



A Longitudinal Analysis of Publications on Maternal Mortality

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Abstract

Background: The fifth Millennium Development Goal formulated by the WHO in 2000 aimed to reduce global maternal mortality by 75% in 2015. We studied the extent to which medical research has supported this by studying maternal mortality. We performed a bibliometric analysis of the literature on maternal mortality and of the development of this literature over time.

Methods: We searched for publications on maternal mortality in the Web of Science database in the period 1994–2013. We visualised the subjects of these publications using a term map showing the most significant terms occurring in the titles and abstracts of publications on maternal mortality.

Results: We identified 3794 publications on maternal mortality in Web of Science. The annual number increased from 87 in 1994 to 397 in 2013. The largest number of maternal mortality publications was found in the field of Obstetrics and Gynecology, followed by the Public, Environmental, and Occupational Health field (increase from 1994 until 2013 of 300% and 700%, respectively). In both fields, the number of maternal mortality publications has increased at a much higher rate than the overall number of publications in the field.

Conclusions: In line with the focus of the fifth Millennium Development Goal on reducing maternal mortality, during the past 20 years, there has been a steady increase in the amount of attention paid to maternal mortality in the medical literature. This is largely driven by an increase, mainly in recent years, in public health research on maternal mortality.

Keywords: *maternal mortality, publications, fifth Millennium Development Goal, obstetrics, environmental health.*

Introduction

On 8 September 2000, world leaders of the United Nations General Assembly adopted the Millennium Declaration, which addresses a number of major problems worldwide, such as unequal global health, poverty, and inequities in development, and which establishes a set of goals to be achieved by 2015. One of these goals, the fifth Millennium Development Goal, aimed to reduce maternal mortality by 75% in 2015 (maternal mortality of 130 000 in 2015) compared with the estimated maternal mortality of 523 000 in 1990.¹ In 2013, 289 000 women died, which represents an achieved reduction in maternal death.² However, maternal mortality is still unacceptably high, not reaching the fifth Millennium Development Goal.² In 2013, a woman's life time risk of dying during pregnancy and childbirth is 1 in 38 in developing areas and 1 in 3700 in the developed world, e.g. maternal

mortality is 957 in South Sudan and 2.4 in Iceland per 100 000 live births in 2013.³

An important component to obtain the formulated improvement in adverse maternal outcome is research. Research provides crucial knowledge needed to build a rational health care system. We studied the extent to which research addresses the problem of maternal mortality raised in the fifth Millennium Development Goal. In this paper, we present a bibliometric analysis of the major health issue of maternal mortality. We used an approach to detect and visualise trends and patterns in bibliographical databases to show the main research topics studied in the literature on maternal mortality. In addition, we studied the development in the number of publications on maternal mortality over time.⁴

Methods

Our general approach was to visualise the structure of a medical research field, in our case the field of maternal mortality research, using a term map. A term map

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is a two-dimensional representation of a research field in which strongly related terms are located close to each other and less strongly related terms are located further away from each other. Different areas in a term map correspond with different subfields or research areas. Colours can be used to highlight the different areas in a term map or to indicate differences between areas in the growth in publication output over time.

We first identified relevant publications in the Web of Science (WoS) bibliographic database. To identify publications related to maternal mortality, we selected all publications in the WoS database in the period 1994–2013 that include ‘maternal mortality’ or ‘maternal death’ in their title or abstract. Each publication in the WoS database has a document type, for instance ‘article’, ‘review’, ‘meeting abstract’, ‘letter’, or ‘editorial material’. Because we wanted to focus our analysis on the most significant types of publications, we excluded all publications that are not of the document type ‘article’ or ‘review’. In this way, we ended up with a selection of 3794 publications on which our analysis is based. For each publication, we collected the title, abstract, and publication year.

We also determined for each publication the fields in the WoS database to which the publication belongs. In the WoS database, each publication is assigned to one or more fields based on the journal in which the publication has appeared. For instance, publications in obstetrics and gynecology journals are assigned to the field Obstetrics and Gynecology. Publications in general medical journals, such as the *Lancet* and the *BMJ*, are assigned to a special field called Medicine, General, and Internal. Some publications belong to more than one field. These publications are counted fractionally in each of the fields to which they belong. For instance, a publication belonging to two fields is counted as half a publication in each of the two fields.

In order to check the accuracy of the data collection, one of us (CJMdG) analysed two sets of publications by reading their titles and abstracts. The first set comprised all 87 publications from 1994 that were included in our selection of publications. The second set comprised 100 publications sampled randomly from the 397 publications from 2013 included in our selection. For the first set of publications, it was found that 95% indeed deals with maternal mortality. For the second set of publications, 96% turned out to be about maternal mortality.

The second step is the linguistic analysis of the publications selected in the first step. Using natural language processing techniques, the titles and abstracts of the 3794 publications were parsed. This yielded a list of all noun phrases (i.e., sequences of nouns and adjectives) that occur in these publications. In order to get rid of insignificant noun phrases that occur in only a small number of publications, we removed all noun phrases occurring in fewer than 10 publications. Of the remaining noun phrases, the 1250 noun phrases that seem to be most relevant were selected using a computer algorithm.⁵ This algorithm aims to filter out general noun phrases such as ‘method’, ‘result’, and ‘study’. In the rest of this paper, we refer to the 1250 noun phrases identified by our algorithm as terms.

In the third step, we determined for each pair of terms the number of publications in which the terms co-occurred. Two terms are said to co-occur in a publication if they both occur at least once in the title or abstract of the publication. The larger the number of publications in which two terms co-occur, the stronger the terms can be considered to be related to each other. The term co-occurrence frequencies served as input for the visualisation of similarities (VOS) mapping technique.⁶ This technique was used to determine for each term a location in a two-dimensional space. The VOS mapping technique aims to position strongly related terms close to each other in the two-dimensional space and terms that do not have a strong relation further away from each other. A clustering technique⁷ was used to assign each term to a cluster. Terms that are assigned to the same cluster tend to be strongly related to each other, whereas terms assigned to different clusters usually do not have a strong relation. In other words, terms that often co-occur in publications are typically assigned to the same cluster, whereas terms that have no co-occurrences or that co-occur only in a small number of publications are likely to be assigned to different clusters. The clustering technique that we used⁷ is available in the VOSviewer software, which is discussed below. This technique is closely related to modularity-based clustering, a popular technique for clustering the objects in a network.⁸

In the fourth and final step, we calculated an age score for each term. The age score of a term equals the average publication year of all maternal mortality publications in which the term occurs (in the title or abstract). The age scores of terms can be visualized using colours. We used colours that range from blue

(score of 1998 or lower) to green (score of 2003) to red (score of 2008 or higher). Hence, if a term is coloured blue, this means that the term occurs mainly in older publications. On the other hand, if a term is coloured red, the term occurs mainly in more recent publications.

We used the VOSviewer software (freely available at <http://www.vosviewer.com>) to visualise our term maps.^{9,10} The interpretation of the term maps can be summarised as follows:

- Each circle represents a term. Sometimes no label is shown for a term. This is done in order to avoid overlapping labels. More labels become visible by using the VOSviewer software to zoom in into a specific area in a term map.
- The size of a term reflects the number of publications in which the term occurs. Larger terms occur in more publications.
- The distance between two terms reflects their relatedness. In general, the closer two terms are located to each other, the stronger their relatedness, as measured by their co-occurrence frequency.
- The horizontal and vertical axes have no special meaning in a term map. Rotating a term map does not affect its interpretation.
- The colour of a term indicates either the cluster to which the term has been assigned or the age score of the term.

Results

Analysis by field

Overall we identified 3794 publications on maternal mortality in the WoS database. Figure 1 shows the

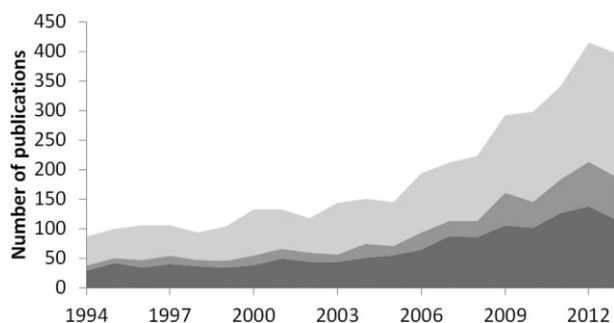


Figure 1. Number of maternal mortality publications in each year in the period 1994–2013, including a breakdown by scientific field. ■, other fields; ■, public, environmental & occupational health; ■, obstetrics & gynecology.

number of maternal mortality publications in each year in the period 1994–2013. As can be seen in the figure, there has been a large increase in the yearly number of publications on maternal mortality. In 2013, there were 397 maternal mortality publications, as compared with 87 publications in 1994, an increase of more than 350%. During the period 1994–2005, the increase in publications on maternal mortality has been relatively small (from 87 in 1994 to 145 in 2005). Starting from 2005, however, there has been a steepening of the increase (from 145 in 2005 to 397 in 2013).

Figure 1 also shows a breakdown of maternal mortality publications by scientific field. A distinction is made between the WoS field Obstetrics and Gynecology (shown in Figure 1), the WoS field Public, Environmental, and Occupational Health, and other WoS fields. Obstetrics and Gynecology is the WoS field with the largest number of maternal mortality publications. The number of maternal mortality publications in the Obstetrics and Gynecology field has increased from 29 in 1994 to 115 in 2013 (increase of 300%). In the WoS field with the second largest number of maternal mortality publications, which is the Public, Environmental, and Occupational Health field, the number of maternal mortality publications has increased from 9 in 1994 to 72 in 2013 (increase of 700%). Notice in Figure 1 that growth has taken place mainly during the most recent years. Somewhat more than half of all maternal mortality publications can be found in fields other than Obstetrics and Gynecology; and Public, Environmental, and Occupational Health. The number of publications on maternal mortality in these other fields has increased from 49 in 1994 to 210 in 2013 (increase of more than 300%). To put the increase in maternal mortality publications in a comparative perspective, we note that the total yearly number of publications in the WoS database has increased by 96% between 1994 and 2013.

For each field, the growth in the number of maternal mortality publications can be compared with the growth in the overall number of publications. We first consider the Obstetrics and Gynecology field (4505 publications in 1994 and 7964 in 2013). In the period 1994–2013, of the 117 169 publications in the Obstetrics and Gynecology field, there are 1331 (1.1%) that deal with maternal mortality. The top panel of Figure 2 shows that the share of maternal mortality publications in the Obstetrics and Gynecology field has increased over time. This follows from the

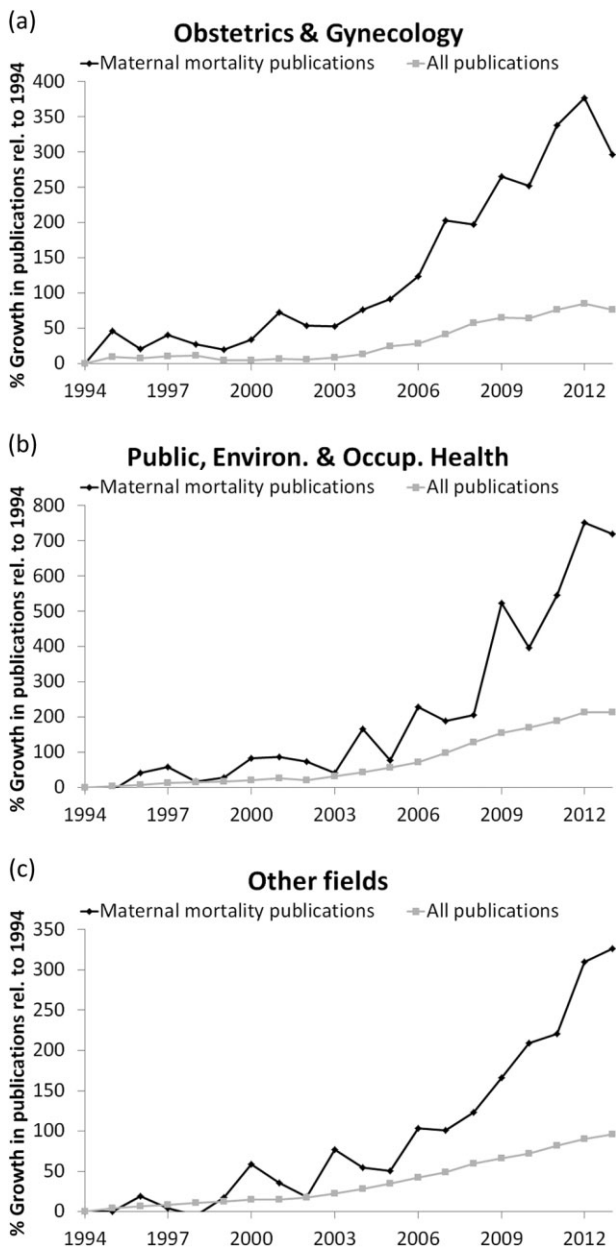


Figure 2. Growth in the number of maternal mortality publications during the period 1994–2013 compared with the growth in the overall number of publications. (a) The top panel relates to the Obstetrics and Gynecology field, (b) the middle panel to the Public, Environmental, and Occupational Health field, and (c) the bottom panel to all other fields. The growth in the number of publications is expressed as a percentage of the number of publications in 1994. Black, maternal mortality publications; grey, all publications.

observation that the number of maternal mortality publications has increased by about 300% between 1994 and 2013, whereas the overall number of publications has increased only by about 80%.

In the Public, Environmental, and Occupational Health field (5222 publications in 1994 and 16 376 in 2013), 550 of the 182 606 publications in the period 1994–2013 (0.3%) deal with maternal mortality (middle panel of Figure 2). Again, a strong increasing trend in the share of maternal mortality publications can be observed. The number of maternal mortality publications has increased by more than 700%, which is much more than the 200% increase in the overall number of publications.

The bottom panel of Figure 2 shows that there has been an increase of more than 300% in the number of maternal mortality publications in fields other than Obstetrics and Gynecology; and Public, Environmental, and Occupational Health. The overall number of publications in these other fields has increased by about 100%.

Analysis using term maps

Figure 3 presents the term map obtained based on 3794 maternal mortality publications in the period 1994–2013. We identified four clusters of related terms. These clusters are indicated using colours in Figure 3. An interactive version of the term map shown in Figure 3 is available online at <http://goo.gl/5RuqfG>. The interactive map offers zooming functionality that allows the map to be explored in much more detail than its static counterpart presented in Figure 3. (Please note that the interactive map requires a web browser with Java support).

The four clusters in the term map in Figure 3 represent the following research areas:

- *Green cluster.* This cluster represents public health research including cost-related analysis. Public health is strongly related to maternal outcome of pregnancy. Poverty, maternal health, and outcomes for both women and child are all interconnected. Income is strongly correlated with quality of prenatal and delivery care.¹¹ Generally, adequate prenatal and delivery care encompasses medical care and educational, social, and nutritional services during pregnancy. For example, proximity to healthcare facilities and access to transportation have significant effects on whether or not women have access to prenatal care. Recently, the increased availability of 'skilled birth attendants' – people with training in basic and emergency obstetric care – to support women give birth has helped to drive down the overall death rates. Figure 3b

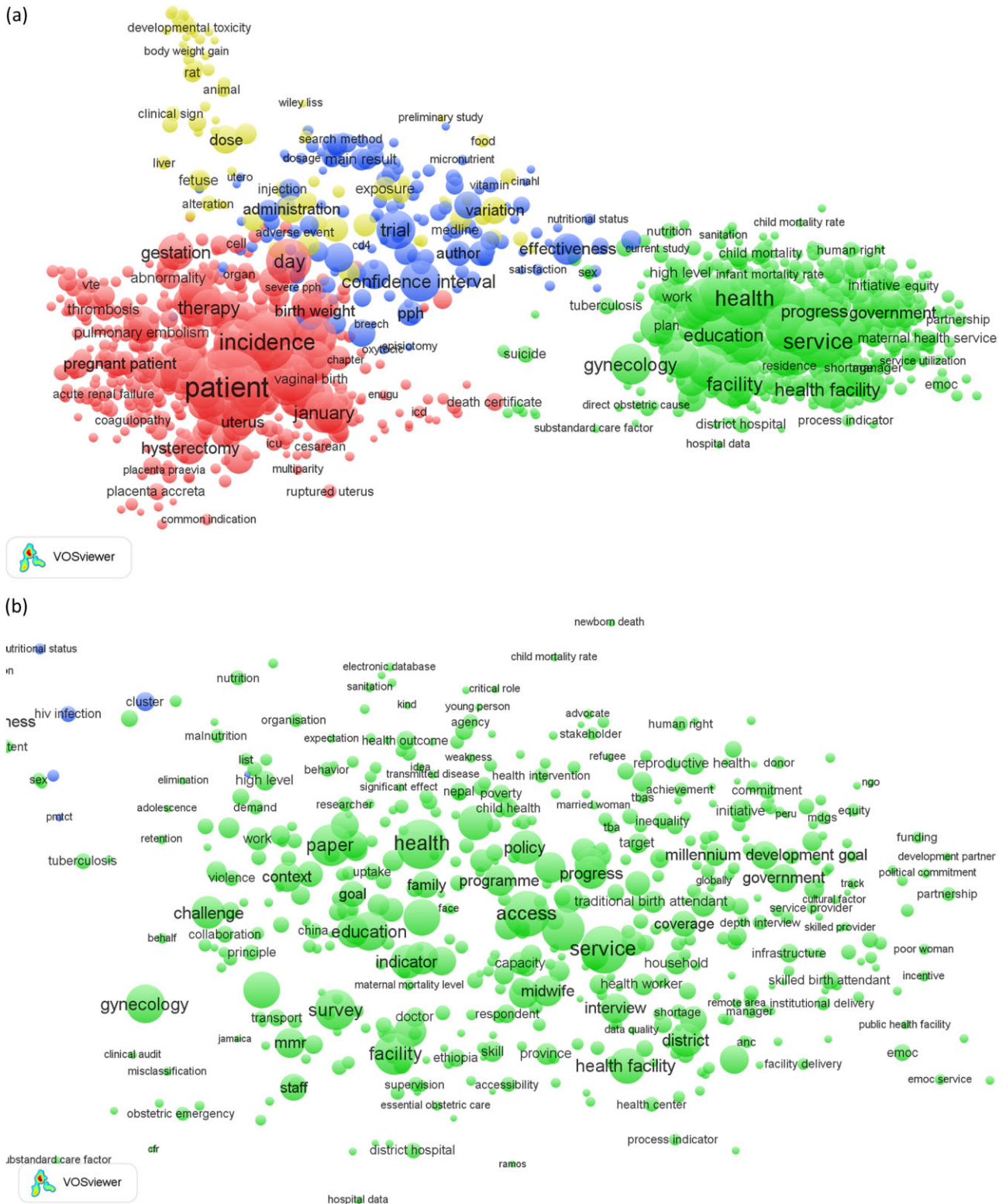


Figure 3. (a) Term map based on 3794 maternal mortality publications in the period 1994–2013. Colours indicate four clusters of related terms. An interactive version of the map is available online at <http://goo.gl/5RuqfG>. The green cluster represents public health research; the red cluster represents epidemiology, including trials and cohort studies; the blue cluster represents trials; and the yellow cluster represents basal, translational research. (b) Zooming in on the public health area (green cluster) in the term map in (a). (c) Zooming in on the epidemiology area (red cluster) in the term map in (a).

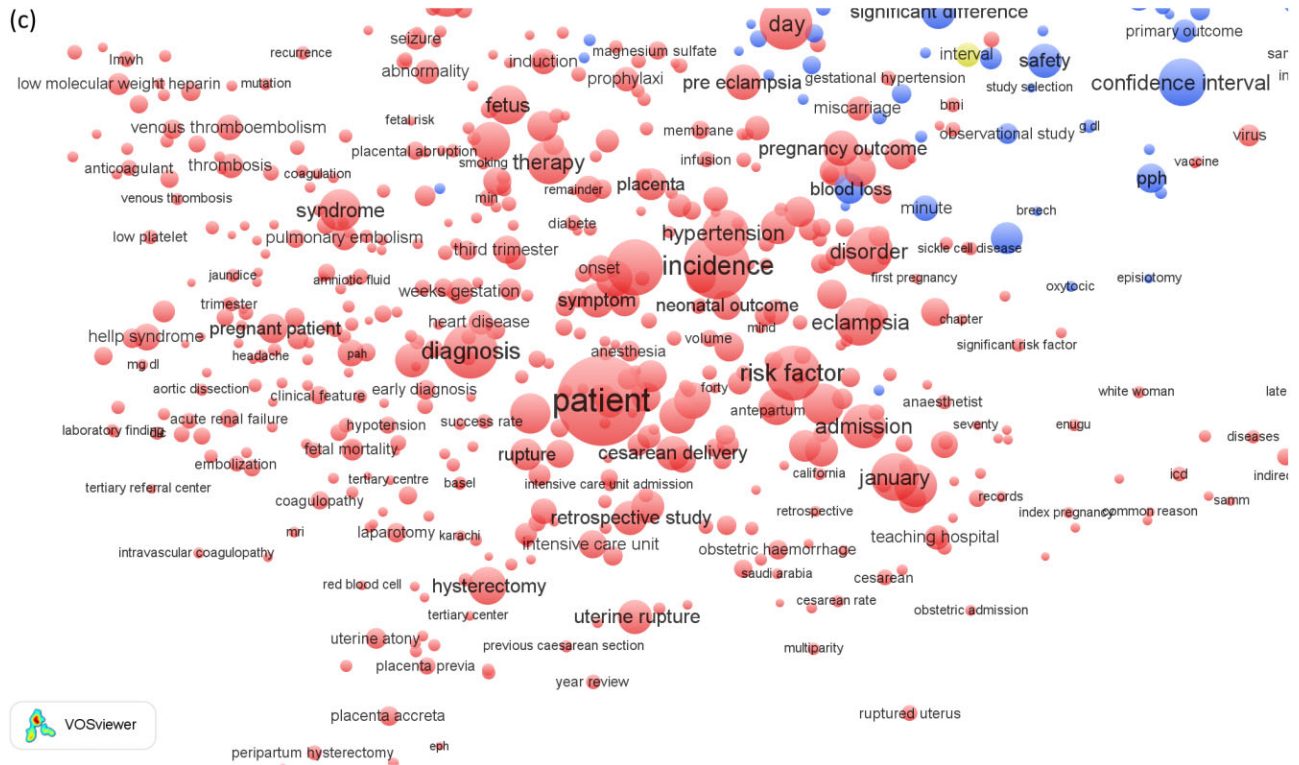


Figure 3. Continued.

provides a detailed insight in the topics of this cluster, including terms such as ‘service’, ‘health facility’, ‘transportation’, ‘education’, ‘poverty’, ‘health worker’, ‘midwife’, and ‘policy’.

- *Red cluster.* This cluster represents epidemiology, including trials and cohort studies. Women die as a result of complications during and following pregnancy and childbirth. Most of these complications develop during pregnancy. Other complications may exist before pregnancy but are worsened during pregnancy. Figure 3c provides a detailed insight in the red cluster, including clinical terms such as ‘hypertension’, ‘therapy’, ‘haemorrhage’, ‘uterine rupture’, and ‘HELLP syndrome’.
- *Blue cluster.* This cluster represents trials, including their methods, with terms such as ‘confidence interval’, ‘search method’, and ‘effectiveness’.
- *Yellow cluster.* This cluster represents basal, translational research, including animal studies with terms such as ‘animal’, ‘rat’, and ‘development toxicity’.

Figure 4 shows the trend in type of research over time. The term map is similar to that shown in Figure 3a, except that the colouring is different. The

colour of a term indicates the age score of the term, that is, the average publication year of all maternal mortality publications in which the term occurs (in the title or abstract). The figure reveals that the area of basal, translational research (upper left, yellow in Figure 3a) does not receive much attention anymore. On average, publications in this area are relatively old, as can be seen from the blue colour of the terms in the upper left area of the figure. On the other hand, the areas of public health (right, green in Figure 3a) and trials (centre, blue in Figure 3a) receive a lot of attention in recent research. There are a lot of orange and red terms in the right and centre areas in Figure 4, indicating that many publications in the areas of public health and trials are from recent years. The increasing interest in public health research is in line with our observation reported above that the number of maternal mortality publications in the Public, Environmental, and Occupational Health field has strongly increased over time. The area of epidemiology including trials and cohort studies (lower left) is in between the others. There are many green terms in the lower left area in Figure 4, which means that these terms occur both in older and in more recent publications.

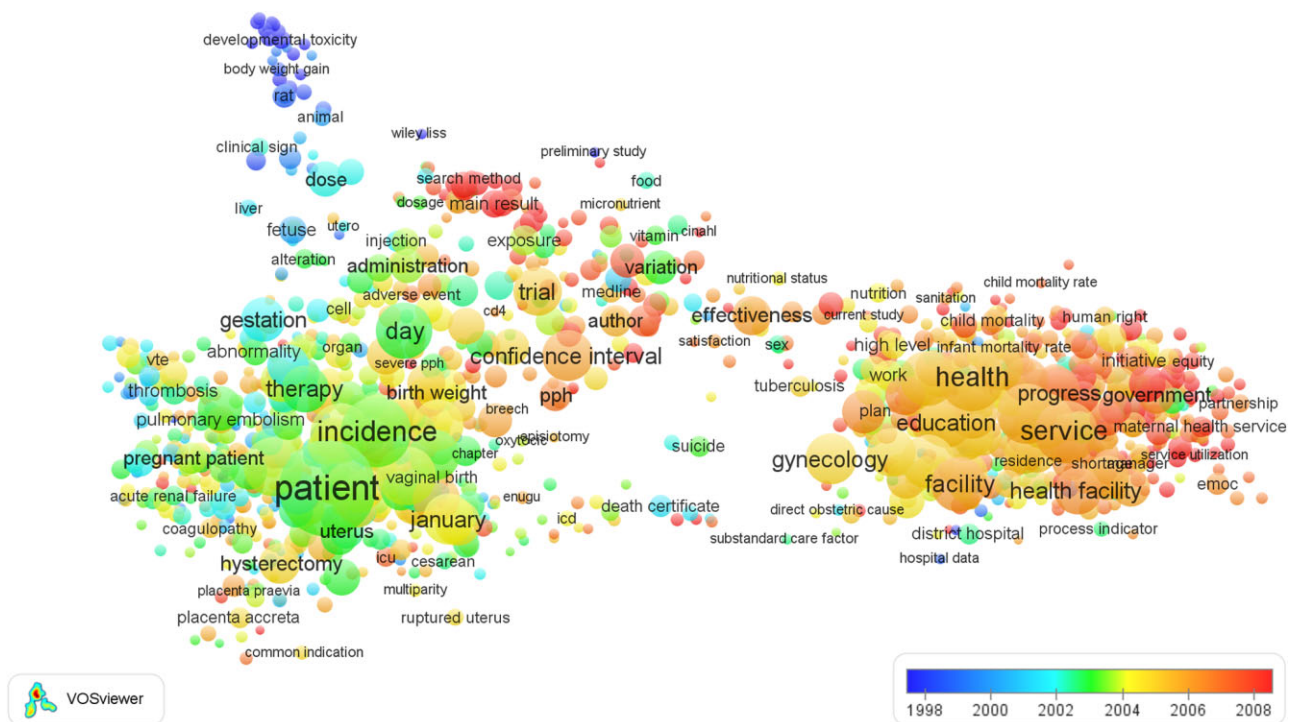


Figure 4. Term map based on 3794 maternal mortality publications in the period 1994–2013. The colour of a term indicates the average publication year of all maternal mortality publications in which the term occurs (in the title or abstract). The figure shows a shift from basic research (blue) to public health research (orange and red). An interactive version of the map is available online at <http://goo.gl/osRxPk>.

Comment

We found, based on a bibliometric analysis of the literature on the major health topic of maternal mortality, a strongly increasing trend in the number of publications on maternal mortality, especially since 2005. Obstetrics and Gynecology is the field with the largest number of maternal mortality publications, followed by the Public, Environmental, and Occupational Health field. In both fields, the number of maternal mortality publications has increased at a much higher rate than the overall number of publications in the field (300% and 700%, respectively). There has been a clear shift in attention from basal, translational research to clinical trials and public health research.

Strengths and limitations

An important strength of our study is its advanced bibliometric methodology. We work not only at the level of predefined fields in the WoS database (e.g., Obstetrics and Gynecology; and Public, Environmen-

tal, and Occupational Health), but we also use sophisticated term map visualisations to study the structure and development of the maternal mortality literature in a bottom-up fashion.¹² Compared with the information obtained from counting publications in predefined WoS fields, the term map visualisations provide insights at a more detailed level. The visualisations for instance show which topics within the field of Obstetrics and Gynecology have received most attention in maternal mortality research and how this has shifted over time.

A limitation of our bibliometric analysis is that some important publications may have been missed. This could be due to issues related to the coverage of the WoS database. Many local journals are for example not covered in this database. To some degree, this could be solved by using multiple databases, such as WoS and Medline, in a combined fashion.¹³ Publications may also have been missed because they do not contain 'maternal mortality' in their title or abstract even though they do in some way relate to the topic of maternal mortality.¹⁴

Interpretation in light of reduction of maternal mortality

Our results indicate, besides an increasing interest in the topic of maternal mortality, also a change of focus from basal research to public health and clinical research. This is in line with the target set in the fifth Millennium Development Goal to reduce maternal mortality by 75% between 1990 and 2015 worldwide. Almost all maternal deaths occur in developing countries (99%²). These countries have major public health problems. They fight against poverty and suffer from limited access to health services including prenatal and delivery care. The limited access to health services is essential in improving outcome, which is illustrated by a recently published systematic review describing that Birth Preparedness and Complication Readiness interventions including women's education are effective in reducing maternal and neonatal mortality in low-resources settings.¹⁵ This example underlines the importance of public health in improving maternal outcome and provides tools especially for women living in areas with a high maternal mortality rate.¹⁶ Another major tool for improving perinatal outcome is the increased development assistance for maternal, newborn, and child health.³

Implications for practice

Although a reduction of maternal mortality in developing countries has been achieved, maternal mortality is still unacceptably high. Interventions aimed directly at improving women's access to care during the intrapartum period are considered the best strategies for reducing high rates of maternal mortality. Interventions targeting the antenatal period and reducing the risk of unwanted fertility and unsafe abortion are also important components of a comprehensive plan to reduce the global burden of maternal mortality.

In developed countries a national audit system of maternal mortality and morbidity is essential to improve not only maternal mortality, which is scare, but also its associated maternal morbidity.¹⁷ In order to improve reproductive health, further insight in patient characteristics, (preconceptional) risk factors and the health care system is necessary in order to develop tools to improve the outcome.

Implications for research

In order to improve maternal outcome, understanding the key factors is essential. Therefore, research for developing countries should be focused on the main issues of public health and issues including human immunodeficiency virus/acquired immune deficiency syndrome and Ebola. For developed countries, the focus for research should be based on the items provided from the perinatal audits and from combined clinical and translational aspects synergistically. These can be further used for developing countries.

Conclusions

In conclusion, given the focus in the fifth Millennium Development Goal on reducing maternal mortality, there has indeed been a strong increase in the number of maternal mortality publications. Most research on maternal mortality still takes place in the field of Obstetrics and Gynecology, but public health research is playing a more prominent role.

In order to reduce maternal mortality worldwide, research is of eminent importance to understand its multi-causal reasons. Research focused on causes in developing and developed countries and implications for investments in health care and socio-economics are necessary.

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