139.3)	1,099(964-1,253)	20,375	44	224	3.1
Official	-		218	33,326	73	-	5.0

† PMDF = proportion of deaths to women aged 15-49 due to maternal causes (see **Table 4** for causes included).

‡ MMR = maternal deaths per 100 000 live births.

* Ratio of observed to expected in each area relates the observed maternal deaths to either the official or the project expected maternal deaths. The official estimates of observed to expected deaths use the number of events observed in the sentinel surveillance.

¶ NSS/AMMP maternal mortality ratios given here are calculated from the observed maternal deaths and the project estimate of number of births.

§ Official maternal mortality ratios given here are the mean of official estimates for 1992 and 1993 for the regions of Dar es Salaam, Kilimanjaro, and Morogoro (which include the surveillance areas)

Table 3. Timing and place of maternal deaths, NSS/AMMP areas (1992-1999)

	Timing of Death (%)			Place of death (%)	
	During Pregnancy	Labour & delivery	Postpartum period	Hospital	Home
Dar es Salaam	38.3	13.1	48.6	71.0	29.0
Hai District	48.2	16.4	35.5	78.2	21.8
Morogoro District	36.2	23.7	40.2	43.7	56.3

Table 4. Proportion of maternal mortality due to direct and indirect causes, NSS/AMMP areas (1992-1999)

	Dar es Salaam		Hai District		Morogoro District	
Cause	%	N	%	N	%	N
Direct Causes	**67.3**	**72**	**79.1**	**87**	**87.9**	**197**
Induced abortion	*7.5*	*8*	*22.7*	*25*	*6.3*	*14*
Spontaneous and unspecified abortion	*4.7*	*5*	*6.4*	*7*	*15.2*	*34*
Hypertensive disorders of pregnancy	*14.0*	*15*	*10.0*	*11*	*4.9*	*11*
Antepartum haemorrhage	*2.8*	*3*	*3.6*	*4*	*0.9*	*2*
Complications in labour & delivery (incl. Ruptured uterus)	*5.6*	*6*	*9.1*	*10*	*13.8*	*31*
Postpartum haemorrhage	*14.0*	*15*	*13.6*	*15*	*29.0*	*65*
Puerperal sepsis	*14.0*	*15*	*7.3*	*8*	*6.7*	*15*
Other direct	*4.7*	*5*	*6.4*	*7*	*11.2*	*25*
Indirect causes	**32.7**	**35**	**20.9**	**23**	**12.1**	**27**
Anaemia	*10.3*	*11*	*6.4*	*7*	*7.6*	*17*
HIV/AIDS	*6.5*	*7*	*3.6*	*4*	*0.4*	*1*
Other indirect	*15.9*	*17*	*10.9*	*12*	*4.0*	*9*
Total	**100.0**	**107**	**100.0**	**110**	**100.0**	**224**

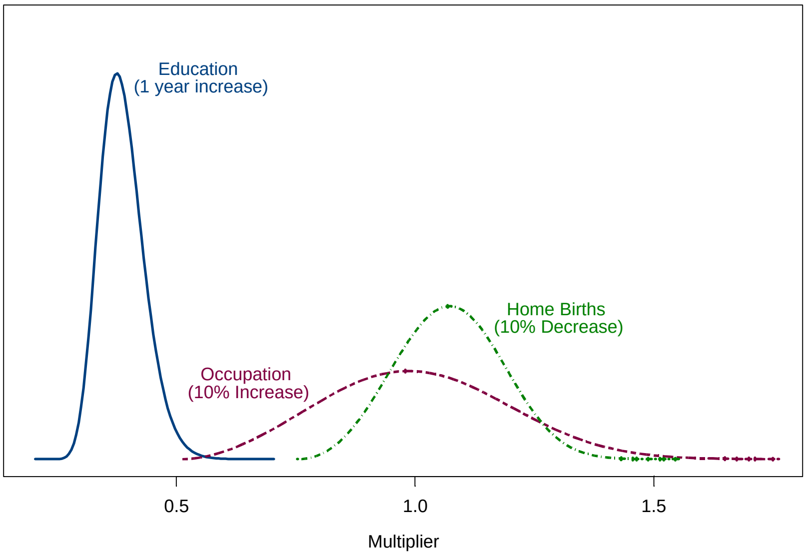

Figure 2. Effect of Covariates on Maternal Mortality at the Ward Level