Documentation for

Data on Maternal Mortality

Historical information compiled for 14 countries (up to 200 years)

Gapminder Documentation constitutes work in stepwise progress.

We welcome all sorts of comments, corrections and suggestions through e-mail to the author.

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Author: Claudia Hanson
E-mail: Claudia.hanson@gmx.de
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This is the documentation for the Gapminder compilation of maternal mortality data (MMR and total maternal deaths). The main data set available at http://www.gapminder.org/world/ includes the unadjusted historical data, described here, available from various sources up to 1980 but uses more complete data from the Institute of Health Metrics and Evaluation for the years 1980 to 2008 [1]. For advanced users the full unadjusted data from the historical series from 1751 up to the most recent date are also available (under "advanced users" at http://www.gapminder.org/world).

Historical time series are available for the following countries:
Australia (since 1871)
Belgium (since 1851)
Denmark (1921-1949 & since 1970)
Finland (since 1751)
Germany (since 1952)
Ireland (since 1871)
Japan (since 1935)
Malaysia (since 1933)
The Netherlands (since 1867)
New Zealand (since 1972)
Sri Lanka (since 1900)
Sweden (since 1751)
United Kingdom (since 1847)
United States (since 1900)

The data is used in the interactive graph *Gapminder World* available at:
http://www.gapminder.org/world

This written documentation is accompanied with an excel-file, which includes both the detailed meta-data, as well as the actual observations. The excel-file, as well as this documentation, are available at:

http://www.gapminder.org/downloads/documentation/gd001

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1 Definition of maternal mortality

According to the recent International Classification of Disease (ICD-10) which was adopted in 1994, ***Maternal Mortality is defined as a death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of pregnancy, from any cause related or aggravated by the pregnancy or its management, but not from accidental or incidental causes*** [2].

The ICD-10 encourages the documentation of ***late maternal deaths*** being a death of women from direct or indirect obstetric causes more than 42 days but less than a year after termination of pregnancy.

The International Classification of Disease also includes alternative definitions for maternal deaths:

A ***pregnancy-related death*** is a death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of deaths.

The definition of pregnancy-related death thus relaxes the causal relationship and includes also accidental and incidental cases. This definition may be particularly useful in places where diagnostics are limited and autopsies are rarely done or where issues of shame and blaming have an impact on documentation of maternal deaths

Maternal deaths should are further subdivided into two groups:

Direct obstetric deaths: those resulting from obstetric complications of the pregnant state (pregnancy, labour and puerperium), from interventions, omissions, incorrect treatment, or from a chain of events resulting from the above.

Indirect obstetric deaths: those resulting from previous existing diseases or disease that developed during pregnancy and which was not due to direct obstetric causes, but which was aggravated by physiological effects of pregnancy.

1.1 *Statistical measures of maternal mortality*

Maternal mortality ratio (usually abbreviated MMR): Number of maternal deaths during a given time period per 100,000 live births during the same time period.
This indicator measures the obstetric risk a woman is facing when she is pregnant. For example, the MMR is estimated at 1575 per 100000 live births in Afghanistan and 5 per 100000 in Sweden [1]. Thus a woman in Afghanistan is facing a 315 times higher risk of maternal deaths when she is pregnant than a women in Sweden.
The total number of live births is used for practical reasons. Ideally one would want to use the number of pregnancies as a denominator. But as the total number of pregnancies in a population is mostly not known - particularly the number of early abortions - the number of live births is used as an approximation [3].

Maternal mortality rate (MM-rate): Number of maternal deaths in a given period per 100,000 women of reproductive age during the same time-period.

This indicator expresses the burden of maternal mortality in the adult female population. The indicator takes into account the risk of deaths while pregnant but also the exposure to risk (number of pregnancies in the adult female population). If fertility in a population is high, many women are at risk of a maternal death. Thus this indicator equals the risk per birth as expressed as the MMR multiplied by the number of women giving birth in a population expressed as the General Fertility Rate = number of live births in the female population. This is why the relationship between MMR and MM-rate is as follows: MM-rate = MMR x General Fertility Rate.

A third indicator is ***the proportion of deaths of all women in reproductive age due to maternal mortality (PMDF)*** or simply number of maternal deaths / female deaths aged 15-49. This is a measurement expressing the share of maternal mortality in relation to all female deaths. This indicator is often used to calculate the MMR as it is thought to be more reliable than a direct estimation of the MMR [4].

A fourth indicator is the ***life time risk of maternal deaths (LTR).*** Looking at the LTR gives a useful idea of the risk of maternal deaths throughout the life period of women in a specific population. The life time risk of maternal deaths of a woman in Afghanistan is for example 1:8 and in Sweden 1:16400 [5] and thus 2050 higher in Afghanistan than in Sweden.
The LTR reflects the chance of a woman to die from childbirth or pregnancy over her 35 years reproductive life span. It is similar to Total Fertility Rate an indicator of risk at a specific time point but not actually expressing the risk a woman would experience 'in reality' if she starts her child bearing today. The LTR is calculated from tables where age-specific deaths rates for reference periods are calculated and summed up. In doing so, it accounts for both the probability of a death due to maternal causes each time a woman experiences pregnancy and the number of times she is at risk. It is calculated as follows: $(1\text{-LTR}) = (1\text{-MMR})^{\text{TFR (Total Fertility Rate)}}$
This equation is used to calculate the MMR when using the sisterhood method as explained below [6].

2 Measurement issues throughout the centuries

Establishment of national systems of deaths registration started in many countries in the mid-nineteenth century. The first international classification of disease, based on work from the English statistician William Farr and the Frenchman Bertillon, was adopted in 1898 in the USA and Canada. Britain adopted a revised version of the first international classification of disease in 1911.

Maternal death registration started in many countries before any definition on maternal mortality was internationally agreed upon. Deaths for which the underlying cause was a maternal condition were counted as maternal deaths. As there was less diagnostic uncertainty for obstetric conditions than for many other diseases - where death was often attributed to debility, marasmus and similar causes - maternal mortality has probably been diagnosed relatively similarly throughout the centuries. Hoyert depicted the MMR and changes in ICD definition in the United States throughout the 1900s and no major jumps could be observed except for the change from the ninth to the tenth revision. [7]. Macfarlane and Mugford [8] estimated that for England and Wales the change in definition of 1911 increased the MMR by approximately 9.5%, but that subsequent changes in definition did not have a major impact on the ratios.

2.1 *Issues in the nominator of measuring the MMR*

Today the **definition of maternal death** covers the time period from the beginning of the pregnancy to 42 days post-partum or post-abortion. During the early times of registration different time periods were used. William Farr set the time period in 1870 to one month, and only in the early years of the 1910s it became customary to define the postnatal period as six weeks after delivery. However, as most maternal deaths actually occur in the first two or three weeks post-partum, this change in definition did not affect maternal mortality ratios much and comparability over time and between countries has been little affected.

A factor with a much larger impact on comparability between countries and over years has been the **omission or inclusion of indirect maternal deaths**. In 1933, in England and Wales maternal deaths were defined as deaths due to diseases of pregnancy, childbirth and the puerperal state, whereas in the United States, indirect maternal deaths, such as deaths during pregnancy or the puerperium due to influenza or tuberculosis were also counted as maternal. In a comparison done by Elizabeth Tandy in 1935, cited by Loudon 1992, p33 [9], differences in the methodology and definition of maternal deaths counted for up to 20%-25% of differences in the MMR between countries. Denmark and the United States were most consistent in inclusion of indirect deaths whereas England and Wales did omit a large part. Sweden had an intermediate position.

The differences in the inclusion of associated maternal deaths are well illustrated by the influence of the influenza peak of 1918 on maternal deaths: Sharp peaks can be seen for the United States, New Zealand, Scotland and Sweden and The Netherlands, but not for England, Wales and Australia (see Fig.1).

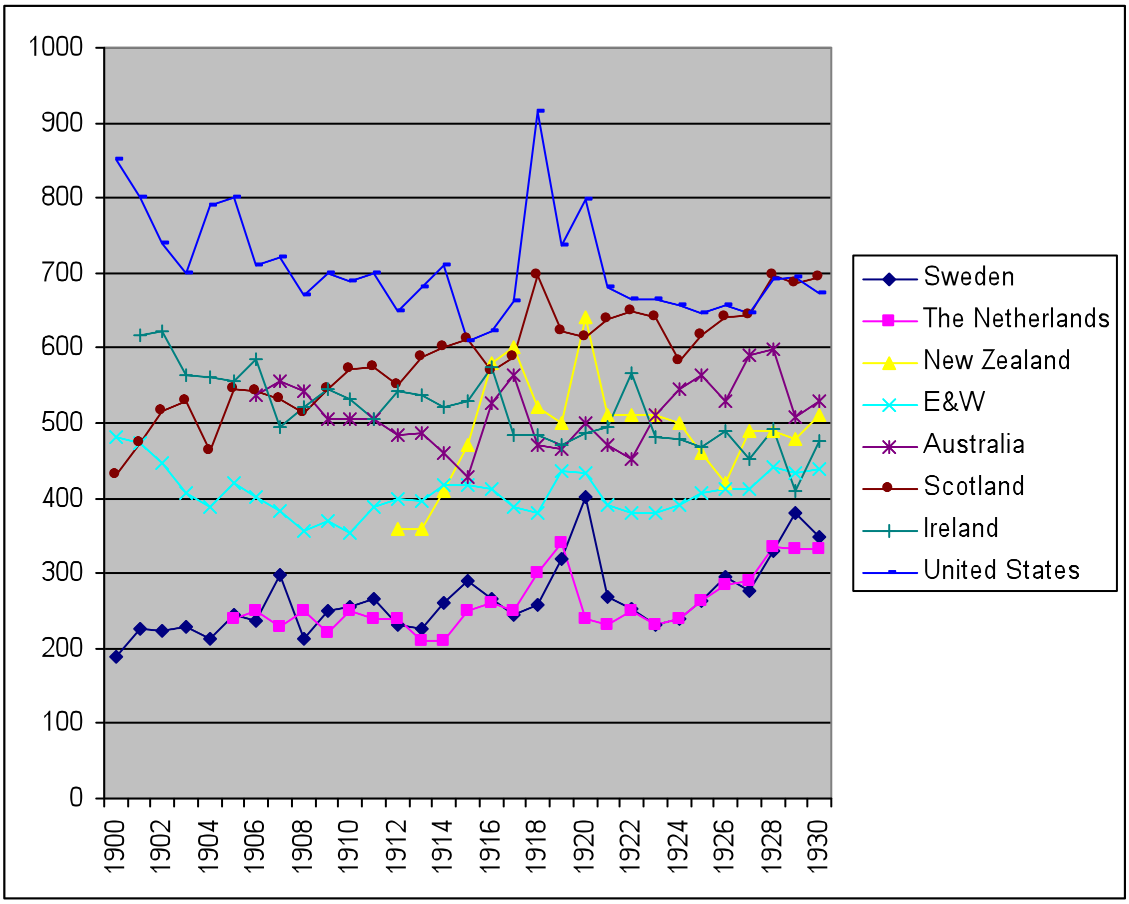


Figure 1: The influenza epidemic in the 1918 and maternal mortality

Another aspect to consider when comparing historical time series is **completeness of recording** within countries. In the 1800s, death and birth recording already covered all counties and regions in Sweden and Finland, while in the United States and Australia recording was not complete until the 1920s.
National data from these incomplete statistics are heavily biased by differences in the population structure and socio-economic conditions in recording and not recording counties/regions. In the United States, for example, the states in the South with a larger black population failed to have full recording until the 1930s. This fact might have biased the MMR published for the United States downwards as maternal mortality throughout the twentieth century was higher in the black than the white population and in fact is still today (see Fig 2).

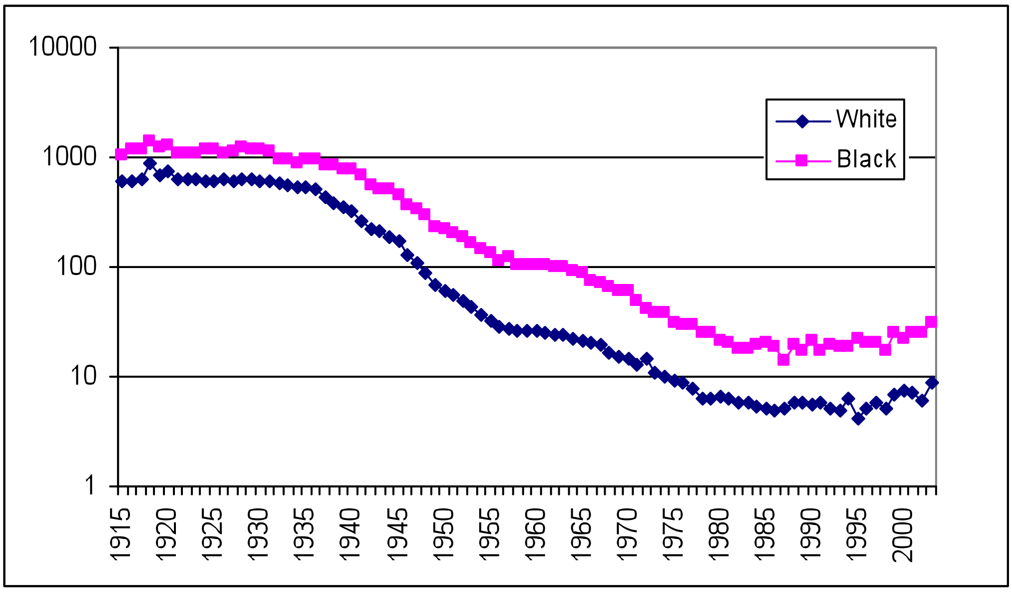


Figure 2: Differences in the United States between the white and black population between 1915 and 2006 (logarithmic scale) Data from [7]

Hidden maternal deaths are another problem in the registration of maternal mortality. This was in particular the case for puerperal sepsis from the mid 1800s onwards because doctors or midwifes were accused of substandard care if a mother died from sepsis. Thus, some of the deaths due to puerperal sepsis might have been recorded as post-partum haemorrhage (which did then not affect the overall MMR) or as peritonitis (and thus escaped the maternal deaths records). - Misclassifications also occur for other causes of maternal mortality. For example hypertensive disorders, which constitute a significant part of the overall MMR were sometimes recorded as a disease of the kidney, particularly before the early 1900s [9].

Another major problem for documentation are maternal deaths due to **abortion.** Whereas maternal death due to spontaneous abortion is very rare, induced abortion, whether illegal (criminal) or therapeutic (to save the women's life), places the woman at risk of death from sepsis, bleeding or air embolus. In England and Wales, induced abortion began to rise in the second half of the nineteenth century and peaked in the 1930s, when deaths due to abortion constituted around 15% of the overall MMR [9]. From 1910s onwards deaths due to abortion were in many country statistics listed separately. Still, there reports did often not include all abortions. Particularly septic abortions were sometimes hidden under the term puerperal sepsis. Loudon 1992, p109 [9] cites a study indicating that in England and Wales 4% of septic abortions in 1934 were actually misclassified under puerperal sepsis. Misclassified abortion

deaths decreased thus the MMR due to abortion but there was most probable less effect on the overall MMR.

The percentage of maternal deaths reported due to abortion varied from only 7% in Ireland to as much as 40% in the United States. Very high levels of deaths from abortion were reported from Germany in the inter-war period in the1920s and 1930s and from France during the nineteenth and early twentieth century. In Sweden, deaths rates due to abortion climbed also rapidly during the inter-war period and it is estimated that abortion accounted for 30% of the total maternal mortality in Sweden during this time, when the overall maternal mortality ratio was already quite low [9].

2.2 *Issues in the Denominator of the MMR*

The maternal mortality ratio is defined as the number of maternal deaths per live births in a given time period. Thus, accurate estimation of live births is needed. In the early Swedish data, only baptised children were registered. Still, this is likely to be a good proxy for live births at that time. In protestant countries like Sweden even sick newborns were baptised immediately after birth and thus only few births might have gone unrecorded.
Countries also differ widely in the time period they started to document stillbirths. For example, stillbirth registration started in Sweden in 1774, but only in 1927 in England and Wales. In most countries throughout the centuries only live births were used to calculate the MMR, but in England and Wales, total births were used since 1927. Also in other countries the use of total births became customary during the 1920s and 1930s. However, the overall bias in the MMR resulting from omission of a few live births or inclusion of stillbirth in the maternal mortality calculations has been judged to be rather small, at 0.4% in a study cited by Loudon 1992, p20 [9].

3 Methods of ascertainment of maternal deaths and measurement issues involved

3.1 *Vital (civil) registration systems*

National birth and death registration system, i.e. vital statistics, are available from most high income countries. Although they are generally a solid basis for documentation of maternal deaths and live births, major underreporting due to misclassification of maternal deaths has been reported from many countries.
Two studies in the Netherlands estimated the level of underreporting of the national MMR to be 26% for the period 1983-1992 and 33% for the period 1993-2005 [10, 11]. Particularly indirect maternal deaths are often not reported as maternal. Misclassification was evident for cerebrovascular disorders, cardiovascular disorders and eclampsia in the earlier study in the Netherlands [10]. Another study examining underreporting in two states in the United States, in Finland and France indicated even more important differences. In Finland 8 out of 11 (72%), in France 30 out of 83 (36%) and in the two American states 31 out of 58 (53%) maternal deaths were not reported in the official statistics, but only found through data linkage of birth and deaths registers [12].
Similarly in Austria 38% of maternal deaths were not reported as maternal deaths and underreporting was even as high as 81% for indirect maternal deaths [13].

The extent of underreporting differs between countries. Hill and colleagues in their global estimates of maternal morality used the country figures as a basis for the point estimate and the lower limit of the uncertainty interval, but used an adjustment factor of 2 to account for underreporting for the calculation of the upper uncertainty interval [4]. The most recent paper on global estimates used a corrected vital registration data set [1, 14].

3.2 *Household surveys*

In countries were no vital registration exists, household surveys or censuses are the only source of information of births and deaths in the population. Demographic and health surveys (DHS) are one of the best known surveys. DHS collect information on deaths in pregnancy using the **direct sisterhood method** (see below). The main advantage of the sisterhood methods both, the direct or the indirect, is that a reduced sample size is needed as women are asked about all their sisters.

Adding a question on death in reproductive age to regular censuses and whether it occurred during pregnancy or in the post-partum period is another opportunity to obtain information on maternal mortality. This application has been recently endorsed by the United Nations [15, 16]. Although this is a very promising approach, methodological issues on adjustments needed for over and underreporting are a concern [17-19]. The main disadvantage of measuring maternal mortality during a census is the costs of censuses, which limits their application to only every five to ten years.

Both methods, census and DHS (or other surveys), face the problem that they do not identify maternal deaths but ***pregnancy-related deaths***. The definition of maternal mortality excludes incidental or accidental causes, thus for example deaths due to injury. Using pregnancy-related deaths thus overestimates maternal mortality. On the other hand, it is known that deaths in early pregnancy due to abortion are notoriously difficult to identify [20-22]. It has been argued, that the overestimation by using pregnancy-related deaths is approximately counterbalanced by unreported abortion deaths [6]. Recent global maternal mortality estimation have not adjusted the estimations based on the sisterhood method for over and underreporting under the assumption explained above [1, 4].

3.3 *Direct and indirect sisterhood method*

The original ***indirect sisterhood*** method was put forward by Graham [23]. The method uses reports by women about aggregate numbers of surviving and dead sisters with additional questions about the timing of deaths to identify pregnancy-related deaths. The data are then organised in a table to derive ‘age’-specific lifetime risk of maternal deaths by the age of the responding sister. By calculating the lifetime risk of maternal deaths and the total fertility rate for the same period of investigation, the MMR is calculated using the equation $(1\text{-LTR}) = (1\text{-MMR})^{TFR}$.
The data are in general covering a period of 40-50 years prior to the survey, but centres on the 12 years before the survey. Thus, the method only gives estimations about a longer period in the past.
The method is based on a few assumptions. These include:

- the women are able to report on their siblings
- no relation exists between the number of siblings and their survival probabilities
- there was no change in the pattern of fertility by age.

The ***direct sisterhood method*** and its data collection are more demanding. The respondent is asked to provide the birth history of her mother, including the age of all living siblings and the age at deaths and years since deaths of all deceased siblings. This allows births and deaths to be placed in a calendar time and permits the calculation of sex and age-specific deaths rates for reference periods. Thus the method allows to calculated adult mortality for both, men and women.
Maternal deaths are identified by questions in relation to the timing of deaths. The questions required for the direct approach includes:

- How many children did your mother give birth to?
- How many of these births did your mother have before you were born?
- What was the name of your brother/sister?

Then for each sibling:

- Is (NAME) male or female?
- Is (NAME) still alive?

- How old is (NAME)?
- In what year did (NAME) die? OR How many years ago?
- How old was (NAME) when he died?

For dead sisters only:
- Was (NAME) pregnant when she died?
- Did (NAME) die in childbirth?
- Did (NAME) die within two months (6 weeks) after the end of pregnancy or childbirth?

The data are used to construct a table. Maternal deaths and exposure years using the age of the sisters are tabulated and the maternal mortality rate per age-group and the overall MM-rate is calculated. Using the formula: MM-rate/ General fertility rate= MM-ratio, the maternal mortality ratio is calculated for a certain time period, often for a time period of 10 or seven years prior the survey.
The direct method requires fewer assumptions and is better able to monitor trends and analyse different time periods of interest. An analysis of the early experience of the use of the method in the 1990s indicated that data collection was relatively complete and could give reasonable estimates of maternal mortality [6].

The DHS, commonly covering a population of around 10,000 households, use the direct sisterhood method to investigate maternal mortality. The analysis of data collected provides information referring to a period of between five and seven years prior the survey. The estimates have wide confidence intervals due to the limited sample size, hence the possibility for monitoring of trends is limited.

3.4 *Special studies (RAMOS)*

Reproductive age mortality surveys (RAMOS) use several sources of data to identify death of women of reproductive age to ensure utmost completeness (triangulation). Sources used might be vital registration, health facility records, burial records, interviews with family members and traditional birth attendants and others.
RAMOS are generally seen as the gold standard for the estimation of maternal mortality ratios [4]. RAMOS has in particular the advantage to identify ‘maternal deaths’ and not ‘pregnancy-related deaths’ if interviews with the deceased families are held to investigate into the cause of deaths. Also they have a great potential to identify deaths due to abortion [24]. But some maternal deaths might still be missed. The level of incompleteness and the accuracy of the estimates depend on the sources used.

The main disadvantage however, is that RAMOS is a very expensive and time consuming method, particularly when it is done on a larger scale. Often only sub-national studies are available which limits the use of RAMOS data to calculate national maternal mortality ratios [25].

3.5 *Verbal autopsy/ demographic sites*

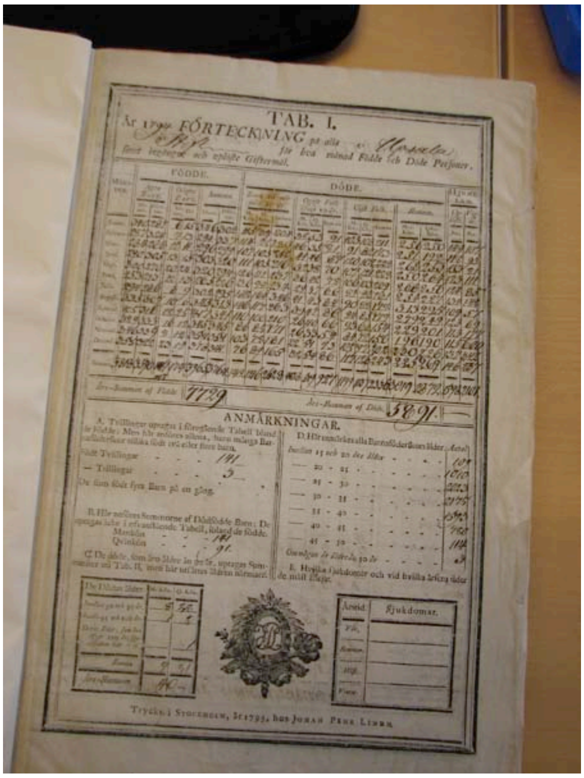
Verbal autopsy is a method used to assign cause of death where medical certification is not available. The deaths are commonly identified in demographic surveillance systems, which are maintained in smaller geographical areas – demographic sites (http://www.indepth-network.org/). But verbal autopsy can also be used in combination with any other method that identifies deaths in reproductive age such as censuses or surveys.
The cause of death is commonly assigned by a physician on the basis of interview findings based on standardised interview techniques with open and closed questions. Alternatively also statistical approaches are used [26].

Several studies have indicated that the method is relatively reliable for identification of direct causes of maternal mortality but weaknesses are described for indirect maternal deaths [27-29]. The approach may also, in particular, fail to identify deaths occurring in early pregnancy (such as deaths due to ectopic pregnancy or abortion).
Demographic surveillance systems are expensive to maintain, and the findings might not be representative for the country as a whole, which limits their relevance to monitor maternal mortality at the national level.

4 Data sources and data quality issues of historical time trends on maternal mortality

4.1 *Sweden*

The Swedish birth and death registration was established by the Swedish clergy that created an information system covering all individuals in their parishes. Since 1749 registration included the whole population. The information from the different parishes were annually compiled by the Office of the Registrar General (Tabellverket) (see figure 3) [30].



Reporting from the parishes to Tabellverket was very complete from the early days on. The reliability of these statistics has been reported reasonable.
Maternal deaths have been reported uninterruptedly since 1751. In the early days a maternal death used to be defined as a death of a women caused by complications of preganancy, labor, or puerperium. The definition thus included only direct maternal deaths, but few indirect deaths might have been included. The death cause list was revised several times in the 1800s but it was not before 1911 that a standardised Scandinavian cause of death list was used. Maternal deaths have only been defined according to the International Classification of disease since 1951 in Sweden [30].

Figure 3: Swedish summary statistics as prepared by Tabellverket

4.2 *England & Wales and Scotland*

Vital registration was introduced in England and Wales in 1837. From 1837-1874 a local registrar had to ensure that all deaths were registered. The Birth and Deaths Registration Act of 1874 placed the obligation of registration on the nearest relative of the diseased and every registration had to be accompanied by a medical certificate. Maternal deaths were divided in two major sub-groups, puerperal sepsis and accidents of childbirth.

Although birth and death registration was not complete in the early days, it has been estimated that already in the 1860s more than 80% of deaths were registered and deaths due to maternal causes were most probably among the most complete as indicated by an investigation

undertaken by the famous statistician Farr, who worked in London (Loudon 1992, p23)[9]. Some geographical variation in the completeness of registrations has been described, with higher completeness in towns. Most unregistered deaths were seen at the extremes of life, in infant deaths and deaths over the age of 80. Moreover, no sudden increase in maternal mortality was seen in 1874, indicating that even before the advance of the Births and Deaths Registration Act of 1874, completeness was relatively good. Still, increased efforts by sending out letters of enquiry for incomplete or ambiguous certificates of cause of deaths by the General Register Office in 1881 resulted in an increase of maternal deaths by 8%. The practise of sending out letters of inquiry did continue also in the later years, but the number of maternal deaths, which were misclassified, had by then been reduced to less than 1% [8].

In 1901 the first International Classification of disease replaced the former classification system. Causes of deaths due to thrombosis and a few others were subsequently recorded as maternal causes. Major changes were introduced with the revision of the classification in 1911. Particularly puerperal nephritis and albuminuria (today classified as hypertensive disorders) previously recorded as disease of the kidney were now included as associated deaths, and thus as maternal deaths. This change made the MMR increase by approximately 9.5% [8].

Since the mid 1920s in England and Wales, deaths due to post-abortive sepsis were separately recorded. Still, deaths, which were known to result from 'criminal abortion' were classified as 'violent deaths' and were only included as maternal deaths with the 5th revision which came into use in England and Wales only in 1940 [8].

Again a major change in recording of maternal mortality was introduced with the 9th revision of the ICD, used since 1980, which from then included deaths associated with pregnancy and childbirth as 'indirect maternal deaths' [8].

4.3 *United States*

In the United States death registration was only expanded in the 1910s and 1920s. States in the South of the country were in particular late in starting with deaths registration. Complete data from the United States are only available from the 1930s onwards. This fact is important as the States in the South were the ones with the higher maternal mortality. However, investigations into this by Woodbury in 1926 cited by Loudon 1992, p369 [9] estimated the distortion of the overall MMR due to this as minor. The major problem of that time might have been hidden deaths. Because of the highly scattered and mobile population it was difficult to collect high quality deaths certificates from doctors. An inquiry by Woodbury into doubtful deaths certificates led to an increase of the MMR by 3.8% in 1900 but only 0.2% in 1920 cited by Loudon 1992, p369 [9].

4.4 *Sri Lanka*

Birth and Death registration started in Sri Lanka already in 1847. The vital registration system is comprehensive and compulsory and the data are judged to be of relatively acceptable quality. Birth and death registration had been assessed in 1953, 1967, and in 1980 and were found to be 89%, 95% and 93% complete. However, there is a concern that the quality of the data reduced in the recent years due to the civil war in the north and east of the country [31]. Mathers et al [32] judge the quality of the data today as low with <70% completeness and >20% ill-defined causes.

Maternal mortality data are available from the 1900s onwards. Completeness has been studied in 1994-95 and revealed 24% underreporting (Bandhutilaka, 1996, cited in [31]). Particularly indirect maternal deaths might be a problem.

4.5 *Malaysia*

The information on maternal deaths from Malaysia is likely to be more incomplete than the data from Sri Lanka in the early years [31]. During the 1950s and 1960s causes of maternal death were only recorded for those deaths that occurred after women went to the hospital or delivered with a skilled attendant. At that time only about 30% delivered with a skilled attendant [31]. Moreover, the data before 1940 relates only to Peninsular Malaysia.

During the 1970s, government midwives working in rural areas instituted a practise of visiting those families that had reported a female death to local Register General, to assess whether it was a maternal death. Moreover the system of deaths registration was expanded and strengthened, but it was not before the 1990s that the birth and death registration system was systematically revised to also include maternal deaths recorded by the Ministry of Health, but not found in the local Register General [31].

Today the vital registration system of Malaysia is judged to be of medium quality with >90% completeness and <10% ill-defined causes of deaths [32].

5 Theories to explain time trends and differences between countries

5.1 *Determinants and explanations of the historical decline in maternal mortality*

A steady and continuous decline in the MMR was seen in Sweden throughout the eighteenth and nineteenth centuries. This is commonly explained by the early introduction of home based midwifery care throughout the country. The pronounced decline between 1870s and 1890s might be the result of training in aseptic techniques [33]. The hub in the MMR in Sweden in the inter-war period between 1920s and 1940s is attributed to higher maternal mortality due to abortion.

In contrast, a much slower reduction in MMR was observed in the United States or United Kingdome during the nineteenth century. This fact is commonly explained by less efficient organisation of delivery care, which was largely based on practitioners with limited training in obstetrics [34].

The tremendous decline in the MMR starting in the 1940s in all Western countries is due to the introduction of new technology (oxytosics, sulphonamides and later penicillin) and better access to blood transfusion and emergency obstetric care due to improvement in overall health care organisation, which were initiated during the 2nd World War [9].

The rapid decline in Sri Lanka is explained by malaria control, then introduction of midwifery care with consequent rollout to rural area and continuous quality improvement and a supportive fertility decline since the 1970s. In Malaysia improved access to midwifery care and later increased institutional deliveries might be the decisive factors for the reduction of MMR [31]. The jump seen in Malaysian data in 1980 is due to correction for underreporting and misclassification as reported by Hogan et al. [1].

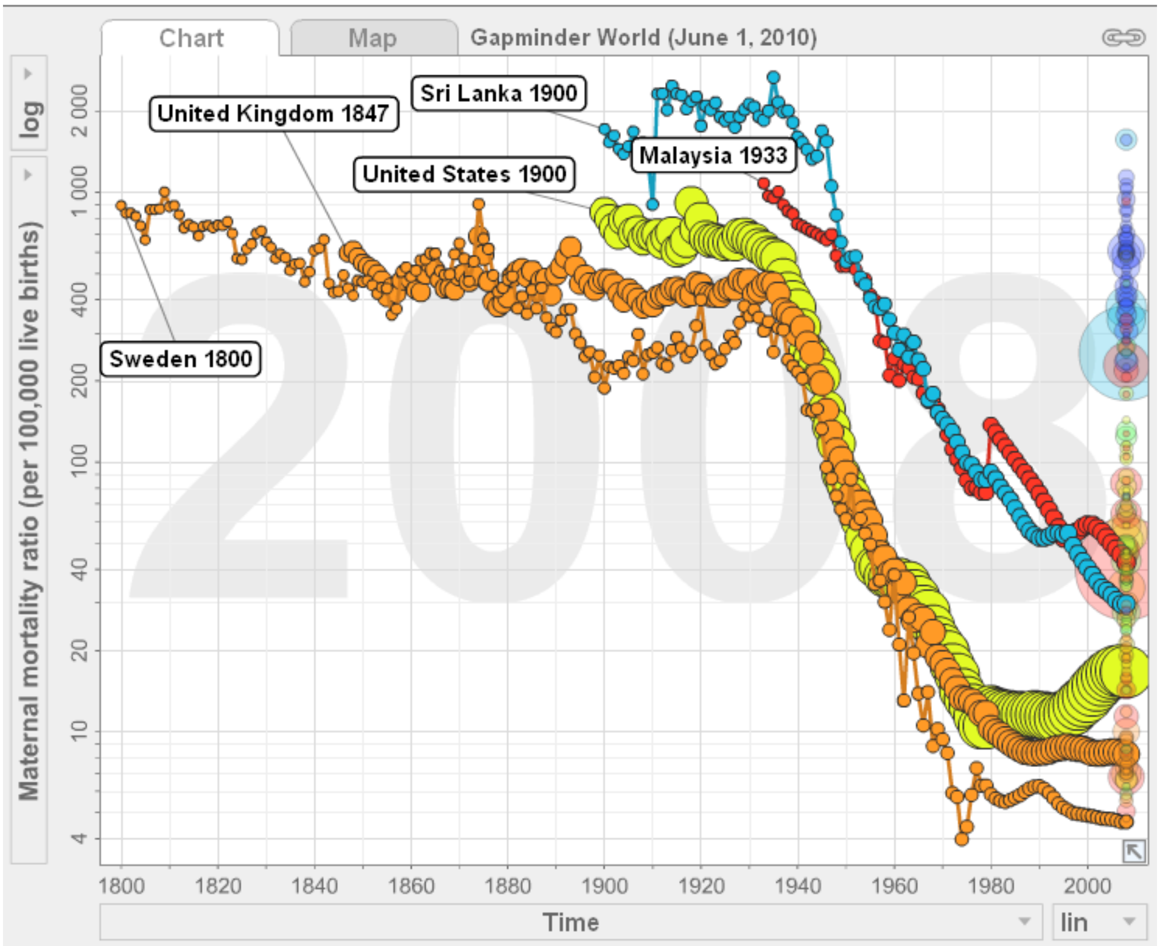


Figure 4: Historical decline in MMR in selected countries

5.2 *Overall socio-economic conditions*

Loudon argues that maternal mortality has been remarkably insensitive to socio-economic factors, but sensitive to standards of obstetric care. If maternal deaths would be sensitive to improvements in the overall living conditions, he argues, the MMR should have declined similarly to infant mortality [34].

Moreover, the decline in maternal mortality only started in the United Kingdom, Australia, New Zealand and the United States only in the 1930s. Declines earlier might have been partly masked by improvements in completeness and revisions of classification as well as the increase in maternal deaths due to abortions. Still, if maternal mortality would have been more sensitive to the overall socio-economic conditions one would have expected a continuous decline starting earlier in the 1890s (see Fig 5).

Further evidence that socio-economic factors did not played a major role in improving maternal mortality comes from the famous 'Rochdale experiment' in Britain the early 1930s. By improving the standard of obstetric care without altering living conditions the rate of maternal mortality fell from 900 per 100,000 in the years before 1930 to around 300, per 100000 live births in 1935 [35].

The display of the historical decline in the MMR of Sweden, the United Kingdome, the United States and Sri Lanka also support the hypothesis that the organisation of delivery care has a major impact. The decline of the MMR in Sweden and particularly Sri Lanka started at a lower GDP than in the United States or the United Kingdome.

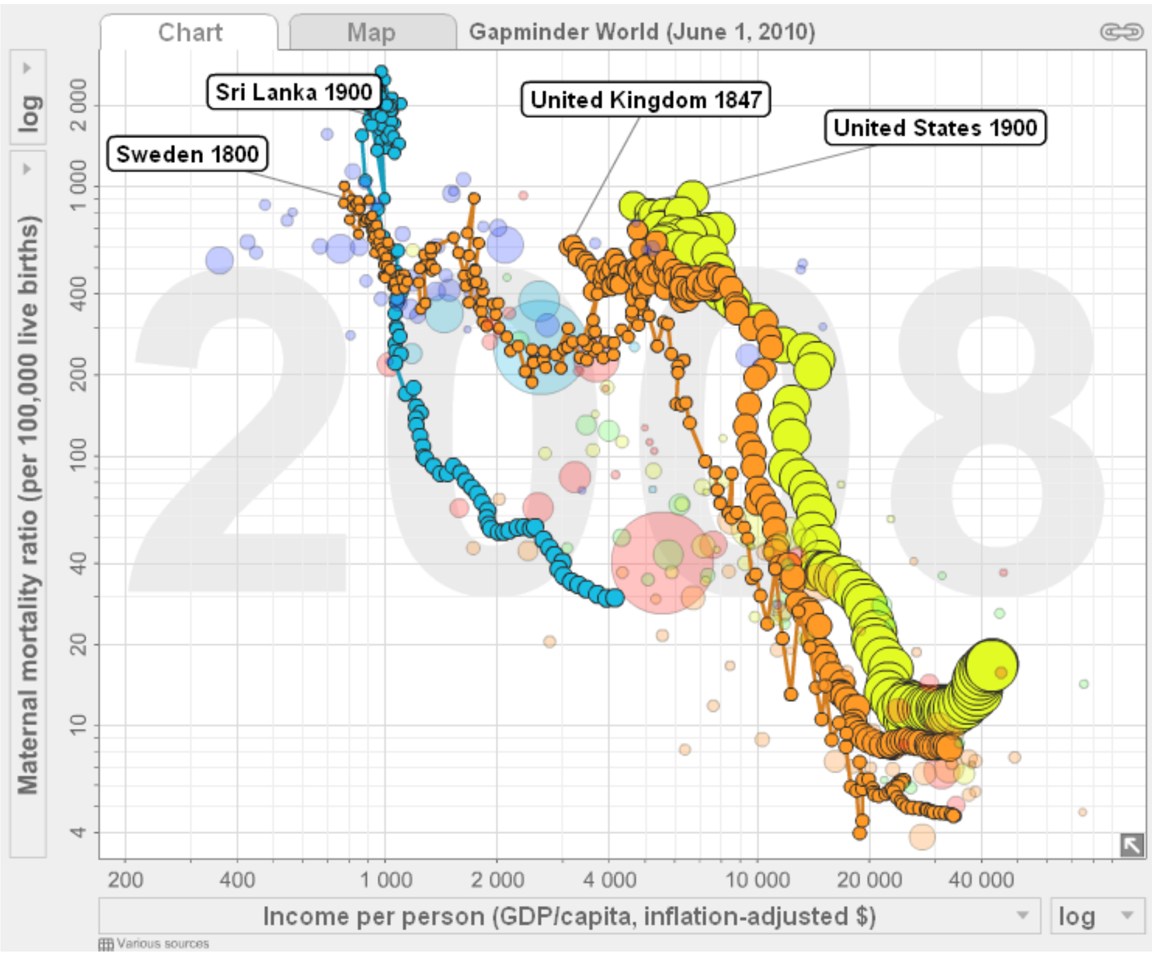


Figure 5: The association between the decline in MMR throughout the nineteenths and twentieth century and GDP per capita

At an individual level higher social class did not have a protective influence on maternal mortality either. An examination of maternal mortality rates by social class using data from England and Wales from 1930-1932 indicated an even small increase in puerperal sepsis, puerperal haemorrhage and toxaemia in higher social class [36].

Today, GDP is a strong predictor of maternal mortality at national level [1, 37]. Also at individual level, higher socio-economic status or higher income is inversely associated with maternal mortality [38-42].
However, co-linearity of the indicator GDP and access to skilled attendance and emergency obstetric care exists. As household wealth is strongly associated with skilled attendance and access to emergency obstetric care [43] it can be argued, that the effect of income and GDP on maternal mortality, which is seen today is affected to a large extent through facilitating access to high quality maternal care which was not available to the rich or poor in the 1930s..

5.3 *Access to skilled attendance at birth and to emergency obstetric care*

Many publications in the recent years have underlined the importance of skilled attendance at birth and it is even used as one indicator to measure progress in maternal heath.

Historically, there was a difference in the MMR between countries early to introduce skilled birth attendance at a national scale (Sweden, Denmark, The Netherlands) and the United States as mentioned above [9, 44]. The strategy of skilled attendance in the Nordic countries and The Netherlands was supported by licensing of midwifery and high quality obstetric education. Traditional midwifery was already banned in 1777 in Sweden, although traditional midwives continued to practise until the end of the 1800s. The midwifes in Sweden had a comprehensive training including vaginal operative procedures, neonatal resuscitation and their performance was closely monitored [33]. It has been estimated that the strategy of midwifery as introduced in Sweden was able to reduce maternal mortality by almost 50% for non-septic deaths between 1861 and 1900 [45].
In addition, community midwives in Sweden were trained in aseptic techniques as early as the late 1870s and the practise was enforced by law since 1881. This is estimated to have prevented around 63% of septic deaths in home deliveries during the late 19th century [45].

In contrast maternal mortality was high during the same time period in the United States. Loudon argues that the lack of standardized midwifery and the over reliance on doctors not well trained in obstetrics at that time might be responsible for the high maternal death rates [34]. Also the high rates of inference in the normal course of delivery, here particularly forceps delivery, has been accused to have caused many unnecessary maternal deaths. DeLee a very influential obstetrician as that time described the ‘prophylactic forceps operation’ including pain relief, delivery by forceps, and manual removal of placenta as preferable to prevent maternal mortality and morbidity as well as to improve fetal outcome [46, 47].
The high prevalence of intervention that time was not only seen in individual practitioners but also at community level. For example, in the State of Iowa, 12% of all deliveries were operative deliveries, and even 23% in hospitals in bigger communities (Loudon 1992, p 359)[9].

A medium position in relation to midwifery and interference with normal delivery as well as in relation to maternal mortality was seen in England & Wales and Scotland. Maternal care in Britain in the 19th century was not well instituted; there was little formal training for

midwives and no regulatory framework. Practitioners, like in the United States played a major role in home deliveries, although they did far less operative deliveries than in the States [9].

The well established and supported midwifery system in the Scandinavian and some Middle European countries has been discussed as the major reason for the differences in maternal mortality throughout the 1800s and beginning of 1900s [9, 44]. Also, the rapid decline in Sri Lanka and Malaysia from 1960s to 1990s has to a large extends been attributed to the introduction of midwifery care, which was well linked to the formal health system [31]. Similarly, the decline in maternal mortality observed in Matlab, Bangladesh between 1976 and 2005 has been explained by improved access to skilled attendance and emergency obstetric care, and also to improved abortion care [38].

5.4 *Maternal mortality and fertility decline*

Changes in overall fertility and the fertility pattern in relation to age group affect maternal mortality in two ways. Firstly if fertility declines and fewer children are born to each mother, the overall risk in women of reproductive age to die from pregnancy and childbirth is reduced, as there are less exposed to this risk. The reduction of risk is best expressed in the life time risk of dying and the MM-rate which measures the risk of deaths due to pregnancy and childbirth in this age group (see 1.1).

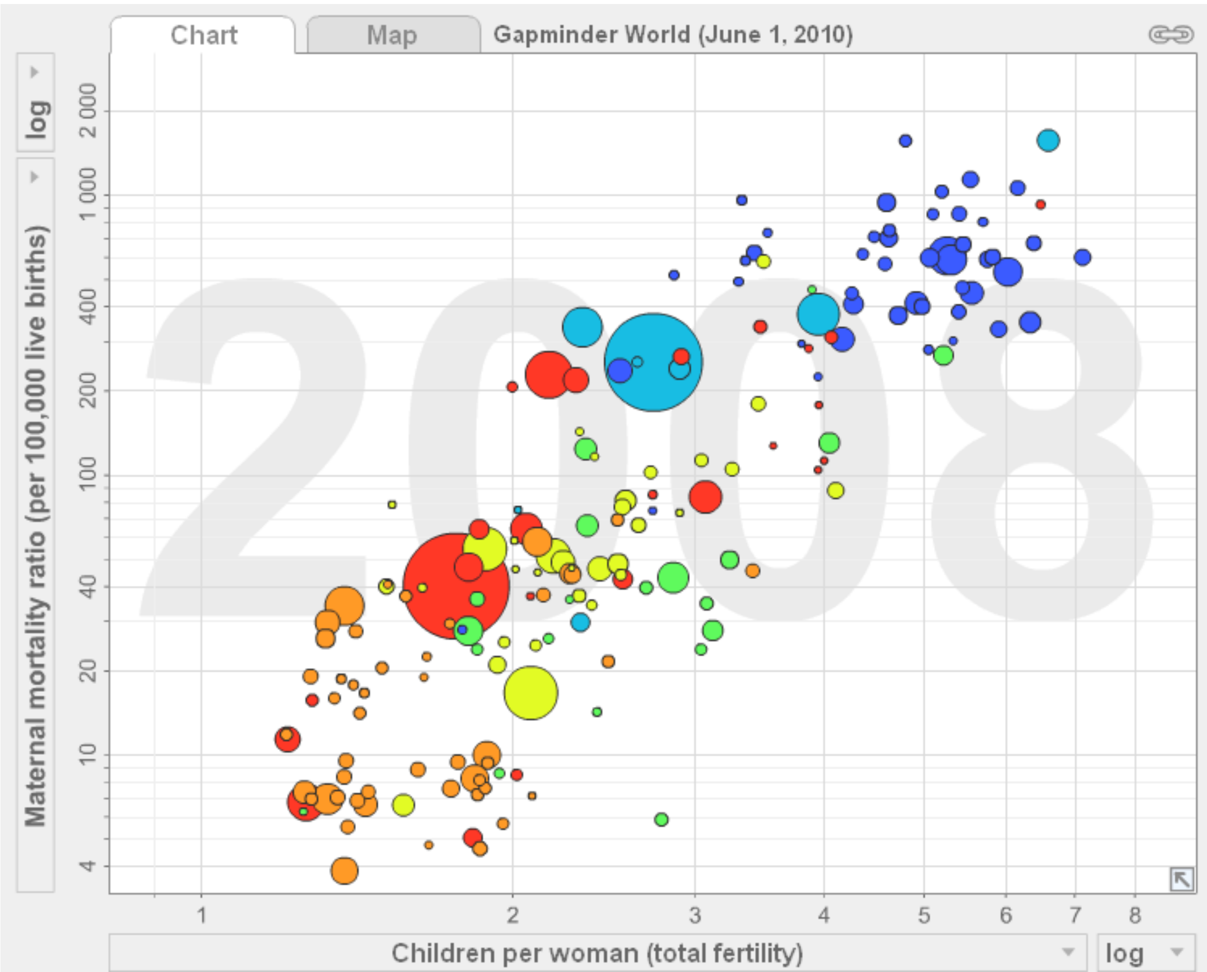


Figure 6: The association between the MMR and the Total Fertility Rate

In addition there is a difference in mortality risk in relation to age and parity. The risk is higher in young and old age, and the first pregnancy and higher parity. In 1984, Trussell and Pebley [48] reported a potential reduction of 24.6% of the MMR by eliminating births outside the safest period between ages 20 to 39 and above parity 5. Fortney [49] in 1987 recalculated the change of the MMR based on the same figures from Bangladesh [50] and estimated a similar reduction in maternal mortality [51]. Marston and Cleland 2004 [52] also reported a theoretical reduction of maternal deaths in high risk groups, but argued for a cautious interpretation of the findings as the estimations are only based on a few studies, mainly from Asia, with small numbers of maternal deaths (see Fig 6).

It is against this background, that family planning services have been much promoted to reduce maternal mortality, the life time risk of dying, MM-rate but also to reduce the MMR. Moreover, family planning is likely to prevent unwanted pregnancies and therewith the need for abortion services and will reduce the number of unsafe abortion where abortion is illegal.

Thus family planning is seen as an important part of a broad multi-pronged strategy including skilled attendance at birth, emergency obstetric care and reproductive health interventions [53]. Hogan et al. [1] also emphasised the influence of changes in general fertility on the reduction of maternal mortality worldwide.

However, how much of the historical decline in the MMR in Europe, the United States or Australia and New Zealand can be attributed to changes in fertility has not been well studied, partly because of lack of data. Högberg calculated that changes in maternal age at birth contributed to almost 3% of the reduction in mortality over the period 1781-1911 and to 5% between 1911 and 1980 [54]. Berry calculated for the United States that between the beginning of 1900s and 1970 up to 18% of reduction of maternal mortality was due to the shifting age and parity distribution [55].
Also, in the two country analyses of Malaysia and Sri Lanka, fertility changes have been discussed as having contributed to the decline of maternal mortality [31]. Still, Seneviratne and Rajapaksa argue, that in Sri Lanka the fertility decline did only have an effect on maternal mortality after the mid-1950s as up to this time fertility remained on a high level [56].

5.5 *Abortion and abortion related deaths*

Deaths due to abortions started to be a major cause of maternal death since the end of the nineteenth century and in the first half of the 20th century. France is said to have been the first country with a major problem of deaths due to abortion in the late 1800s [9]. Very high maternal mortality due to abortion has been described from several countries during the inter-war period. The number of abortions in Germany per 100 live births rose there from 3 in the period 1902-04 to 16 in 1929 (cited in Loudon, p 116 [9]).

In Sweden, it was estimated that in the period 1931-1980 approximately 20% of the overall maternal mortality was due to abortion, a large part due to septic complications [57]. From 1931-1935 the proportion might have been even as high as 30%. A similar proportion has also been reported in England and Wales in the 1930s and 1940s (see Fig 7).

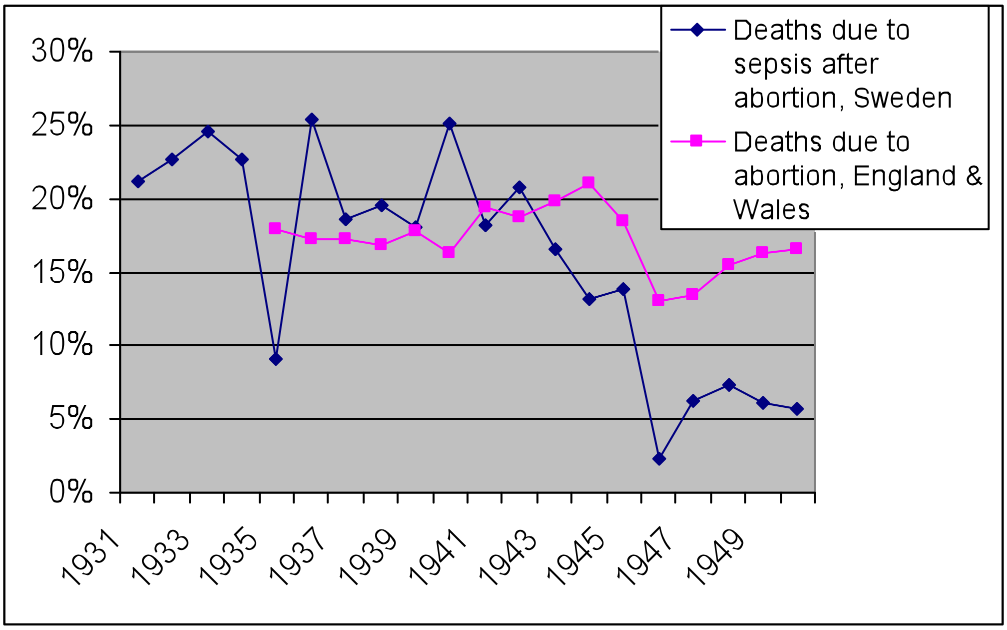


Figure 7: Proportion of deaths due to sepsis after abortion (Sweden) and abortion (England & Wales) of all maternal deaths between 1931-1950

Deaths from septic conditions after abortion declined rapidly after antibiotics became more widely available in the 1940s.

A very interesting example of how much abortion and abortion related policies can impact on maternal mortality is the example of Romania during the time of the pronatalist policies of the Ceaucescu regime which banned access to contraception and legal abortion. The abortion related-related MMR climbed up to 150 per 100,000 live births whereas the MMR due to non-abortion related causes was only 20 per 100,000. [58]. The liberalisation of abortion in 1989 led to a sharp decline in the MMR (see Fig 8).

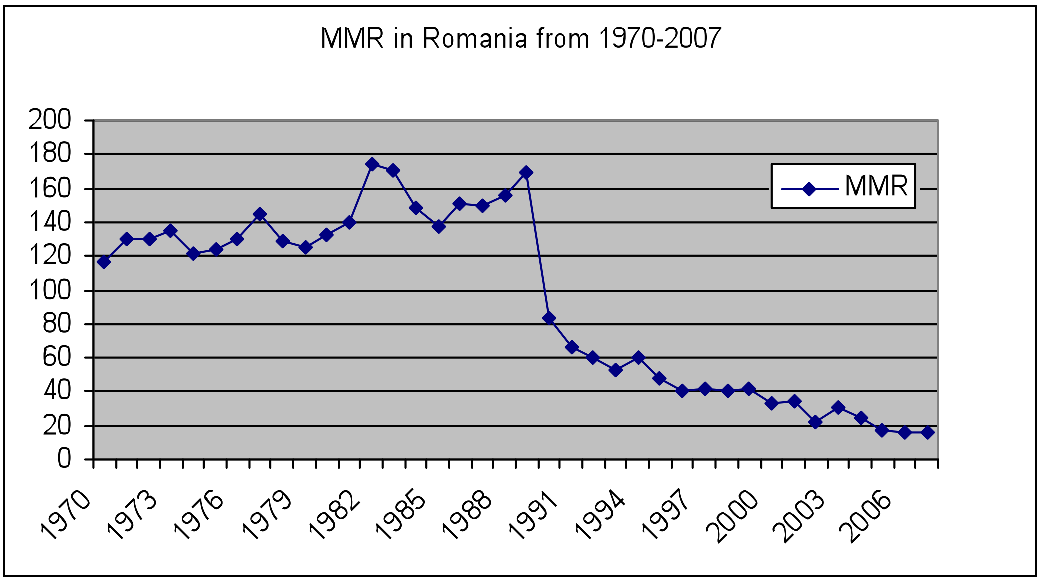
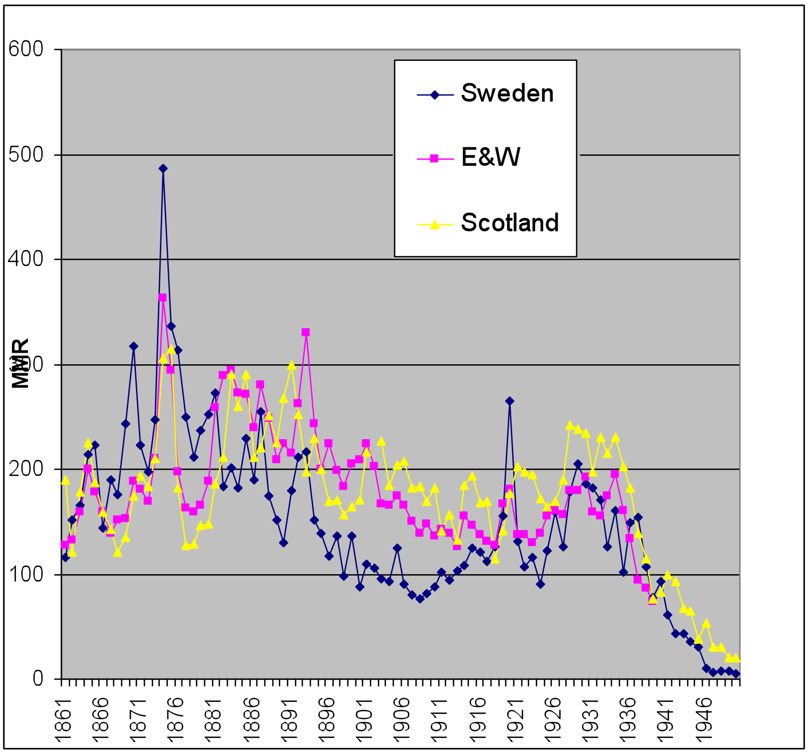


Figure 8: Maternal mortality in Romania between 1970 and 2007
Data From: WHO Europe health database http://data.euro.who.int/hfadb/

5.6 *Puerperal sepsis and the epidemics of streptococcus in the hospitals*

Puerperal sepsis has been a major cause of maternal mortality in many countries up to the 1940s when antibiotics become more widely available. Throughout the 1800s Sweden, England & Wales as well as Scotland had a MMR attributable to puerperal sepsis of about 200 deaths per 100,000 live births. One characteristic of the MMR due to sepsis was its great fluctuation with steep increases due to major epidemics as for example seen in 1874 in England & Wales where 52% of all maternal deaths were due to puerperal sepsis [34]. Changes in the virulence of streptococcus were probable the most important factors in determining short-term fluctuations in the trend of mortality due to puerperal sepsis before sulfonamides were introduced [34]



In Sweden the deaths due to sepsis started to decline already in 1880s. The training of midwives in antisepsis, which started in the 1880s, probably contributed to the decline (see also 5.2). Similarly deaths to puerperal sepsis in England & Wales declined when measures of antisepsis became widely accepted. The higher rates of sepsis in the inter-war period between 1920 and 1940 might to some extent be due to the higher rates of abortions and therewith septic Complications during this time (see also 5.4).

Figure: MMR due to puerperal sepsis between 1861 and 1900

Puerperal sepsis has been a particular problem in the big maternity hospitals in the eighteenth and nineteenth century. Virtually all bigger hospitals had major outbreaks and mortality rates were extremely high.

In Vienna, at the time when Ignaz Semmelweis studied the causes of puerperal fever, the hospital MMR was as high as 9800 per 100,000 live births in the years 1841-46 (p 67 in Loudon, 1992 [9]).

Three famous physicians, Gordon, Holmes and Semmelweis in the early 1800s suggested that doctors were transmitting the disease and that better hygiene would prevent the so-called ‘childbed fever’. Semmelweiss showed that with measures of antisepsis (using chlorinated lime for hand disinfection) maternal mortality dropped from an average of 9800 per 100,000 in the years 1841-1846 to 1270 in the first maternity clinic in 1948 [9].

However, the work of Semmelweiss and the other famous physicians was neglected in large parts of Europe as their thinking was not in line with prevailing explanations of causes of disease at that time.

Thus, although deaths due to sepsis started to decline in the beginning of the 1900s, a steep decline of maternal deaths due to sepsis were only seen after 1930, probably first due to reduced virulence of streptococcus and later due to sulfonamides, which became available after 1937.

6 Conclusion

Although the measurement of maternal mortality has its problems and limitations, historical data are available from several countries enabling comparison between countries and throughout time. Midwifery based organisation of delivery care is suggested as the most important factor of the early decline of maternal mortality in Sweden, Denmark, and The Netherlands. Also, the rapid decline in Malaysia and Sri Lanka between the 1950s and 1990s is attributed to the expansion of skilled attendants at delivery together with a decline in fertility. However, regardless of the historical organisation of delivery care, improved assess to obstetrical and general hospital care in all high income countries together with the availability of new drugs such as oxytocin, sulphonamides & penicillin, as well as improved blood transfusion led to the tremendous decline in maternal mortality between 1940 and 1969 from 400 to 30 deaths per 100,000 live births in 30 years.

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http://www.maternal-mortality-measurement.org/index.html

http://www.immpact-international.org/