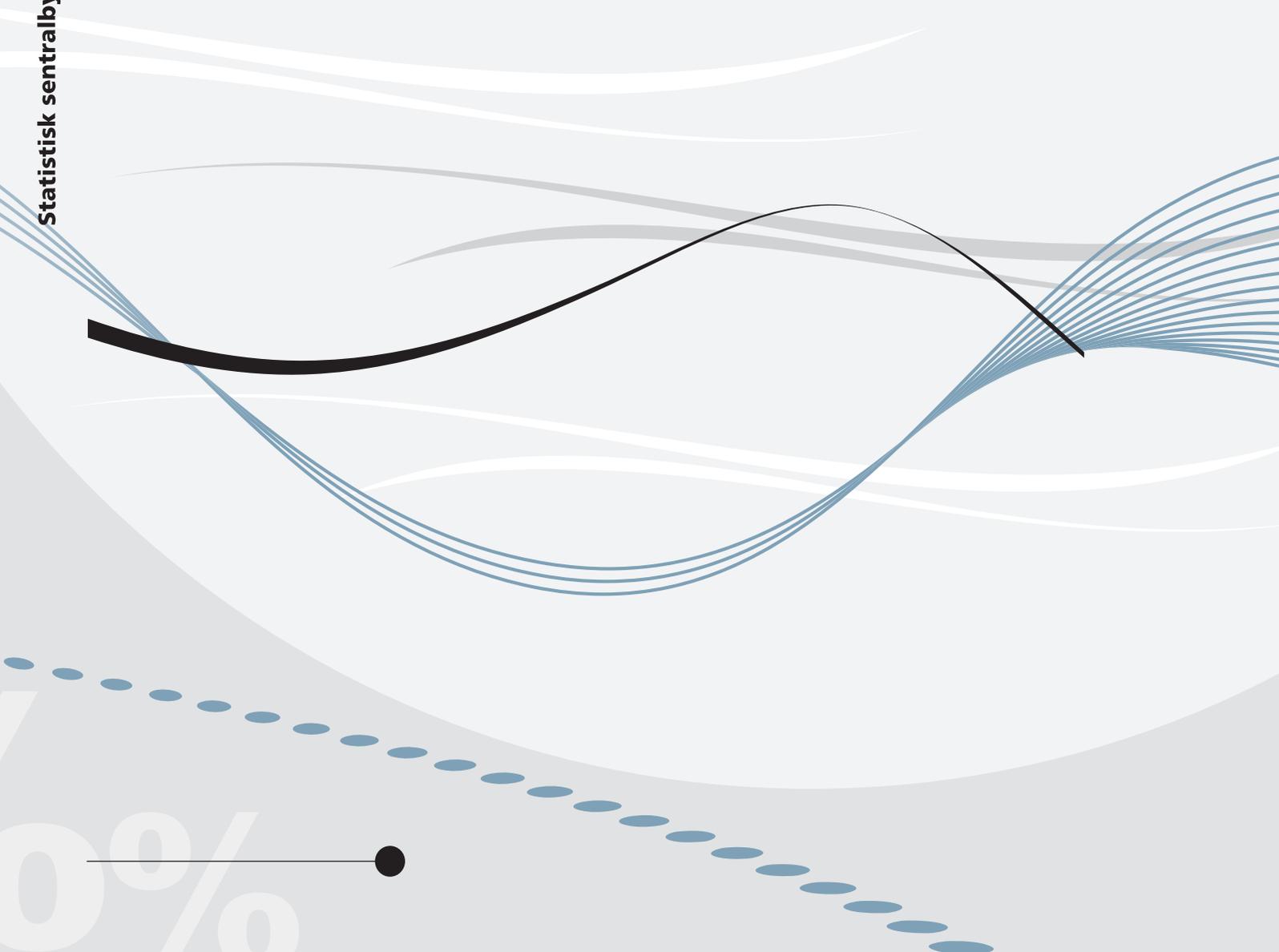


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Adjusting maternal mortality data for international comparisons

The case of vital registration systems



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Abstract:

Register data on maternal deaths is adjusted in international reports to account for underreporting; however, there has been controversy around these adjustments. The objective of this article is to review the adjustment factors applied to maternal mortality register data.

A literature review provided 72 studies on underreporting showing differences in the definition of maternal mortality. This has not previously been taken into account when calculating average adjustment factors. Our analysis showed that including psychiatric disease and maternal deaths occurring 42 days post-partum had significant effects on the adjustment factor. When using the strict WHO definition of maternal mortality, a median adjustment factor of 1.5 was calculated which is identical to the one used by the WHO.

Guidelines on inclusion criteria for maternal deaths need to be clarified in order for figures to be internationally comparable.

Keywords: Maternal mortality ratio (MMR), misclassification, underreporting, incompleteness, World Health Organisation (WHO)

JEL classification: I18

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Sammendrag

Å redusere mødredødeligheten er et av målene i FNs tusenårsmål, men det er lite gode data tilgjengelig. Registerdata på mødredødelighet er ofte underrapportert og blir derfor justert for å få internasjonalt sammenliknbare mødredødelighetsestimater. Målet med denne artikkelen er å gå gjennom justeringsfaktorene som brukes på registerdata på mødredødelighet for å finne ut om de er godt nok begrunnet.

Vi gjennomførte systematisk søk etter studier om underrapportering av mødredødelighet og fant 72 ulike studier som inneholdt informasjon om justeringsfaktorer. En viktig observasjon, som man etter vår viten hittil ikke har tatt høyde for, er at det er stor variasjon i definisjon av mødredødelighet og dermed hvilke dødsfall som blir inkludert i studier om underrapportering. Vår analyse viste videre at inkludering av psykiatriske lidelser og mødredødsfall mer enn 42 dager etter fødsel hadde signifikant effekt på justeringsfaktoren. Brukte vi WHO definisjonen på mødredødelighet, fant vi en gjennomsnittlig justeringsfaktor på 1.5. Dette er same faktor som WHO bruker i sine mødredødelighetsberegninger.

Vår litteraturstudie viser at det er behov for generelle retningslinjer for hva som skal inkluderes når man definerer mødredødelighet i studier om underrapportering for at dataene skal bli internasjonalt sammenliknbare.

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1. Introduction

The fifth millennium development goal is to improve maternal health. The main indicator to measure it is through the maternal mortality ratio (MMR). Most developed countries register maternal deaths along with other vital statistics. The quality of these reporting systems varies and the inclusion criteria for maternal deaths differ between countries despite being based on the International Classification of Diseases (ICD) and the World Health Organization (WHO) definition.

Over the years, many countries have carried out enquiry studies to evaluate the quality of their maternal mortality civil registers. In almost all cases, the number of maternal deaths in civil registers is lower than that found using other or multiple data sources. This results in an adjustment factor greater than one, by which civil register can be multiplied by to account for underreporting. This paper provides an extensive literature review of enquiry studies on civil register maternal mortality data and searches for additional studies not previously used by international meta-analysis studies.

Additionally, the definition of maternal mortality varies among countries and enquiry studies. This paper investigates differences in the definitions used among enquiry studies for maternal mortality and shows how this impacts on the adjustment factors. Finally, we look at characteristics of the registration system to explain differences among adjustment factors.

1.1. What is the Maternal Mortality Ratio?

The United Nations defines maternal mortality ratio (MMR) as the annual number of female deaths from any cause related to or aggravated by pregnancy or its management (excluding accidental or incidental causes) during pregnancy and childbirth or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy (expressed per 100,000 live births) [1].

When applying this definition in practice, many challenges are encountered. Different approaches to data collection are used in different vital registration systems. The definitions used in different countries are part of each country's health system, a system serving other purposes than reporting maternal mortality. It is not a straight forward task to align the definitions used in all countries, even though the standard for International Classification of Diseases (ICD) facilitates comparability among countries. Further, the quality of registers varies in respect to the varying ability to capture occurrences of maternal deaths.

Different registers define maternal mortality in different ways. The criteria for including/excluding cases can differ due to national practices or the ICD-version they use (ICD-9 and ICD-10 is most widely used, but some countries still use ICD-8 as well). This represents a challenge for comparing figures between countries. A significant change in ICD-10 was the introduction of late maternal deaths which are deaths occurring between 42 days and one year after abortion, miscarriage or delivery caused or aggravated by pregnancy or its management. The inclusion/exclusion of these deaths is likely to affect the MMR.

Additionally, some vital registration systems include psychiatric disease as an indirect maternal death (a death aggravated by, but not directly caused by, the physiological effects of pregnancy). If psychiatric disease is included in the definition of maternal death, the MMR will be higher than if these are not included.

Under the current UN definition, late maternal deaths and maternal deaths from psychiatric diseases should not be included in the MMR. These examples show the importance of adjusting vital registry data when viewed in an international context. Adjustments should focus on correcting for differences in the definitions used and the different inclusion criteria between countries and through time.

1.2. Adjusting data for MMR

There are two main reasons for adjusting maternal mortality data from civil registers : 1) To adjust for the underreporting of maternal deaths, ie maternal deaths that are misclassified or have incomplete death records (see box below) and 2) to align definitions of maternal mortality between countries and systems. The adjustment factors we deal with in this paper address both of these issues. This is the first investigation we are aware of that investigates how seriously the definition of maternal mortality affects the adjustment factor.

Misclassification: When coding in the civil registration is incorrect. It does not cover maternal deaths that are not registered at all.

Incompleteness: Refers to incomplete death registration. This includes both unidentified individual deaths and the national coverage of the register.

Underreporting: Covers both misclassification and incompleteness.

1.3. Completeness of registers

In the most recent WHO publication of maternal mortality figures [2], countries with civil registers are split into two groups (labelled A and B), depending on the quality of their data. Countries in group A are regarded as having high quality civil registers with reliable maternal mortality data.

For these countries, the WHO uses the register information directly, only applying an adjustment factor before publishing the data.

Countries with registers that are of a lower quality because of low coverage rate of the population or missing data years are put into group B. For these countries, the maternal mortality ratio estimates are based on a statistical model that includes the adjusted registration data. Countries that do not have registers or other good quality data are put in group C.

2. Different practices for calculating adjustment factors

There are different ways of adjusting vital registration data for underreporting and comparability of the maternal mortality ratio (MMR). The general approach is to create a simple factor that can be applied directly to the registration data. How these adjustment factors are calculated and applied varies and is described in the following paragraphs.

The World Health Organisation (WHO) relies on national underreporting studies to adjust the vital registration data on maternal mortality. For countries where one or several studies exist, they use the factor given in these studies directly to adjust the data. For countries without underreporting studies of their own, the WHO applies a value of 1.5 as the adjustment factor [3]. This is the median value from a previous literature review published by WHO [3]. This factor implies that vital registration systems underreport maternal deaths by 50%. An adjustment factor of 1.5 is also supported by a previous WHO study [4] which used the median value of the results from studies of underreporting in France, the United Kingdom and USA.

In previous years, the Institute for Health Metrics (IHME) has published their own international figures on maternal mortality. They also adjusted vital registration data but instead base the factors on the frequency of so called Garbage Codes in each country [5]. Garbage Codes are codes in the ICD-system that are unlikely to be the cause of death, and redistribute them to other codes that can be associated with death. Although the average adjustment factor is 1.4, the ratios vary from 1 to 5 giving large differences among countries. The approach focuses solely on misclassification, but is used as a proxy indicator for other weaknesses in the reporting system.

An alternate review study done in 1999 [6] looks at how maternal deaths were classified in 13 European countries. The study only covers misclassification of deaths which means that unreported deaths are not taken into account. It gives a picture of how heterogeneous the reporting was at this time, even among European countries. By linking different registers, surveys and confidential enquiries to the official data, they found that several deaths had been wrongly classified. The overall correction index they found was 1.14, but there were large variations from country to country.

A new approach for extrapolating adjustment factors for countries or years that are not covered by enquiry studies has recently been described by Chao and Alkema [7]. It is based on a Bayesian hierarchical time series model and takes into account the number of years that the enquiry studies cover. It also provides a way to calculate uncertainty around the adjustment factors. It is a better alternative for estimating an appropriate adjustment factor for countries with good registers but lacking enquiry studies compared to a basic median value from literature reviews. It is not yet used in practice though, and still heavily relies on the quality of the data from enquiry studies.

2.1. Problems with the currently used adjustment factors

Previous literature reviews have identified up to 38 studies on underreporting of maternal mortality. They show that adjustment factors vary greatly between studies and countries. There are many countries where the MMR is based on civil registers (classed in Group A) that do not have enquiry studies listed in previous literature reviews. This paper aims to search for additional underreporting studies which can be used to calculate adjustment factors.

Additionally, adjustment factors currently do not reflect the methods and definitions used in the enquiry studies. This paper will address this in two key definitions. These are 1) the inclusion/exclusion of late maternal deaths (direct and indirect maternal deaths occurring after 42 days but before 1 year) and 2) inclusion/exclusion of psychiatric diseases in maternal deaths. This second point is one of many grey areas of maternal mortality registration which is likely to impact the amount of underreporting. Additional areas are addressed in a qualitative approach and are discussed further in the results.

3. Literature review methods

The aim of this literature review is to identify as many underreporting studies on maternal mortality as possible and to describe and isolate some of the methodology and definition congruencies among these studies. For nationally representative studies, absolute numbers of maternal deaths were extracted and

compared to World Health Organisation (WHO) vital registration data (which we received 01 May, 2013). For Sub-national and sub-population studies, the number of maternal deaths was compared to official numbers given in the enquiry studies.

A central problem with previous underreporting of maternal mortality reviews is that they do not consider any of the methodological differences between the studies and how this affects the adjustment factors. We have chosen to look specifically at the inclusion/exclusion of 1) psychiatric diseases and 2) late maternal deaths. These figures were extracted from the studies where possible.

3.1. Search strategy

Enquiry studies on underreporting of maternal mortality were searched in the academic and general public domains. We have chosen to include reports that are not peer-reviewed because of the merit of unpublished national enquiry studies. Studies were identified in the following ways:

- A number of studies were sent to us directly from WHO. These were generally publically available, published studies that had previously been sent to the WHO from contact people in the individual countries.
- Additional studies were identified from previous WHO reports
- Additional studies were identified from a previous review paper published in Lancet. [8]
- Additional studies were identified from the reference lists of other enquiry studies
- The search engine Google Scholar was used to identify further additional enquiry studies. The keywords: *maternal mortality*, *misclassification* and *underreporting* were used. The search was carried out for several languages including: English, German, Portuguese, Russian and Spanish.
- Studies that only included data prior to 1985 were excluded.

3.2. Meta-analyses

Paired t-tests were used to compare adjustment factors including and excluding psychiatric disorders and including and excluding late maternal deaths. A Bonferroni adjustment was made for multiple comparisons.

A regression model was used to investigate trends of underreporting through time and register completeness in a country. Studies not containing data for maternal mortality excluding psychiatric disorders and late maternal deaths (WHO definition of a maternal death) were first imputed if an adjustment factor was available using another criterion. The imputation method was based on the mean percentage difference between the criteria groups.

Studies were allocated to the year-groups: 1988-1992, 1993-1997, 1998-2002, 2003-2007, 2008-2012 based on which years were investigated. The midpoint year was used for the groups (1990, 1995, 2000, 2005 and 2010) and reflects the methods used for maternal mortality registry data by WHO [9]. If a study covered more than one of these periods it was allocated to multiple year-groups and weighted accordingly so that each study had a total weight equal to 1.

The country's civil registration in terms of availability, completeness and quality of information produced, was classified using the same system used in the previous WHO MMR estimates [2]. Countries with maternal mortality registration data characterized as complete with good attribution of cause of death are labelled with an A and those lacking completeness but with some quality data available are classified as B.

The following model was used for the adjustment factor (AF) in study i :

$$AF_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \varepsilon_i$$

Where x_{1i} is the allocated year for study i , x_{2i} is the dummy variable for register completeness for study i using countries with classification A as the base level, and ε_i is the error term associated with study i . An additional model classifying year as a factor was used to investigate a non-linear time trend.

We have chosen to treat studies performed within the same country as independent from one another. This may be an issue as they could be more correlated than studies from different countries. However, many of the studies within the same country had different organisations undertaking them and were using different data collection methods (e.g. Mexico). Hence, we suggest that they can be treated as independent. Future meta-analysis studies may consider this aspect further.

All analyses were run in R version 3.0.0 [10] using the functions *lm*, *t.test* and *p.adjust* from the base package.

4. Literature review results

In total, 72 studies were identified as relevant for this literature review where adjustment factors were able to be calculated for maternal mortality underreporting. Below we first show results for the two areas we have chosen to focus on; inclusion/exclusion of psychiatric diseases and late maternal deaths. Other factors that may affect the results are mentioned briefly afterwards.

4.1. Psychiatric disease

The inclusion of maternal deaths due to psychiatric diseases varies between countries and studies. This is not a significant issue if the proportion of these deaths is small, however studies indicated that this may not be the case. For example, 3 of the 9 maternal deaths in New Zealand in 2008 were maternal suicides (33 percent) [11] and in the UK, 10% of obstetric deaths were from psychiatric causes between 2006-2008 [12].

Of the 72 studies investigated, only 19 featured data including and excluding psychiatric diseases for comparison. When psychiatric disease is included in maternal mortality, underreporting in the civil registry system is on average 10 percent higher than if it is excluded and was significant ($p < 0.01$) (based on maternal deaths before 42 days postpartum).

Table 1. Nineteen studies with maternal mortality underreporting rates including and excluding psychiatric disease. Numbers are calculated adjustment factors

Country	Year/Period	Reference	Including Psychiatric	Excluding Psychiatric
Argentina	2002	[13]	1.54	1.15
Australia	1994-1996	[14]	1.27	1.23
Australia	1997-1999	[15]	2.07	1.80
Australia	2000-2002	[16]	2.21	1.97
Denmark	2002-2006	[17]	3.63	3.25
Finland	1987-1994	[18]	1.26	1.03
Georgia	2006	[19]	1.91	1.82
Mexico	2001- 2002	[20]	1.22	1.16
New Zealand	2006	[21]	1.56	1.11
New Zealand	2007	[22]	0.85	0.85
New Zealand	2008	[11]	1.71	1.29
Singapore	1990-1999	[23]	2.17	2.04
Sweden	1988-2007	[24]	1.68	1.54
Sweden	1997-2005	[25]	1.56	1.50
UK	1994-1996	[12]	1.70	1.64
UK	1997-1999	[12]	1.94	1.82
UK	2000-2002	[26]	1.76	1.66
UK	2003-2005	[27]	1.86	1.74
UK	2006-2008	[12]	1.68	1.60

4.2. Late maternal deaths

The inclusion of late maternal deaths (from 43 days to 1 year postpartum) also effects the level of the adjustment factor and is inconsistently reported in registers and enquiry studies on maternal mortality. This may have substantial effect on the adjustment factor as shown in a Danish enquiry study [28] where late deaths made up 44 percent of maternal deaths.

Twenty enquiry studies were identified that contained figures for the inclusion and exclusion of late maternal deaths (excluding psychiatric disease). The mean percentage difference for the adjustment factor came to 14 percent and was significant ($p < 0.01$). This indicates that enquiry studies *including* late maternal deaths will over-report the adjustment factor if the strict definition of maternal mortality is held.

Table 2. Twenty studies with maternal mortality underreporting rates including and excluding late maternal deaths. Numbers are calculated adjustment factors

Country	Year/Period	Reference	Up to 42 days	Up to one year
Argentina	2002	[29]	1.10	1.12
Argentina	2002	[13]	1.15	1.33
Australia	2000-2002	[16]	1.97	2.16
Austria	2000-2006	[30]	1.47	1.74
Brazil	1985-1991	[31]	1.54	1.59
Brazil	2002	[32]	1.40	1.63
Canada	1988-1992	[33]	1.53	1.61
Denmark	1985-1994	[28]	1.94	3.29
Finland	1987-1994	[18]	1.03	1.29
Georgia	2006	[19]	1.82	2.73
Mexico	2003	[34]	0.98	1
Mexico	2008	[35]	0.99	1.01
Slovenia	2003-2005	[36]	2.5	4
Sweden	2003-2006	[37]	3.00	4.00
UK	2000-2002	[26]	1.66	1.86
UK	2003-2005	[27]	1.74	2.14
UK	2006-2008	[12]	1.60	1.71
USA	1995-1997	[38]	1.50	1.64
USA	1999-2005	[39]	1.11	1.28
USA (Maryland)	2001-2008	[40]	1.02	1.02

4.3. Other important factors affecting underreporting

There are many other factors affecting the adjustment factors in these studies. They can be split into two main areas: 1) variables that are associated with the underreporting in the register including the ICD revision of coding, coverage of and inclusion of additional indirect causes the register and issues

surrounding pressure on healthcare staff, and 2) variables associated with the quality of enquiry studies including its coverage, ability to detect abortion related deaths, and age-boundaries investigated. These are summarised using a qualitative approach in the following paragraphs.

The studies we have looked at use different revisions of the *ICD coding* (Although there are different updates of each revision, we have not looked into that). Since the different ICD codes contain different specifications, this also affects the level of underreporting. A Canadian study from 2002 [33] shows that under the ICD-10 definition, data from revision 9 is likely to have higher underreporting than ICD-10, particularly among indirect deaths. ICD-9 does not allow for late maternal deaths to be counted, which potentially are a large proportion of maternal deaths. A 2010 study on maternal missclassification [5] has also shown that the percentage of “garbage codes” found among the classified deaths have been reduced with newer versions of the ICD-codes, at least from ICD-7 to ICD-10.

Pressure/penalties on doctors: In many countries investigations are carried out if a death is reported as maternal. Health personnel therefore have an incentive either not to report the death as maternal at all or to report ICD codes that indicate that the death was unavoidable. In Kazakhstan a Confidential Enquiry [41] showed that many deaths reported in the register had been misclassified or not properly reported. The study indicates that the rate of underreporting may be higher when health personnel are afraid to report correctly.

Some of the studies are from *countries where registers do not meet the WHO quality criteria*. In these countries the rate of underreporting is likely to be much higher than confidential enquiries or other similar studies can discover. The reason is that many births take place outside the health system and are therefore not registered. In a study from South Africa [42] it is estimated that only 20-66 % of maternal deaths in the rural areas occur in health institutions. Maternal deaths outside health institutions are not covered by the register or confidential enquiries. Other methods will have to be applied to find the true maternal mortality rate in these cases.

There are many causes which are inconsistently included in indirect maternal deaths among countries. Psychiatric diseases are one which we have chosen to focus on in this review. Others *causes which are inconsistently reported include hormone dependent malignancies, diabetes, epilepsy, and domestic abuse/homicide*. The inclusion/exclusion of these will affect the MMR. In the United Kingdom, enquiry studies include a much greater range of indirect maternal causes than the official statistics [27]. The extended criterion is seen to be of national importance to capture a full picture of the maternal mortality

problem. When comparing the enquiry figures with officially reported numbers it is important to recognise these extra cases, and if possible exclude them when calculating adjustment factors.

Many of the enquiry studies *cover only parts of the population*. This is often due to financial constraints related to doing the study. As long as the study is representative for the whole country, this is not a problem, but often either only the most developed or least developed parts of the country are considered; central regions only or remote areas only, and in some cases only high level health institutions, not including community health care [42, 43].

A study from Finland [18] where death records were linked to the countries abortion registry showed that a high proportion of *deaths relating to abortions* were not registered as maternal deaths. This shows that maternal deaths relating to abortions are a contributor to underreporting. In many countries, abortion records do not exist making it difficult to identify additional deaths which have resulted from abortions; especially true for RAMOS and confidential enquiries using registry linkage with birth records. This is perhaps of special importance in countries where abortion is illegal. An enquiry study from Mexico used verbal autopsy methods to identify abortion related cases not previously reported [20]. It identified 5 maternal deaths relating to abortions, none of which were reported officially. In most cases among Group A countries (including the Mexico example), this will be a case of misclassification rather than a missing death record (incomplete).

Several countries have reported an increased risk of maternal mortality among certain *minority groups*, compared to other residents [12]. In addition, deaths among minorities are more often not registered as maternal deaths, than among other groups as shown in a Swedish study [37]. In addition, while the common *age inclusion* is 15-49 years, some studies include women down to the age of 10, while others only include women up to 45 years. Studies have shown [44] that the maternal mortality is higher among women of high age. The evidence is not as clear for young mothers, but one should be aware that the age limit used in the different studies may influence the adjustment factor.

In general, the national enquiry studies ability to find additional maternal deaths varies greatly. This is due to the infrastructure of the reporting system, access to register data, resources available for the enquiry study, follow-up etc. These methodological differences do not directly affect the underreporting of maternal mortality, but our ability to detect it. This makes comparisons of studies with different methodologies difficult and not always appropriate, however, we do not currently have methods to fully take into consideration all these factors.

4.4. Meta-analysis of underreporting studies

A total of 71 studies were used in the meta-analysis. The one Swedish study [37] with a snowball design was excluded due to the severe lack of representativity. Imputation methods were applied to 8 of the studies which did not have adjustment factors excluding psychiatric disorders and late maternal deaths. Studies are shown and referenced in table 3.

The regression models showed no significant effects for year or completeness of registry (Group A or Group B classification, see section 1.3 for more details) ($p > 0.05$ for all). The model had a better fit (lower AIC score) when the variable: *year* was numeric, however, this did not effect the outcome. Output is shown in appendix 1.

Adjustment factors were reasonably symmetrically distributed but contained a couple of high outliers. Therefore we believe that the median values are best used to represent the overall adjustment factor average. The overall median adjustment factor value came to 1.5. To address issues surrounding sub-national and sub-population study coverage, studies which were not nationally representative were removed for comparison (see table 3 studies indicated with a *). This left a total of 40 studies with good national coverage. The median value for these studies was also 1.5.

Table 3. Adjustment factors excluding late maternal deaths and psychiatric disease for 71 studies used in the analysis.

Country	Year/Period	Reference	Adjustment factor
Argentina *	2002	[29]	1.10
Argentina *	2002	[13]	1.15
Argentina *	2008	[45]	(2.66)
Australia	1994-1996	[14]	1.23
Australia	1997-1999	[15]	1.80
Australia	2000-2002	[16]	1.97
Austria	1980-1998	[46]	1.61
Austria	2000-2006	[30]	1.47
Brazil *	1985-1991	[31]	1.54
Brazil *	1991-2005	[47]	1.70
Brazil *	1992-1994	[48]	1.67
Brazil *	1997-2005	[49]	(1.34)
Brazil *	1999-2006	[50]	2.00
Brazil *	2002	[32]	1.40
Canada	1988-1992	[33]	1.53
Canada *	1997-2000	[51]	1.52
China (Taiwan) *	1984-1987	[52]	1.58
Denmark	1985-1994	[28]	1.94
Denmark	2002-2006	[17]	3.25
El Salvador *	2005-2006	[53]	1.41
Finland	1987-1994	[18]	1.03
France	1988-1989	[54]	2.25

France	1999	[55]	1.13
France	2001-2006	[56]	1.39
Georgia	2006	[19]	1.82
Germany (Bavaria) *	1983-2000	[57]	1.02
Ghana *	2000	[58]	2.35
Ghana *	2002	[59]	1.77
Guatemala	1989	[60]	2.57
Guatemala	2000	[61]	1.88
Guatemala	2007	[62]	1.73
Italy *	2000-2007	[63]	(2.41)
Jamaica	1998-2003	[64]	3.15
Japan	2005	[65]	(1.07)
Mexico *	1995	[66]	1.29
Mexico *	1997-2001	[67]	1.40
Mexico *	2001	[43]	2.73
Mexico *	2001-2002	[20]	1.16
Mexico	2003	[34]	0.98
Mexico	2008	[35]	0.99
Morocco	2009	[68]	1.06
Netherlands	1983-1992	[69]	(1.16)
Netherlands	1993-2005	[70]	(1.29)
New Zealand	2006	[21]	1.11
New Zealand	2007	[22]	0.85
New Zealand	2008	[11]	1.29
Singapore	1990-1999	[23]	2.04
Slovenia	2003-2005	[36]	2.5
South Africa *	1998-2003	[71]	1.01
South Africa *	1999-2001	[42]	1.05
South Africa *	2002-2004	[72]	1.12
South Africa *	2005-2007	[42]	0.86
Surinam *	1981-1990	[73]	(1.31)
Sweden	1988-2007	[24]	1.54
Sweden	1997-2005	[25]	1.50
Switzerland *	1995-2004	[74]	1.25
Tanzania *	1995-1996	[75]	(2.25)
UK	1988-1990	[12]	1.39
UK	1991-1993	[12]	1.52
UK	1994-1996	[12]	1.64
UK	1997-1999	[12]	1.82
UK	2000-2002	[26]	1.66
UK	2003-2005	[27]	1.74
UK	2006-2008	[12]	1.60
USA (Michigan)*	1986-1995	[76]	2.44
USA	1991-1997	[77]	1.45
USA (Maryland)*	1993-2000	[78]	1.61
USA	1995-1997	[38]	1.50
USA (New York)*	1997	[79]	1.88
USA	1999-2005	[39]	1.11
USA (Maryland)*	2001-2008	[40]	1.02

* indicates a sub-national or sub-population study

() Adjustment factors in brackets indicate that the values have been imputed based on adjustment factors with alternative criterion.

5. Discussion

5.1. Inclusion criteria for maternal mortality

According to the current ICD definitions, maternal deaths from psychiatric disease are not to be counted as maternal deaths. Our literature review indicated that the adjustment factor is on average 10% higher if psychiatric disease is included. If these deaths will not be counted as maternal in the forthcoming version of the ICD coding (ICD-11), only studies of underreporting where it is possible to exclude these cases should be included when calculating the adjustment factor.

Additionally the treatment of late maternal deaths needs to be clearly defined. While the WHO definition of maternal mortality [1] does not include late maternal deaths, it is part of the maternal mortality ICD-10 coding (classified as O96 and O97) and therefore is generally included in official figures. There is a general consensus in the literature that late maternal deaths are important to include in the maternal mortality figures mainly because improved medical techniques allow women to survive longer with serious childbirth complications that may still die of related causes after the 42 day period. Additionally underreporting among late deaths may be higher because of the increased proportion of indirect maternal deaths, which are generally more difficult to classify. Finally available data does not always distinguish between deaths occurring before and after 42 days and it may be easier to use a 1-year definition. Our review showed on average a 14 percent increase in the adjustment factor when late deaths were included (see chapter 4.2 and table 2). A change in the definition of maternal deaths ought to be made to align with the general consensus of including late maternal deaths.

Furthermore, there are many causes which are inconsistently included in indirect maternal deaths, like hormone dependent malignancies, diabetes, epilepsy, and domestic abuse/homicide. In the United Kingdom, enquiry studies include a much greater range of indirect maternal causes than the official statistics [27]. Similar exercises ought to be undertaken in other countries.

5.2. Time trends in adjustment factors

In countries with fully functioning registration systems, improvements over time would lead to increase in the accuracy of information. This should result in lower adjustment factors in more recent years due to better detection of the maternal deaths. However, we have not found any strong evidence from our meta-analysis to support this (see appendix 1 for model output). We believe this is not because of a lack of improvement in the registration systems but perhaps an indication of

improvements in detection of underreporting within enquiry studies. An example is the confidential enquiry studies from the United Kingdom. From these studies we can see that the rate of underreporting appears to be quite stable, with smaller variations, through time. It is likely that underreporting in the civil registry system is decreasing, however improvements in detecting new cases in the enquiry studies is overshadowing this [12, 26, 27].

Additionally, the studies investigated are very different from one another in their methodology and there is perhaps too much extra noise to detect any underlying time trends. Without further additional studies, the current review supports using a model without time.

5.3. Coverage of civil registers

We believe it is important to consider the completeness of the civil registers within the country. Countries with complete civil registries should have the best systems in place to identify all maternal deaths. In theory, this should result in lower adjustment factor. Our results, however, do not strongly support this.

There could be a range of reasons for this, including that countries without complete civil registries may also have problems identifying all maternal deaths in enquiry studies. These countries are likely to have the best register coverage in urban and developed parts of the country. One considerable issue we came across here was that about half of the studies from group B countries covered only maternal deaths that occurred within the health system. It is likely that these studies underestimate the required adjustment factor. Future work could use survey and census information to assess differences in maternal mortality ratios among women that give birth within and outside of the health system. This would provide further insight into maternal mortality outside the health system.

There were 31 studies that covered only part of the country/health system. Taking these out of the calculations did not significantly influence the median adjustment factor.

5.4. Methodological differences among underreporting studies

It is important to note the limitations of this meta-analysis. Most importantly, the methods of the studies included varied greatly, often measuring different aspects of underreporting. Some studies were able to access a wide range of extra data from registers and reports while others were based on a single extra data source. This results in varying levels of underreporting which are not strictly comparable.

Even among underreporting studies with the same general data collection methods, slight differences in their approach are likely to influence their results. For example, it was noted that verbal autopsies with open style interviews gave more complete answers than verbal autopsies based on a questionnaire [43].

The methodology of the study was generally constrained by the infrastructure of the reporting system, access to register data, and the resources available for the enquiry. Current comparisons do not allow for differences in methods and we believe this is a key reason why other factors (eg changes through time) are not detectable. There is simply too much additional noise.

6. Future adjustments

This review has focused on improving the database of enquiry studies and highlighted how definitions of maternal mortality affect what is registered and the level of adjustment needed. To our knowledge that has not been done earlier. We found that several factors need to be in place in order to increase the reliability of the adjustment factor; the knowledge base needs to be expanded by carrying out more studies and guidelines for how to carry out national enquiries should be established. Work on improving the registers should be continued in parallel.

The inclusion/exclusion of late maternal deaths and maternal deaths from psychiatric disease causes highlight the need for clear guidelines on inclusion criteria for reported figures and for the studies on underreporting. We acknowledge that maternal deaths can be very difficult to classify and there is currently no clear consensus around some of the criteria. We hope that some of the issues will be resolved by the Mortality Reference Group and with the development of ICD-11. The mandate of the group is to address the need to clarify mortality coding rules and to recommend new rules and codes to meet the needs of mortality statistics.

Another issue is that certifiers need to complete death certificates properly. Death certificates may need to be revised to ensure they are aligned with international standards.

Additionally, WHO should make it as clear as possible what they require of a study in order to include it in their calculations. It is also important that the studies investigating the maternal mortality registration data are clear on the inclusion/exclusion criteria.

Currently only a few countries have carried out studies to assess the rate of underreporting and even fewer have done so on a regular basis. We have also found several national enquiry studies that address issues of underreporting, but which do not give data from own findings. We encourage all countries that report civil registry data to undertake regular underreporting studies. The studies ought to follow an international standard to ensure comparability and cover maternal deaths occurring within the entire country, occurring both within and outside the healthcare system.

Further analyses of the adjustment factors in countries without complete registers are recommended, including the underreporting of maternal deaths that are not taking place in health care facilities. In addition, studies which compare differences in maternal mortality ratios and reporting of these within and outside of the health system should be carried out. This can be done by using available survey and census information.

There is still the important issue of which adjustment factor to use for countries without studies. Up until now, WHO have used a flat median value of 1.5 for all countries without an enquiry study. In Chao and Alkema [7], a Bayesian hierarchical time series model provides a novel way to calculate adjustment factors for missing study years and for countries missing enquiry studies [7]. It takes into account the number of years that are covered by the enquiry studies and allows the calculation of the uncertainty around the adjustment factors. It is a step in the right direction, however, it still relies on good quality enquiry studies with aligned definitions of maternal mortality. More studies on register quality that include adjustment factors should therefore be carried out in countries, supported by a guideline for how to count and what to include in the measures.

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Appendix 1

Output from model of MMR adjustment factor with year and register coverage as factor variables. Year 2005 includes those studies allocated to both 2005 and 2010 due to the small number of studies in the 2010 group. The reference year is 1990 and reference register coverage level is A.

Parameter	Coefficient	Standard error	p-value
Intercept	1.64	0.12	<.0001
Year			
Year (1995)	-0.04	0.17	0.79
Year (2000)	-0.02	0.15	0.92
Year (2005)	-0.13	0.15	0.40
Register coverage			
ABcountry (B)	0.03	0.12	0.79

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