Extended Abstract

Decomposing estimates of the maternal mortality ratio

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The goal of this paper is to better appreciate how estimates of the maternal mortality ratio (MMR) are related to estimates of fertility and female reproductive age mortality and how changes in the MMR can be placed within the broader context of recent changes in fertility and adult mortality. To achieve this goal an alternative expression for the maternal mortality ratio, that incorporates measures of fertility and mortality, will be presented. This expression will also be used as a tool for comparing estimates of the MMR derived from different data sources to better understand why there are large discrepancies in estimates for individual countries. Finally, special consideration will be given to the set of countries that have experienced large changes in reproductive age female mortality due to the rise in AIDS mortality.

Recently an interagency working group of the United Nations published estimates of trends in maternal mortality from 1990 to 2010, with an emphasis on changes in the maternal mortality ratio and the estimated number of maternal deaths for countries, regions and the world (World Health Organization, et al., 2012). They estimated that globally the MMR declined from 400 to 210 maternal deaths per 100,000 live births, with maternal deaths declining from 543,000 in 1990 to 287,000 in 2010. The methodology used to produce these estimates involved estimating the proportion of deaths classified as maternal in a given year, PM (taken from either a regression model or vital statistics, depending on the country), multiplying that by an estimate of deaths to reproductive age women and dividing by births:

$$MMR = (100,000)(PM)(_{35}D_{15})/(Births). \qquad\qquad (1)$$

Deaths to reproductive age women were estimated by combining population estimates from the UN Population Division with age-specific mortality rates from WHO life tables: $_{35}D_{15} = \sum(_5P_x)(_5M_x)$. Births were also taken from UN Population Division estimates.

Plugging in the global figures for 1990 and 2010 into this identity yields:

1990: $400 \approx (100,000)(.163)(3,334,000)/(134,594,000)$

2010: $210 \approx (100,000)(.077)(3,729,000)/(136,169,000)$

Dividing both deaths and births by the number of reproductive age women, $_{35}W_{15}$, the identity above can be re-expressed as:

$$MMR = (100,000)(PM)(_{35}D_{15}/_{35}W_{15})/(Births/_{35}W_{15})$$

$$MMR = (PM/GFR)(100,000*_{35}M_{15}), \qquad\qquad (2)$$

where GFR is the general fertility rate and $_{35}M_{15}$ is the all-cause mortality rate for women 15 to 50. Plugging in the global values for 1990 and 2010 yields:

1990: $400 \approx (.163/.107)(255)$

2010: $210 \approx (.077/.076)(211)$

Using the first equation, both births and deaths are seen to not have changed substantially and the reduction in the MMR is associated with the decline in PM from .163 to .077 over the 20 year period. This, however, ignores the 36 percent increase in the global number of reproductive age women from 1.31 to 1.78 billion over the same period of time.   Using the second equation we can appreciate that all-cause mortality, $_{35}M_{15}$, declined from 255 to 211 annual deaths per 100,000 reproductive age women and that the general fertility rate declined from .107 to .076 annual births per woman over the same period. This clarifies that the reduction in the MMR is also associated with a decline in all-cause mortality and with the proportion of the deaths classified as maternal, PM, having declined more than the GFR declined.   We can see that in 1990 the chance of a maternal death per 100,000 births was 1.52 (.163/.107) times greater than the annual chance of a woman dying of any cause between the ages of 15 and 50. By 2010 the ratio PM/GFR had declined to one (.077/.076) such that the global measure of obstetric risk, the MMR, was essentially equal to the global value of $_{35}M_{15}$[1].

The individual country level estimates presented in the UN interagency report are implicitly based on the estimates of GFR and $_{35}M_{15}$ that were used to generate the estimated numbers of births and deaths that went into the calculations described by equation 1. Descriptions of the study methodology focus on derivation of the values of PM, which for many countries were estimated by a regression equation (Wilmoth, et al., 2012). One of the goals of this paper is to make explicit the assumptions about fertility and female reproductive age mortality that also underlie those estimates and which can be used to understand why those estimates may differ markedly from estimates from other sources.

In Figure 1, the 180 countries included in the 2012 UN study are displayed with estimates of the ratio PM/GFR on the horizontal axis and $_{35}M_{15}$ on the vertical axis. Estimates for 1990 are shown as blue diamonds and estimates for 2010 are shown as red squares. Since the MMR is the product of these two quantities, the set of all combinations of $_{35}M_{15}$ and (PM/GFR) that correspond to a given level of MMR form a hyperbola-shaped line on this graph. Figure 1 displays the lines corresponding to MMR levels of 200, 400 and 800 maternal deaths per 100,000 births. In 1990 there were 27 countries with estimated MMR's greater than 800 and the ratio PM/GFR for those countries varied between 1.2 and 2.2. The country with the highest MMR in 1990 was Laos (MMR=1602), with an MMR 2.1 times greater than its $_{35}M_{15}$ of 763. By 2010 only 4 countries were estimated to have MMR's greater than 800 (Chad, Somalia, Sierra Leone and the Central African Republic) and their ratios of PM/GFR varied between 0.91 and 1.60. In 1990 there were only four countries with female reproductive age mortality ($_{35}M_{15}$) estimated at more than 800 deaths per 100,000 women. In 2010, after the advent of the AIDS epidemic, there were 9 countries above 800 (6 of them greater than 1000).

The cases of Laos and Lesotho illustrate the distinctive paths followed by different countries. The estimated MMR for Laos declined from 1602 in 1990 to 475 in 2010, which coincided with a reduction in reproductive age mortality from 763 to 345 and a decrease in the ratio PM/GFR from 2.10 to 1.38. In Lesotho, which has experienced some of the highest AIDS mortality rates in the world, the MMR was estimated to have increased slightly from 521 to 618, against the backdrop of $_{35}M_{15}$ increasing dramatically from 307 to 1446 and the ratio PM/GFR declining from 1.69 to 0.43.

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[1] It should be emphasized that the denominators of the MMR and $_{35}M_{15}$ are not the same. The MMR gives the risk of dying of maternal causes per 100,000 births in the population while $_{35}M_{15}$ gives the annual risk of dying of any cause per 100,000 reproductive age women. Also, $_{35}M_{15}$ is the mortality rate in the population ($_{35}D_{15}/_{35}W_{15}$), which is distinct from the mortality rate that would be calculated from a female life table ($_{35}d_{15}/_{35}L_{15}$). For countries with positive growth rates the observed age distribution is younger than the stationary population associated with its life table so that the $_{35}M_{15}$ observed in the population will be less than the equivalent measure in the life table.

Figure 1 also illustrates that for countries with an MMR less than 200 there is a considerably narrower range of values for $_{35}M_{15}$ (mostly between 25 and 200), and that most of the variation in MMR 's at this lower level coincides with variation in the ratio PM/GFR.

Table 1 presents summary information, from the database[2] of the UN study, where countries have been categorized into 5 groups according to their estimated MMR in 1990 and 2010 (<100, 100-200, 200-400, 400-800, and >800). As mentioned earlier, there were 27 countries with an estimated MMR greater than 800 in 1990, but only 4 countries in this category in 2010. The >800 category accounted for 12 percent of global births and 31 percent of global maternal deaths in 1990, but only 1 percent of births and 4.5 percent of maternal deaths in 2010. In contrast, the number of countries in the 200-400 MMR range grew from 15 to 29 and from representing 4 percent to 43 percent of global maternal deaths.

The right hand side of Table 1 provides estimates of PM, GFR and $_{35}M_{15}$ aggregated across countries at different levels of MMR in 1990 and 2010. From this aggregated information it can be appreciated that lower levels of MMR are simultaneously associated with lower values of reproductive age mortality and lower values for the ratio PM/GFR.

This abstract provides a summary of global data from the aforementioned UN study that have been re-tabulated to highlight how female adult mortality and fertility are embedded in the estimates of the MMR. The proposed paper will provide more detailed information for individual countries and world regions using the database of the UN study and make comparisons to estimates from other data sources, with an emphasis on higher MMR countries where demographic surveys and RAMOS studies have been conducted. We also propose to consider in greater detail the set of countries with high AIDS mortality in order to place maternal mortality estimates within the context of the leading cause of death for reproductive age women in these settings.

References

Wilmoth, J., Mizoguchi, N. Oestergaard, M., Say, L., Mathers, C., Zureick-Brown, S., Inoue, M., and Chou, D. (2012). A new method for deriving global estimates of maternal mortality. *Statistics, Politics, and Policy*, 3(2):1-37.

World Health Organization, UNICEF, UNFPA, and the World Bank (2012). *Trends in maternal mortality: 1990 to 2010.* World Health Organization, Geneva.

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[2] Database obtained from WHO's Global Health Observatory website:
http://www.who.int/gho/maternal_health/mortality/maternal/en/index.html

Figure 1. 180 Countries displayed according to estimates of female reproductive age mortality ($_{35}M_{15}$) and the ratio of the proportion of reproductive age deaths classified as maternal (PM) to the general fertility rate (GFR) in 1990 and 2010
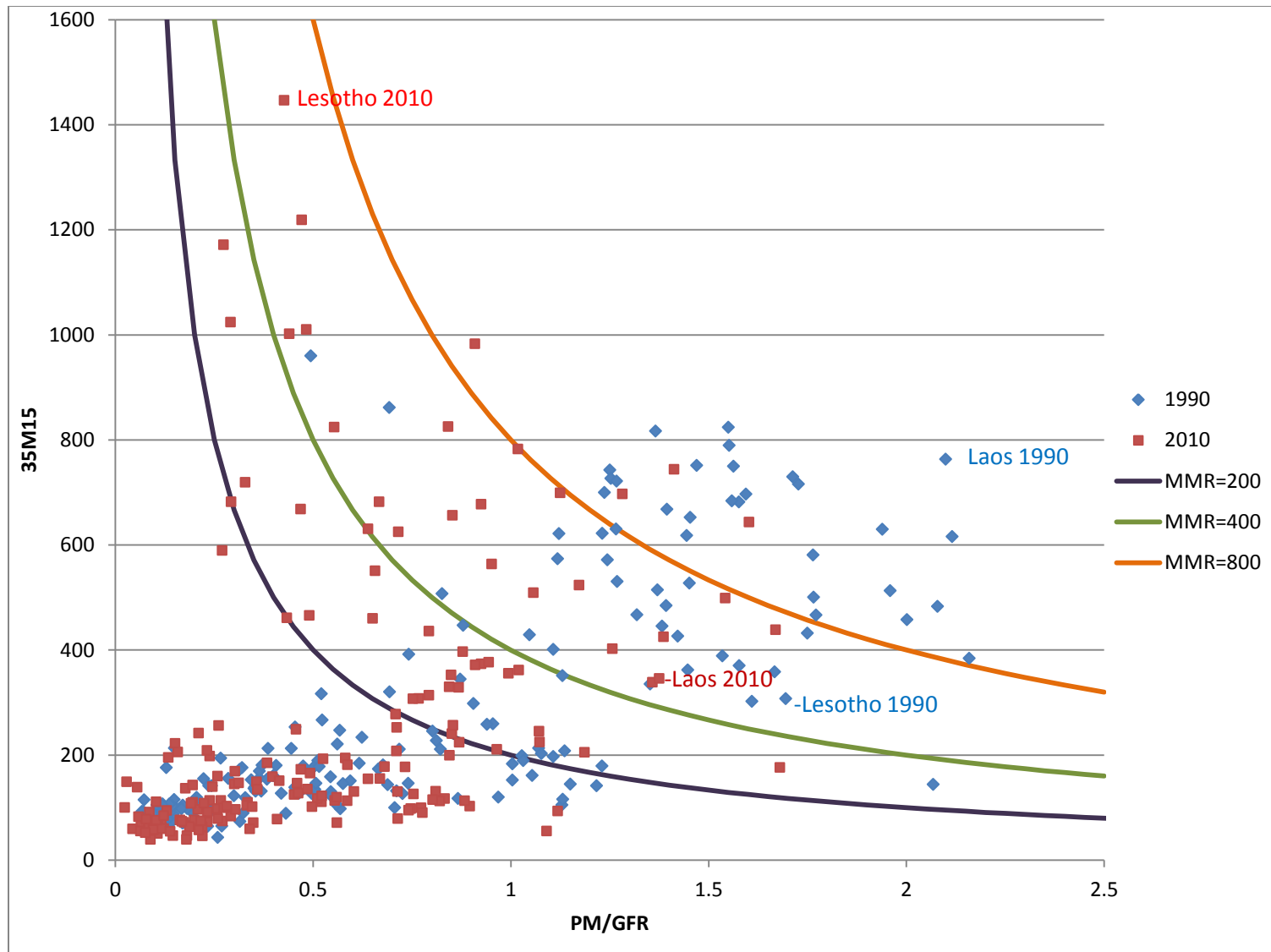
Table 1. Aggregated estimates of the global numbers of reproductive age women, births, maternal deaths and all deaths to reproductive age women, classified by level of the maternal mortality ratio (MMR) in 1990 and 2010.

1990						1990				
MMR	Countries	Women, 15-49	Births	Maternal Deaths	All deaths, women 15-49	PM[3]	GFR[4]	PM/GFR	$_{35}M_{15}$[5]	MMR[6]
>800	27	80,386,384	16,528,553	169,638	536,900	0.316	0.206	1.54	668	1026
400-800	25	347,805,263	48,447,711	293,017	1,430,664	0.205	0.139	1.47	411	605
200-400	15	63,658,305	8,503,797	22,305	150,970	0.148	0.134	1.11	237	262
100-200	24	404,110,308	35,319,606	45,437	738,472	0.062	0.087	0.70	183	129
<100	89	412,305,661	27,369,532	12,192	476,504	0.026	0.066	0.39	116	45
Total	180	1,308,265,921	136,169,200	542,590	3,333,511	0.163	0.104	1.56	255	398
>800	15.0%	6.1%	12.1%	31.3%	16.1%					
400-800	13.9%	26.6%	35.6%	54.0%	42.9%					
200-400	8.3%	4.9%	6.2%	4.1%	4.5%					
100-200	13.3%	30.9%	25.9%	8.4%	22.2%					
<100	49.4%	31.5%	20.1%	2.2%	14.3%					
Total	100.0%	100.0%	100.0%	100.0%	100.0%					

2010						2010				
MMR	Countries	Women, 15-49	Births	Maternal Deaths	All deaths, women 15-49	PM	GFR	PM/GFR	$_{35}M_{15}$	MMR
>800	4	7,204,430	1,291,525	12,890	53,279	0.242	0.179	1.35	740	998
400-800	22	124,198,244	21,400,953	120,703	807,912	0.149	0.172	0.87	651	564
200-400	29	559,906,279	51,908,140	124,208	1,619,307	0.077	0.093	0.83	289	239
100-200	15	46,771,896	3,746,427	5,591	93,008	0.060	0.080	0.75	199	149
<100	110	1,032,882,931	56,246,933	23,263	1,155,126	0.020	0.054	0.37	112	41
Total	180	1,770,963,781	134,593,978	286,655	3,728,633	0.077	0.076	1.01	211	213
>800	2.2%	0.4%	1.0%	4.5%	1.4%					
400-800	12.2%	7.0%	15.9%	42.1%	21.7%					
200-400	16.1%	31.6%	38.6%	43.3%	43.4%					
100-200	8.3%	2.6%	2.8%	2.0%	2.5%					
<100	61.1%	58.3%	41.8%	8.1%	31.0%					
Total	100.0%	100.0%	100.0%	100.0%	100.0%					

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[3] Proportion maternal of deaths to women, aged 15 to 49.
[4] General fertility rate – mean annual births per reproductive aged woman.
[5] Annual deaths per 100,000 women, aged 15 to 49.
[6] Maternal deaths per 100,000 live births.