

Jordan E Wrigley. Millennium Development Goal 5 Maternal Health Publications: An Open Bibliometric Mapping and Analysis. A Master's Paper for the M.S. in L.S degree. April, 2020. 78 pages. Advisor: Dr. Claudia Gollop

In 2000, the United Nations adopted the Millennium Development Goals (MDGs) as frameworks to guide the reduction of global poverty and inequality including maternal mortality (MDG 5). After the adoption, there is a substantial increase in maternal health publications. The following was a bibliometric mapping and analysis using an open data source (MEDLINE via PubMed) and open source software (VOSViewer) to identify the characteristics of those publications through visualization of terms, keywords, and author countries. Findings suggest maternal health publications associated with MDG 5 emphasized addressing maternal mortality and infant health but an increasing focus on integration of social barriers to biomedical interventions. Further, the findings in this research supported previous research illustrating the inequity of high-income and low-middle income collaborations. These findings will be valuable in informing the research for interventions associated with the current Sustainable Development Goals (SDGs) relating to maternal health.

Headings:

Bibliometrics

Medical librarianship

Data visualization

Millennium Development Goals

Maternal health

Maternal mortality

MILLENNIUM DEVELOPMENT GOAL 5 MATERNAL HEALTH PUBLICATIONS:
AN OPEN BIBLIOMETRIC MAPPING AND ANALYSIS

by
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A Master's paper submitted to the faculty
of the School of Information and Library Science
of the University of North Carolina at Chapel Hill
in partial fulfillment of the requirements
for the degree of Master of Science in
Library Science.

Chapel Hill, North Carolina

April 2020

Approved by

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Table of Contents

List of Tables	2
List of Figures	2
Introduction.....	3
1.1 An Open Bibliometrics Approach	5
Literature Review.....	7
1.2 Millennium Development Goal 5	7
1.3 Bibliometrics	13
1.4 Bibliometric and Mapping Analyses of Maternal Health Literature	20
Research Question.....	26
Methods	27
1.5 Data Collection	28
1.6 Operationalization and Iterative Visualization.....	29
1.7 Visualization, Thesauri, and Analyses.....	30
Results	32
1.8 Text-Mined Term Map.....	33
1.9 Author Keyword Map.....	35
1.10 Medical Subject Heading (MeSH) Map.....	38
1.11 Country Collaboration Network	41
Discussion.....	45
1.12 Impact of MDGs and MDG 5 on Maternal Health Research Publication	45
1.13 Comparison of Mined Terms, Author Keywords, and MeSH	48
1.14 Women and Neonatal Health.....	50
1.15 International Collaboration.....	51
1.16 Open Bibliometrics Process	53
Conclusions.....	55
Limitations.....	57
Bibliography	58
Appendix A: Sustainable Development Goals	69
Appendix B: Search Strategy.....	71
Appendix C: Term Map Thesaurus.....	72
Appendix D: Author Keyword Map Thesaurus.....	75
Appendix E: Country Collaboration Network Thesaurus	76

List of Tables

Table 1: Maternal mortality and health publications associated with MDG 5 by year.....	32
Table 2: Top 30 frequently occurring terms in publication titles and abstracts	34
Table 3: Top 30 frequently occurring author selected keywords.....	36
Table 4: Top 30 frequently occurring MeSH terms	39
Table 5: Top 30 countries with greatest total link (collaboration) strength	41

List of Figures

Figure 1: Overlapping Metrics (Onyachaya, 2014)	14
Figure 2: Tweet by Dr. Tom Frieden, Director of the CDC regarding ZIKA research	21
Figure 3: Map of Terms Text Mined from Publication Titles and Abstracts (n=378).....	33
Figure 4: Map of author selected keywords (n=74).....	37
Figure 5: Map of MeSH terms associated with publications in dataset (n=226).....	40
Figure 6: Collaboration Network of Author Countries (n=116).....	43
Figure 7: Main Cluster of Collaboration Network of Author Countries (n=116).....	44

Introduction

The improvement of maternal health and the reduction of maternal mortality have been enduring and complex challenges in the global health context requiring addressing inequity through interdisciplinary approaches to find effective interventions (Anderson, 2009; McPherson, 2016). Global leadership has sought to address these challenges via iterative policy goal setting. In 2000, the United Nations (UN) resolved to adopt measures to address extreme global poverty with also included addressing maternal health and mortality. The resulting document was signed by all 191 UN member states at that time and is known as the United Nations Millennium Declaration. This declaration was the founding document for the eight Millennium Development Goals (MDGs). These goals were a series of poverty reduction and development targets falling under eight goals to be reached by 2015 and were the overarching framework for global development efforts (Sachs, 2012). The fifth MDG (MDG 5) “to promote maternal health” sought to reduce maternal mortality rates and improve maternal health.

In 1990, annual global maternal mortality was estimated at 532,000 (WHO Maternal Trends). The MDG addressed the high rate of maternal mortality and lack of access to adequate maternal health care via two targets:

Target 1: to reduce the global maternal mortality rate by three-quarters by 2015.

Target 2: to achieve universal access to reproductive health by 2015 (van den Broek & Falconer, 2011).

Though neither of these targets were reached, from the time of the conception and adoption of the MDGs, and MDG 5 specifically, publication of maternal health research increased rapidly (300%) between 1994 and 2013 (de Groot et al., 2015). While this increase does not constitute direct causation between the adoption of MDG 5 and the sudden growth in maternal mortality and health research, it shows a substantial body of knowledge on this topic was generated during the implementation years from 2000 to 2015. It is on and from this body of knowledge further maternal health and mortality research will be based. This takes on particular importance as the newly created UN Sustainable Development Goals (SDGs), successors to the MDGs, are currently being implemented from 2015 to 2030, and a new wave of knowledge generation to identify and recommend approaches to maternal health is underway.

The following thesis provides a bibliometric analysis of maternal health research publications associated with the conception and adoption of MDG 5. Although a previous study of maternal mortality research provided bibliometric analysis from the mid-1990's to 2015 (de Groot et al., 2015), the analysis in this thesis drew a more distinct relationship between the adoption of MDG 5 and subsequent maternal health research via text mining maternal health article titles and abstracts for specific references to the MDGs. Using this approach, key characteristics such as co-authorship networks and the relationships between concepts within maternal health research referencing the MDGs were identified. These analyses of the scholarly output and dynamics of biomedical publications of global maternal health research during the implementation of the MDGs contribute an understanding of the research of the past. This knowledge and collective understanding of completed maternal health research adds to conversations that inform

the research needs of the future as well as science policymakers and those who set research agendas such as funding agencies and institutional administrations.

1.1 An Open Bibliometrics Approach

Policymakers are not the only populations this research has sought to inform.

Although analysis of MDG 5 associated research and publications was the main crux of this thesis, this research was completed with an "open bibliometrics" viewpoint. Open bibliometrics is one of many "threads" in the discourse around open access (OA) of scientific research including publications and data (Stuart, 2018). Stuart (2018) posits open bibliometrics as a tool for the discovery of undiscovered public knowledge by coalescing otherwise fragmented pieces of knowledge by finding relationships that are not apparent – a phenomena articulated by Swanson (1986). Stuart (2018) also noted the necessity of the democratization or free availability of the data sources and tools used in open bibliometric analyses. These currently often require access to cost-prohibitive subscription-based citation databases (Al Hamzy et al., 2019; Bruijns et al., 2017). The core tools and data sources used in this research were selected based on their accessibility to researchers, policymakers, and decisionmakers working in low access contexts. Such low access contexts include global regions where medical policy and independent technological access for research are growing. Other contexts are junior and regional institutions seeking to set research agendas for community-based health action. Use of open source and publicly available tools and data sources leaves open the opportunity to expand the reproducibility of this research beyond subscription-dependent users. By an accessible and open bibliometrics approach, this research sought to provide an open bibliometric methodology that may be adapted to any topic and used by a range of

individuals regardless of institutional or individual access. The use of accessible tools and data sources in this research may also encourage future researchers in these contexts to adapt them to new and emerging technologies and approaches.

Literature Review

The eight MDGs set in the 2000 Millennium Declaration were:

MDG 1: to eliminate extreme poverty and hunger;

MDG 2: to achieve global primary education;

MDG 3: to empower women and promote gender equality;

MDG 4: to reduce child mortality;

MDG 5: to promote maternal health;

MDG 6: to fight malaria, HIV/AIDS, and other diseases;

MDG 7: to promote environmental sustainability; and

MDG 8: to develop a universal partnership for development (United Nations, 2000).

The following review of literature begins with a brief background of the MDG 5 and the outcomes and dilemmas of its adoption in the first section. The second section is an overview of bibliometrics and their use in examining research beyond the known uses of research evaluation.

1.2 Millennium Development Goal 5

The origins of the MDGs pre-date the *Millennium Declaration*, most likely taking initial shape at the Children's Summit of 1990. The International Development Goals (IDGs), predecessors of the MDGs, were curated by the Organization for Economic Co-operation and Development's (OECD) Development Assistance Committee (DAC) in a 1996 document titled *Shaping the 21st Century* which included reproductive health goals. The conception and eventual adoption of the *Millennium Declaration* and the eight

MDGs required the IDGs either be integrated or discarded. This left the inclusion of reproductive goals open to opposition (Hulme, 2010a).

The inclusion of MDG 5 and its targets encountered gender-based adversity. Target 5b (universal access to reproductive health) was removed entirely in the initial list of goals as a result of pressure by what Hulme (2010b) referred to as an "unholy alliance" of the Vatican and conservative Islamic states (p. 20). This was in spite of recommendations by gender experts that inclusion of reproductive health including contraceptives was a major factor in poverty reduction efforts (Fehling et al., 2013). Reports by the Millennium Project headed by Jeremy Sachs, made clear that lack of reproductive health access was and would continue to be a major factor in poverty reduction and continuing development. These reports had the effect of catalyzing new commitment to reproductive health access and the UN General Assembly subsequently added Target 5b and its associated indicators to the official MDG list in September 2005 (Hulme, 2010a).

In terms of gender equity and access, transgender has recently become part of conversations in maternal health. People who are assigned female at birth but who choose gender-affirming hormone treatments and procedures may retain their ability to give birth (Brandt et al., 2019). Transgender reproductive health was not addressed in the MDGs and continues unaddressed in the SDGs. This is despite negative social perceptions and marginalization acting as barriers to maternal and reproductive health care (ex. Bundy et al., 2017 and Vun et al., 2014).

Although the global targets of MDG 5 were not met, progress toward improved maternal health outcomes was made based on the indicators selected for each target.

These indicators for the respective targets were:

Target 5a: To reduce maternal mortality by three quarters between 1990 and 2015:

5.1 Reduce the maternal mortality rate (MMR)

5.2 Increase the number of births attended by skilled health personnel

Target 5b: To achieve universal access to reproductive health by 2015:

5.3 Increase the contraceptive prevalence rate

5.4 Reduce adolescent birth rate

5.5 Increase antenatal care coverage

5.6 Reduce unmet need for family planning (van den Broek & Falconer, 2011, p. 27)

Based on UN data, since 1990, global MMR has declined by 45% with the majority of the reduction occurring during the MDG implementation period (2000-2015). In Southern Asia and sub-Saharan Africa (regions with high rates of maternal mortality), the ratio of maternal deaths per live births was reduced by 64% and 49%, respectively. During the implementation period, births attended by a skilled health worker increased from 59% to over 71%. The proportion of women receiving four or more antenatal visits increased from 50% to 89%. Lastly, contraceptive prevalence among girls and women 15 to 49 years of age who were married or in a union, increased from 55% to 64% globally (United Nations, 2015).

From a medical perspective, the main causes of maternal mortality (obstetric hemorrhage, hypertensive disorders such as eclampsia, infections, labor complications and obstructions, and unsafe abortion) as well as the current optimal interventions (those

indicated by targets MDG 5.1-5.2 and MDG 5.3-5.6) are known (van den Broek & Falconer, 2011). Despite this awareness, these causes are frequently underrepresented in medical maternal health literature and can vary depending on the regions or country that is the focus of the research and the origin of the publishing researchers (Chersich, Blaauw, Dumbaugh, Penn-Kekana, Dhana, et al., 2016; Chersich, Blaauw, Dumbaugh, Penn-Kekana, Thwala, et al., 2016; Chersich & Martin, 2017; Gil-González et al., 2006).

The success of MDG 5 and its targets has also been uneven across regions due to social, cultural, and economic difficulties in different contexts (McPherson, 2016). These difficulties in goal and target progress present particular barriers and dissidence for medical and public health researchers. For example, though contraceptives might be an obvious answer to unwanted pregnancy and provided as per Target 5.3, there is little to no guarantee women will be able, allowed, or willing to use them due to cultural gender roles and social stigma (McPherson, 2016). Other social considerations and barriers for the implementation of MDG 5 include the economic burden of poverty on women and lack of equity in education. Therefore, multidisciplinary approaches to addressing MDG 5 targets are particularly important to MDG outcomes though they are not often acknowledged or addressed in medical literature (Gil-González et al., 2006; van den Broek & Falconer, 2011).

At first glance, the MDGs may seem somewhat siloed based on their language, the struggles for inclusion of reproductive health access illustrate that MDG 1 (to eradicate extreme poverty and hunger; a burden suffered disproportionately by women) and MDG 3 (to promote gender equality and empower women) are inextricable socially from MDG 5. Biomedically, MDG 5 is also linked with MDG 4 (to reduce child

mortality) and MDG 6 (to fight malaria, HIV/AIDS, and other diseases). Therefore, MDG 5 becomes inherently complex and intricate when its achievement depends on and assumes the previous achievement or simultaneous achievement of other goals (McPherson, 2016). Although these might be the most obvious goals to interrelate with MDG 5, a case can be made for the inter-relatability of every goal with the others. The recognition of the necessity of multi-faceted approaches to improving maternal health also requires awareness of the lived experiences of women affected by maternal mortality and lack of access to reproductive health (McPherson, 2016). This is perhaps in part due to a lack of authorship and participation in maternal health research from placed-based researchers and reliance on research originating from high-income countries (HICs) (Chersich et al., 2016; Gil-González et al., 2006).

In a collection of ethnographic studies examining MDG in Africa and Oceania, McPherson (2016) uses the term “cosmopolitan obstetrics”, a term coined by Jordan (1992) and derived from the concept of cosmopolitan medicine developed by Frederick L. Dunn in 1976, to describe the hyper-Westernized approach to MDG 5 research and application. Cosmopolitan obstetrics emphasizes Western biomedicine’s dependence on urban context, technological resources, and presumption of agency in reproductive decision-making for women. As the ethnographers in this collection repeatedly illustrate, this is a context rarely available to the populations of women most affected by maternal mortality and lack of access to maternal and reproductive health.

With the conclusion of the MDG implementation period in 2015, all UN member states adopted *The 2030 Agenda for Sustainable Development* which lists 17 new Sustainable Development Goals (SDGs) (Appendix A) with accompanying targets and

indicators many of which build on the previous MDGs. MDG 5 as well as MDG 4 (to reduce child mortality) and MDG 6 (to fight HIV/AIDS, malaria, and other diseases) were medically linked and subsumed into SDG 3 (ensure healthy lives and promote well-being for all at all ages). Other MDGs socio-economically linked with MDG 5 have been more explicitly retained such as MDG 1 (eradication of poverty and hunger) which remains as SDG 1 (end poverty in all its forms everywhere) and SDG 2 (end hunger, achieve food security and improved nutrition and promote sustainable agriculture). MDG 3 (to empower women and promote gender equality) was retained as SDG 5 (achieve gender equality and empower all women and girls). New goals such as SDG 4 (ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), an incarnation of MDG 2 (to achieve global primary education), and SDG 6 (ensure availability and sustainable management of water and sanitation for all) are also arguably linked with maternal health socially and medically.

The interlinked nature of these goals is also being more explicitly addressed. In the 2018 report of goals progress, Zhenmin Liu, Under-Secretary-General for Economic and Social Affairs, acknowledged the necessity of health equity writing “access to basic services is not only a fundamental human right, but also a stepping stone to sustainable development” (2018). Achieving the targets set by the new SDGs by 2030 requires active research to identify past and potential research gaps (Sweileh, 2018). Jeffrey Sachs, a leader in the creation of the MDGs emphasizes the need for the SDGs to “build on the MDGs, which have helped to advance the world’s agenda in the fight against poverty, hunger, and disease” (Sachs, 2012, p. 2209). By examining the maternal health research associated with the adoption of MDG 5 and its related goals, researchers can better

understand how they can effectively contribute to further progress toward the achievement of the goals set by the MDGs and continued by the SDGs.

1.3 Bibliometrics

Bibliometric analyses are most associated with scholarly impact measurement (i.e., *h*-index and other impact factors) for authors, articles, and journals. This purpose is rapidly evolving. Originally designed by librarians as an efficient way of selecting journals for purchase for collection development, the purpose of bibliometrics is speedily evolving. Post-World War II, rapid growth in scholarly publishing created a need for an organized way for researchers to locate relevant publications and potential collaborators in their specific fields and specialties. It was not until the 1970's and 80's and the advent of "science policy" and research evaluation that bibliometrics began to take on a structure and purpose that would be familiar to researchers today (Gingras, 2016).

Bibliometrics are one form of metric used to study scholarly output and are part of the more general category of informetrics. Broadly, informetrics are methodologies that recognize, identify, and analyze or model patterns of information across all walks of life and, therefore, are valuable in many contexts including the examination of scientific publications (Tague-Sutcliffe, 1992). Within informetrics, in addition to bibliometrics, several overlapping approaches to informetric analysis exist, as demonstrated by the figure adapted by Onyancha (2014) from Ingwersen and Björneborn (2004) (Figure 1). Bibliometrics are specifically concerned with analysis of written communication which typically takes the form of publications and citation data (Gingras, 2016; Onyancha, 2014). Scientometrics and bibliometrics are often used interchangeably and often rely on similar data types including citation data but scientometrics is more often focused on

production and personnel as well as funding structures (Gingras, 2016). Overlapping with both bibliometrics and scientometrics are cybermetrics which includes both webometrics and, more recently, altmetrics. These approaches utilize web-based data such as PDF download counts and view rates, mentions on social media (ex. Twitter), references by news media, and saves to citation management software. Webometrics might examine online collaboration networks via Facebook or scholarly knowledge management platforms such as VIVO (<https://duraspace.org/vivo/>) whereas altmetrics approaches overlap more with scientometrics rather than bibliometrics as they are similarly more

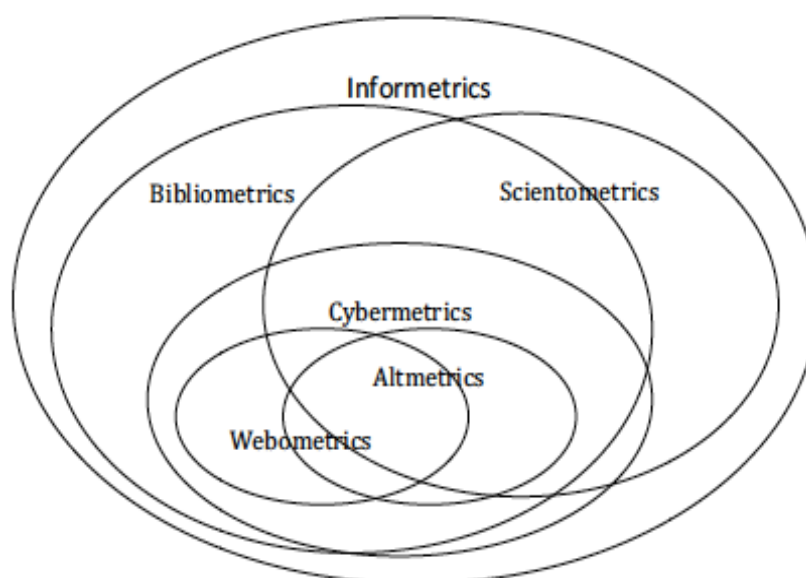


Figure 1: Overlapping Metrics (Onyachaya, 2014)

concerned with production and impact (Onyancha, 2014). Gringas (2016) offers a final metric category, technometrics, which uses non-article publication such as patents to analyze scientific information patterns beyond academic scholarly output.

Within bibliometric analysis, there are two main approaches: 1) performance analysis or the quantitative tracking of productivity and impact (where impact is defined as citations per article over time) of scientists and scientific output including articles,

journals, and institutions or organizations and 2) bibliometric mapping (also known as relational bibliometrics) or the analysis of the structure of scientific literature through publication data such as relationships between citations, authors, or terms (Gingras, 2016; Nakagawa et al., 2018; Onyancha, 2014). The first has come to be associated with research and researcher evaluation, and the latter with more modern and inclusive approaches to examining research production. These two approaches to bibliometric analysis can be used separately but are also used together along with techniques from overlapping metrics (such as cybermetrics) to achieve a specific purpose, typically telling a story of about a particular topic (ex. tropical diseases) (Falagas et al., 2006), research community (Bender et al., 2015; Wrigley et al., 2019), or other grouping of scientific work research such as a journal (Tur-Porcar et al., 2018) or a body of literature funded from a grant (Llewellyn et al., 2019; Schneider et al., 2017).

Gingras (2016) points out the real value of bibliometrics is when they are used at an appropriate scale to analyze the dynamics of scientific research as a tool for science historians and sociologists to understand the changes and trends in scholarly research and research communities. In this way, bibliometric analysis is used to characterize a specific set of publications or a body of literature to see what has been researched. This is particularly the case with relational bibliometrics where approaches such as network analysis and bibliometric mapping bring together otherwise fragmented pieces of knowledge to form a cohesive image of current knowledge (Nakagawa et al., 2018; Stuart, 2018). Bibliometric approaches like these have been used to understand "big science" or gain a bird's-eye-view of a particular topic (Schneider et al., 2017). These bibliometric analyses have informed scientific policies and can aid translational research

goals by analyzing the pathways of published knowledge to practice and its clinical value (Debackere & Glänzel, 2004; Onyanha, 2014; Smith et al., 2017). Further, bibliometric analysis with data visualization components has the opportunity to engage members of the public outside of the biomedical research community (including those studied by biomedical researchers) by helping to make sense of the research landscape as a whole (Allen, 2018; Nakagawa et al., 2018).

The use of open bibliometric data sources and tools also opens the replication of analyses to any individual or institution with internet access. Yet, there are challenges to free and open-source data and tools. Bibliometric analysis assumes, at least to some extent, the accuracy of publication and citation data (Onyanha, 2014). However, this can vary based on the queried database as other factors. The sources for publication data are typically large aggregate and multidisciplinary databases such as Web of Science (Clarivate) or Scopus (Elsevier) (Onyanha, 2014). In a recent call for open bibliometric approaches including tools and citation data sources, Stuart (2018) pointed out this dependence on paid subscription-based services limits bibliometricians in collecting fragmented research via publications and citations into cohesive public knowledge. The fragmented nature of research and the inaccessibility of data sources and tools are problematic when, presumably, the majority of biomedical research in particular is completed for the sake of improving the health of those studied and often uses public funds in the process of completing research.

Accessibility to resources can also affect local authorship from low-income regions. Despite the greater ability of place-based researchers to define and approach local issues, the vast majority of research on LMIC health issues is generated by HIC

researchers (Beran et al., 2017). Previous bibliometric and mapping studies have shown a lack of representation in local research authorship in studied LMIC regions along with a high rate of "north-south" and "north-north" collaborations with fewer to no "south-south" collaborations depending on the topic (Chersich, Blaauw, Dumbaugh, Penn-Kekana, Dhana, et al., 2016; Vargas et al., 2016). In the case of these studies, "north" refers to the global north or typically HICs including Australia and New Zealand and "south" refers to the typically LMICs often including those in the Northern hemisphere. Other studies have found high rates of collaboration and shared authorship between local LMICs and HICs to be high when controlling for study country (Jacobsen, 2009). Yet, the ratio of LMIC to HIC first authorship continues to favor HIC authors in most regions (Chersich, Blaauw, Dumbaugh, Penn-Kekana, Dhana, et al., 2016). This ratio may be in part due to a continuing dependence on HIC funding sources which creates inequitable partnerships (Beran et al., 2017; Gautier et al., 2018).

Bibliometric and mapping analyses have the potential to illuminate these partnerships and may give LMIC researchers a tool to explore, define, and direct future research partnerships and agendas. Yet, a lack of access to some of the largest and best-curated but subscription-based publication databases (ex. Embase (Elsevier), Web of Science, or Scopus) prevents adequate data retrieval for comprehensive bibliometric analyses. In 2013, in response to the galvanizing effect of the MDGs on global health research, researchers released a list of 60 LMIC relevant resources which included databases such as MEDLINE, Embase, and others (Stansfield et al., 2013). While the majority (75%) of these resources were said to be free, some (such as Embase) were subscription-base and potentially cost-prohibitive without access to adequate funding to

purchase a subscription. These may also be available via the HINARI program set up by the World Health Organization (WHO) which allows LMIC access up to 15,000 journals including a significant range of biomedical research publications (World Health Organization, n.d.).

MEDLINE records via PubMed as maintained by the National Library of Medicine (NLM) are another publicly available biomedical citation data source. As part of this maintenance, the NLM employs specialists and indexers to apply Medical Subject Heading (MeSH) terms as part of a controlled vocabulary to publications within the database thereby tagging research with highly specific terms in a hierarchical tree for greater findability (Bachrach & Charen, 1978). Various digital modalities of this process, which, until recently had been a largely manual process, were and are being vetted to decrease the indexing time for newly added publications (ex. Jimeno-Yepes et al., 2013).

Although publication data from PubMed are sometimes thought of as poor quality due to a lack of completeness (Stuart, 2018), PubMed as a citation data source tends to be as viable as Web of Science and Scopus in analyses. A previous study showed journals have incorrectly entered author affiliation data leading to a lack of retrieval of relevant records when searching based on the affiliation field in both Scopus and PubMed (Schmidt et al., 2016). These sorts of inaccuracies can also occur when data is input by the publication author(s). In a comparative scoping review, Li et al. (2017) found publication abstracts are not consistently representative of their full reports across several databases. Another study also found funding data from PubMed more challenging to obtain and operationalize for bibliometric analysis than Web of Science or Scopus but had a greater portion of articles (14.6%) from selected journals with funding data than

Scopus (7.7%) though lower than Web of Science (29%) (Kokol & Vošner, 2018). Though operationalizing publicly available citation and publication data retrieved through PubMed may present challenges, its value as an open resource and its focus on biomedical literature and first source for many clinicians and clinical decision-makers makes it an ideal source of data for bibliometric analyses of biomedical research (Falagas et al., 2007).

Though also potentially challenging, more open source and free options exist for bibliometric analysis and mapping tools. A range of tools exists both for purchase and as open-source downloads (Nakagawa et al., 2018; Pradhan, 2016). For the purposes of finding relationships within publication datasets, VOSviewer (<http://www.VOSviewer.com>) is a particularly valuable tool created to visualize the relationships found in publication and citation data. By creating networks of nodes and lines, VOSviewer shows the interconnectedness of data points (van Eck & Waltman, 2010, 2017). VOSviewer has been used to map a range of bibliometric topics and datasets including the interdisciplinarity of research areas (Nettle & Frankenhuis, 2019; Youngblood & Lahti, 2018), detect international collaborative networks (Tirgar et al., 2019), and map the conceptual trends of a given research topic (Gao et al., 2018). The visualization of these analyses via VOSviewer allows the coalescing of fragmented publication and citation data into a comprehensible visual of the trends and dynamics of scientific research within the retrieved dataset.

Using the bibliometric approaches, information researchers can explore and identify the who's, where's, when's, what's, and how's of a body of literature that has surpassed a volume that would be realistic for a traditional literature analysis. These

approaches are used to examine various aspects and behaviors of research and researchers as well as the strengths and weaknesses of a given body of literature (Debackere & Glänzel, 2004). This is achieved through visualization (using tools such as VOSviewer) of analyses such as research collaboration networks (network analysis) and concept relationships (term co-occurrence maps) which can provide an opportunity to check the literature for both expected and unexpected emphases and topics (Nakagawa et al., 2018). This last is referred to as "gap-finding" in bibliometric method literature and adds to conversations in funding and translational science policy, wherein generated research is translated to clinical practice, by denoting places for improvement in evidence-based knowledge (Boerma et al., 2008; El Lawindi et al., 2015; Schneider et al., 2017; Smith et al., 2017). This last has been noted to be particularly important in relation to implementing measures to reduce maternal health and mortality derived from scholarly research in part due to the multidisciplinary approaches required to address social, cultural, and economic barriers along with biomedical challenges (van den Broek & Falconer, 2011).

1.4 Bibliometric and Mapping Analyses of Maternal Health Literature

A longitudinal analysis of maternal mortality literature catalyzed by MDG 5 using bibliometric approaches by de Groot, Leeuwen, Mol, and Waltman (2015) showed a rapid increase in the volume of publications between 1994 and 2013 by 300%. The relationship between MDG 5 and the publications within the analyzed dataset was hypothetical in part due to the broad search strategy that did not include any terms directly linking the retrieved citation data to MDG 5 or the MDGs. Nonetheless, the authors attributed this rapid growth to the adoption of MDG 5. This rapid increase of

maternal health biomedical research is difficult to correlate directly to the adoption of MDG 5 and related MDGs. However, it is likely such informal research agenda setting via implementation of socio-political leader organizations would play a role in directing global medical research agendas by bringing attention to specific issues and gaps in research literature. For example, in the wake of the 2016 ZIKA cluster outbreak, on

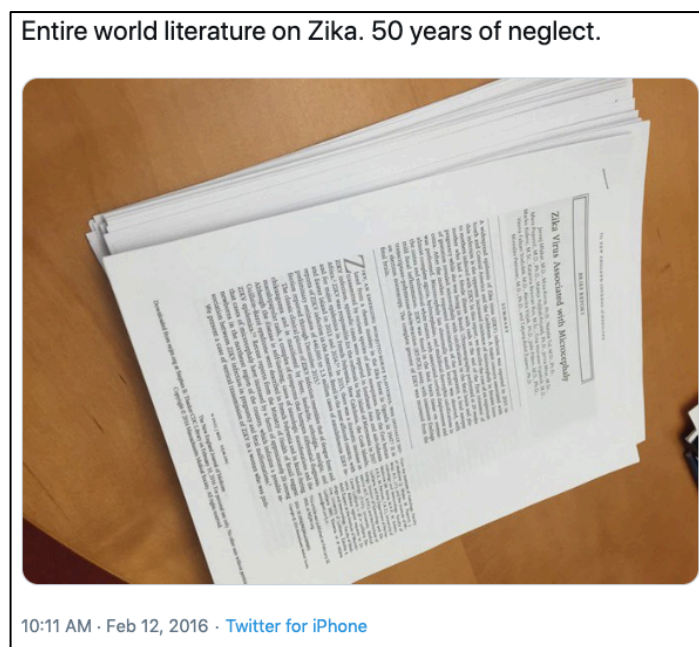


Figure 2: Tweet by Dr. Tom Frieden, Director of the CDC regarding ZIKA research

February 1, 2016 the World Health Organization (WHO) declared a health emergency (World Health Organization, 2016). Likewise, the Director for Center for Disease Control and Prevention (CDC), Dr. Tom Frieden, tweeted an image of the collected research on ZIKA (a very small pile of documents) with the caption "Entire world literature on Zika. 50 years of neglect" on February 12, 2016 (Figure 2).

After this, research on ZIKA increased explosively (Moraes et al., 2017). A simple search for the term *zika* in PubMed (completed on July 28, 2019) alone shows publication records on the disease increasing from 42 in 2015 to 1,752 in 2016. Again,

while this does not prove a direct correlation, it can be argued that both informal and formal policies influence the directionality of medical research by pointing to gaps in knowledge.

The gaps in maternal global health research require similar attention. In 2011, researchers part of the Multilateral Association for Studying health inequalities and enhancing North-south and South-south Cooperation (MASCOT) undertook a comprehensive mapping analysis of 2,292 maternal health and mortality publications focused on low and middle income countries (LMICs) from 2000 to 2012 including assessments of intervention research alignment with known clinical mortality and morbidity factors and geographic research emphases (Chersich, Blaauw, Dumbaugh, Penn-Kekana, Thwala, et al., 2016; Chersich & Martin, 2017), publication authorship (Chersich, Blaauw, Dumbaugh, Penn-Kekana, Dhana, et al., 2016), and policy impact (Vargas et al., 2016). In terms of research gaps, these studies found complex regional relationships between the most common conditions leading to maternal mortality and the amount of research dedicated to understanding those conditions. For example, the researchers found hemorrhage during pregnancy to be generally underrepresented in the literature and only 30 publications from South Africa addressed it despite it being the most common cause of maternal mortality in the country (Chersich, Blaauw, Dumbaugh, Penn-Kekana, Thwala, et al., 2016, p. 12). General findings included a dominant emphasis on malaria and HIV in terms of number of studies focused on these topics. Studies of clinical conditions with hemorrhage, pregnancy-related hypertension, and non-HIV sexually transmitted infection (STI) had received far less attention. Pregnancy-related hypertension studies were also almost double that of hemorrhage. The number of

HIV studies has also declined over time along with other sexually transmitted infections (STIs) studies (Chersich & Martin, 2017, p. 2). The MASCOT studies also found an increasing application of qualitative research methods, particularly in relationship to HIV studies. In general, HIV studies also tended to focus on infected children rather than women. An overall lack of appearance of qualitative methods and health promotion studies may signify an "over-medicalized" approach in some portions of the literature (Chersich & Martin, 2017, p. 4). These support arguments McPherson (2016) and Gil-González, Carrasco-Portiño, & Ruiz (2006) made of the overemphasis on Western techno-based clinical solutions that do not address the socio-cultural or economic barriers or maternal health. In a later analysis of maternal health literature, de Groot, Leeuwen, Mol, and Waltman (2015) observed an increasing emphasis on public health aspects of maternal mortality and a decrease in emphasis on basic science. Therefore, it may be that researchers have begun to more intentionally address the socio-economic aspects of maternal health solutions.

The MASCOT studies also examined authorship networks in maternal health research with particular focus on the collaborative research relationships between LMIC and HICs. Increased research capacity has been identified as key to locally-led and placed-based health solutions (Lansang & Dennis, 2004). Discrimination has been an issue in global research where LMIC researchers do not always receive adequate authorship credit despite guidelines such as that created by the International Committee of Medical Journal Editors (ICMJE) (Zachariah et al., 2013). The vast majority of research published addressing LMIC health issues and interventions is authored by researchers affiliated with institutions in HICs. According to findings by Chersich et al.

(2016), up to 60% of maternal health intervention research has been led by LMIC affiliated researchers. This again speaks to assertions that past research does not reflect the lived reality of the health and maternity challenges faced by women and female-persons in LMIC regions but is currently changing and becoming more reflective in part due to increasing locally-led research and publication. Chersich et al. (2016) also noted, despite an increased rate of locally LMIC-led research lead authorship into the 2000's, the rate of first authorship among LMIC researchers has slowed. This may also affect the topics selected for research within LMICs. Lastly, south-south collaborations ("south" typically being used to refer to globally low-income regions where "north" is used to refer to globally high-income regions) are rare. North-north and north-south collaborations in the case of LMIC-based studies are typical with north-south or south-south studies of HICs being nonexistent as has been found to be typical in global publishing partnerships (Chersich, Blaauw, Dumbaugh, Penn-Kekana, Dhana, et al., 2016; Jacobsen, 2009).

The adoption of the MDGs and MDG 5 provided biomedical research foci for global maternal health and mortality. Although the goal encountered resistance early on, the specific targets and indicators laid groundwork for future research on these topics. However, many topics with maternal health and mortality remain inadequately researched such as the social, cultural, and economic factors at play in accessing and using reproductive health services and resources.

Bibliometrics, and bibliometric mapping in particular, are optimal tools to assess generated publications. If free and open data sources and tools are used, this also opens the opportunity for researchers in highly impacted but low resource areas to provide

place-based guidance to the global research community via formative bibliometric mapping of current research. Previous research and similar phenomena (such as the explosion in ZIKA research publications) have suggested the adoption of MDG 5 catalyzed astronomical growth in maternal health and mortality research publications. Mapping studies of maternal health and mortality literature have found significant variations in topics covered, regional output, and authorship patterns with a multitude of potential variables and causes. This research sought to build on and synthesize these discourses and examine the research generated to address a complex global health challenge laden with disparities (both for the researched and the researchers) when semi-formal broad goals and targets were offered as foci.

Research Question

The improvement of global maternal health is a complex challenge that the fifth MDG set in 2000 attempted to address through guiding goals and targets. The setting of these goals and targets can also be argued to have catalyzed a wave of research around relevant topics. This body of published research then became the evidence base for responses and efforts to improve maternal health.

The following research consisted of a bibliographic mapping of maternal health publications associated with MDG 5 roughly from 2000 to present with "association" being defined as a reference to both maternal health and the MDGs in the title, abstract, or keywords of a given article. By examining this literature at a broad scale, this research sought to answer the question: What are the characteristics and trends of the biomedical research catalyzed by and published in response to MDG 5?

Methods

The following section details the methods used in this research. Bibliometric analysis and mapping through text mining and visualization were the methods chosen to answer this question and characterize the collected body of research literature. Broadly, this consisted of three steps:

1. Data collection
2. Cleaning and operationalization
3. Iterative visualization and analysis

An exhaustive search strategy for PubMed was developed to collect as much relevant publication data as possible for text mining analysis and visualization in VOSviewer (Version 1.6.14). To achieve this, the data required cleaning and operationalization. VOSviewer uses a combination of natural language processing and mapping to visualize the relationships between data points such as co-occurrence of terms and co-authorship between authors or institutions (van Eck & Waltman, 2010, 2017). For example, in a concept map, terms for public health would appear clustered together more closely than those associated with biostatistical science. Likewise, public health clusters would be more likely situated more closely to behavioral sciences than chemical sciences. Similarly, clusters of authors would be grouped more closely depending on the number of times they have co-authored.

In the implementation of these methods, the tools and data sources used were selected based on their accessibility to potential future researchers in working with low accessibility to subscription-based tools and sources. With this in mind, the citation data sources (MEDLINE publication data retrieved via PubMed) and tools (Zotero and VOSviewer) were used as the platform for data retrieval, data management, and visualization respectively.

Throughout the execution of this research, a record of the process of using open source tools and data was maintained. The goal of this record was to elucidate the potential challenges for future researchers seeking to replicate these methods with the same or similar tools and data.

1.5 Data Collection

To collect data publications associated with MDG 5, an exhaustive two-part search strategy was developed. The parts of this search were 1) maternal health and 2) the Millennium Development Goals. The search strategy built on the search created by de Groot, Leeuwen, Mol, and Waltman (2015) by first expanding the number of terms (including Medical Subject Headings or MeSH terms) and keyword synonyms for maternal health.

The second part of the search required all included publications to mention to some extent "millennium development goals" in the title, abstract, or author-selected keywords to illustrate more clearly the association between collected maternal health literature and MDG 5. For the purposes of this research, maternal health publications that also reference the MDGs will be considered to be associated with, and potentially inspired or catalyzed by, the conception and adoption of MDG 5 to some extent. This

includes publications directly or indirectly associated with MDG 5 and maternal health through overlap with related goals such as MDG 4. No limits were placed on publication type or publication dates. A full search strategy is appended to this thesis in Appendix B.

The search was executed in PubMed and results were exported in MEDLINE file format. A preservation copy of this original export was retained for analysis. All publication data were also imported into Zotero reference management software for organization and preservation.

1.6 Operationalization and Iterative Visualization

The operationalization of retrieved MEDLINE publication data for visualization in VOSviewer required greater attention due to challenges with data organization and lack of consistency. In particular, affiliation and country data for authors lacked disambiguation and structure. This issue and the limitations it placed on analysis was noted by VOSviewer creators in the *VOSviewer Manual* (Van Eck & Waltman, 2013) when using PubMed MEDLINE files. To address this, PubMed2XL (Kiseliov, 2010), an application which converts PubMed files to Excel files (.xls) was used to extract author affiliation and data from the PubMed export file. The resulting .xls file was imported to Google Sheets for hand cleaning including the addition of relevant fields and removal of records lacking data to be useful in analysis.

Completing data cleaning in a spreadsheet file presented another issue in operationalizing the data for importation and visualization in VOSviewer. At the time of this research, VOSviewer was not compatible with Excel formats with the exception of Scopus results exported as comma-separated values (.csv) files. Operationalization for VOSviewer was achieved by creating a mock-Scopus .csv file via hand cleaning of

syntax and field structure. Effectively, this allowed the import of the collected and cleaned dataset from PubMed to be imported into VOSviewer as a Scopus file and function similarly. This created a second dataset specifically for the visualization and analysis of author affiliation and country data.

1.7 Visualization, Thesauri, and Analyses

Analyses of publication data was achieved in two ways:

- 1.) Visualization and visual analyses of term or keyword maps and mapping of author country collaboration networks.
- 2.) VOSviewer maps files which include statistical data (ex. frequency of occurrence and total link strength) for data points which are were generated alongside visualizations. These were examined to provide richer quantitative points in analyses.

The network visualizations created through VOSviewer consist of a network of nodes or bubbles representing data points (ex. author countries or terms) with the potential addition of lines or links between nodes to represent relationships between the data points. The distance between nodes in the network visualization also signifies the relatedness of the nodes; the closer two nodes occur the more frequent their co-occurrence in the dataset. For example, if two terms appear together often in text-mined titles and abstracts, they will be more likely to appear nearer in a term map visualization. Likewise, authors or countries that frequently collaborate will appear nearer in a network visualization of collaborative relationships.

One challenge to this approach is the concept of synonymy that occurs in topical discourse and publication writing in terminology. For example, "skilled health attendant"

and "skilled birth attendant" might be considered synonymous and organized under "skilled attendant". Within VOSviewer, a thesaurus of terms can be created to collect similar terms associated with a single concept. In this way, data was further iteratively cleaned and re-visualized to be cleared of noise or redundancies and created clearer mapping visualizations. The thesauri created for each visualization as needed can be found in Appendices C-E. Lastly, the final mapping visualizations were saved as VOSviewer map and network files (.txt).

Results

Using the search strategy, 1,303 MEDLINE publication records were retrieved on August 28, 2019 via Legacy PubMed. The records spanned from 2000 to 2019. As seen in Table 1, the increasing publication rate was gradual, peaking in 2013 and tapering off thereafter.

Table 1: Maternal mortality and health publications associated with MDG 5 by year

Year	Total Publications	Free full-text Publications
2019	38	26
2018	59	42
2017	88	63
2016	118	81
2015	147	94
2014	159	104
2013	164	99
2012	149	78
2011	135	70
2010	85	30
2009	69	35
2008	54	18
2007	56	25
2006	42	12
2005	17	8
2004	7	1
2003	2	0
2000	1	0

92 synonymous terms (ex. "skilled attendant" and "skilled attendance" were synonymized under "skilled care"), reduced the extracted terms to 24,077. For the purposes of this research, terms in the term map with a frequency less than 20 in the overall dataset were removed to focus on the most common or frequent terms and concepts occurring the dataset. The final visualized concept term map contained the 378 most frequent terms as mined from the titles and abstracts of publication records. The terms were grouped into three close clusters with high interrelation (Figure 3).

Within publication title and abstracts, terms referencing the MDGs or Millennium Development Goals were the most frequently occurring (n=1,087) mined terms. Other terms in the top 30 most frequently occurring terms (Table 2) were maternal mortality (n=509), women (n=482), mortality (n=471), intervention (n=454), child (n=369), access (n=341), "birth labor" (n=283), community (n=260), and determinant (n=257). Although the term "country" (n=615) as a broad geographic term was in the top occurring terms, Africa (n=204) was the most frequently occurring specific geographic term in result set.

Table 2: Top 30 frequently occurring terms in publication titles and abstracts

Label	Occurrences	Average Publication Year
MDGs	1087	2012.6495
time period	697	2012.7561
country	615	2012.6537
study	583	2013.6192
data	522	2013.4023
maternal mortality	509	2012.6955
women	482	2012.8589
mortality	471	2012.6837
intervention	454	2012.707
progress	423	2012.9669
health	409	2012.6161
analysis	392	2013.6582
child	369	2012.6992

care	368	2012.4728
service	343	2012.6735
access	341	2012.3695
pregnancy	336	2012.8065
level	334	2012.7904
reduction	317	2012.8013
delivery	316	2012.5538
mother	306	2013.0131
strategy	301	2012.6346
use	297	2012.4242
birth labor	283	2012.8834
rate	279	2012.8638
facility	267	2012.9326
effort	264	2012.6667
community	260	2012.5654
need	259	2012.7568
determinant	257	2013.3424

1.9 Author Keyword Map

A map of author-selected keywords (those authors input on submission of their manuscript to a journal) was created to examine what terms authors have assigned their research within this dataset. VOSviewer extracted 1,245 keyword terms. A thesaurus (Appendix D) reduced extracted terms to 1,231. Keywords with fewer than three occurrences were removed leaving 93 keywords of which the 74 most connected were retained for visualization. Keywords for MDG/s were the most frequent (n= 71) followed by keywords for "maternal mortality" (n=66) and "maternal health" (n=46). The average publication years for records including these keywords were 2014.5 and 2015.8 respectively. Also included in the top 30 most frequent terms (Table 3) were geographic references to Africa (ex. Sub-Saharan Africa and Nigeria both had 14 occurrences) as well as references to infant- and child- health (ex. child health (n=13) and "maternal and

child health” (n=11)). Keywords such as health systems (n=10), community health worker (n=9), skilled birth attendant (n=9), determinants (n=8) and equity (n=7) also occurred. Less frequent were epidemiological keywords such as HIV (n=6), postpartum hemorrhage (n=4), or preeclampsia (n=3). Direct keywords for "Millennium Development Goal 5" or "MDG 5" were rare with four occurrences.

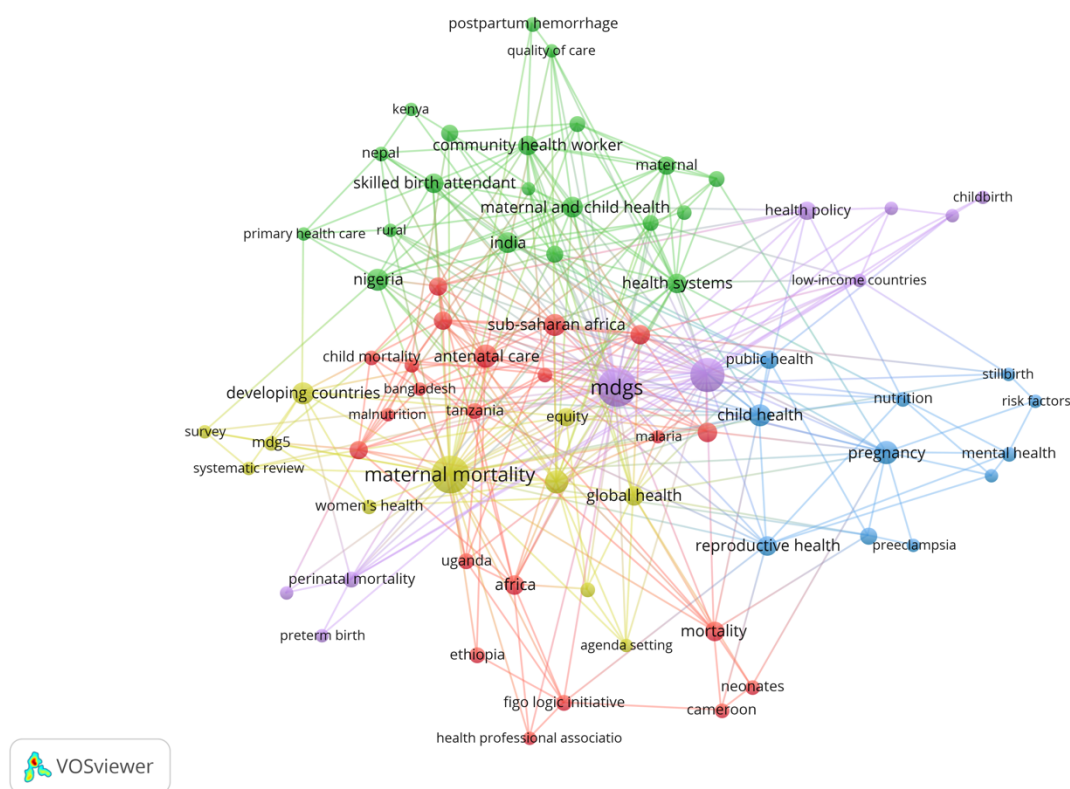
Table 3: Top 30 frequently occurring author selected keywords

Label	Occurrences	Average Publication Year
MDGs	71	2014.6901
maternal mortality	66	2014.5606
maternal health	46	2015.8478
SDGs	16	2017.4375
pregnancy	16	2015.125
antenatal care	16	2014.875
sub-Saharan Africa	14	2015.8571
Nigeria	14	2014.9286
child health	13	2016.7692
developing countries	13	2014.1538
maternal and child health	11	2015.6364
India	11	2014.4545
health systems	10	2016.2
neonatal mortality	10	2015.3
reproductive health	10	2014.7
Africa	9	2015.1111
community health worker	9	2014.8889
Ghana	9	2014.8889
skilled birth attendant	9	2014.7778
global health	9	2013.7778
mortality	9	2013.7778
determinants	8	2016
maternal	8	2016
public health	8	2015.375
health policy	7	2016.5714
under-five mortality	7	2016.4286
infant mortality	7	2016
equity	7	2015.4286

qualitative research	6	2016.1667
HIV	6	2014

A visual examination of the keyword map (Figure 4) showed maternal health closely clustered with MDGs. Maternal mortality, by contrast, was not clustered with and situated slightly farther from MDGs. Within the visualization, relationships could be seen between certain keywords as well as between geographic references and keywords.

Figure 4: Map of author selected keywords (n=74)



For example, maternal mortality, while linked to "skilled birth attendant" was not linked to "community health worker" which was, rather, linked to maternal health. "Community health worker" was also linked to the epidemiological keyword, postpartum hemorrhage. Although neighboring, "skilled birth attendant" and "community health

worker" were not linked directly to one another. The visualization also showed Bangladesh as a keyword closely grouped with keywords related to child and infant health. Similarly, Nigeria was situated near Bangladesh but clustered and linked with both "skilled birth attendant" and "community health worker".

1.10 Medical Subject Heading (MeSH) Map

A map of MeSH terms was created to examine what terms specialists and indexers working within a controlled vocabulary by NLM had assigned to the publications within the dataset. VOSviewer extracted 1,207 MeSH terms for initial visualization. As MeSH were already part of a controlled vocabulary and significant overlap in concept terms was unlikely, no thesaurus was applied to this visualization. Although the number of terms extracted by VOSviewer was similar to the author keyword map visualization, the nature of the terms as part of a controlled vocabulary increased the frequency of occurrence for each term. This led to an extremely dense initial visualization. To address this, terms in the MeSH map with an occurrence frequency less than 10 were removed leaving 226 MeSH in the final visualization and analysis set.

The MeSH terms most frequently used to tag and index the publications in the dataset, in descending order, were: humans (n=1,137), female (n=966), pregnancy (n=663), "infant, newborn" (n=417), and adult (n=395) followed by "maternal mortality" (n=389) and "maternal health services" (n=343). The average publication years for records including "maternal mortality" and "maternal health services" in MeSH were very similar at 2012.3 and 2012.4 respectively.

Table 4: Top 30 frequently occurring MeSH terms

Label	Occurrences	Average Publication Year
humans	1137	2012.5655
female	966	2012.5683
pregnancy	663	2012.463
infant, newborn	417	2012.5084
adult	395	2013.157
maternal mortality	389	2012.3393
maternal health services	343	2012.3907
infant	311	2013.1801
developing countries	266	2011.7256
infant mortality	248	2012.2944
adolescent	244	2013.0041
male	224	2012.7054
young adult	220	2013.8273
child, preschool	216	2012.6481
child	208	2012.8269
global health	190	2012.0895
socioeconomic factors	185	2012.9351
health services accessibility	181	2012.0276
middle aged	180	2013.3778
child mortality	167	2013.0539
maternal welfare	131	2010.8473
prenatal care	130	2013.2692
health policy	125	2012.096
child health services	116	2012.3793
delivery, obstetric	114	2013.2456
cross-sectional studies	113	2013.7257
risk factors	103	2012.6408
rural population	97	2014.0412
goals	90	2013.5444
midwifery	90	2012.2333

Also within the top 30 most frequently occurring MeSH terms (Table 4) were infant (n=311), "developing countries" (n=266), "infant mortality" (n=248), adolescent (n=244), male (n=244), "global health" (n=190), "socioeconomic factors" (n=185),

of links (lines) was reduced (n=500). In the visualization, the cluster of MeSH related to health policies (red) neighbored and overlapped with the cluster of MeSH related to health service accessibility (green). Additionally, terms exist in both that could be equally suited to the other conceptually. For example, "reproductive health services" and "family planning services" were clustered within health policy concepts (red) but could also easily fall in with concepts of health service accessibility (green). Also, conceptually clustered with accessibility are midwifery and "delivery, obstetric". A visual inspection of the blue cluster situated farther from both the policy and accessibility clusters, showed several MeSH terms for specific study types as well as specific pathologies.

1.11 Country Collaboration Network

A collaboration network visualization consisting of the countries for each author as node-data points was created. During operationalization for VOSviewer, some records lacked needed country data (n=181) and were removed leaving 1,122 records (86%) of the original 1,303 for visualization. VOSviewer extracted an initial 139 country labels from author affiliation data. Application of a thesaurus (Appendix E), combining synonymous place terms (ex. "California" was synonymized with "United States") resulted in 124 countries being included. No minimum publication or citation limit was applied. The final visualization was limited to those countries with the greatest interconnection (n=116).

Table 5: Top 30 countries with greatest total link (collaboration) strength

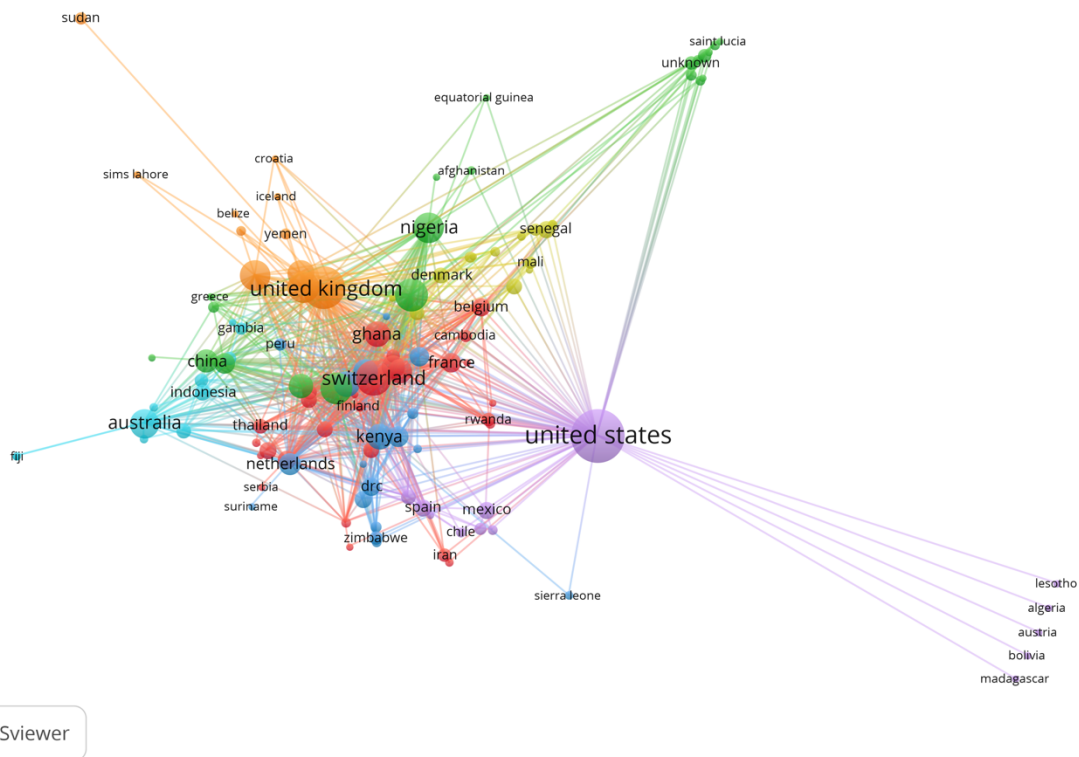
Label	Total Links	Total Link Strength	Total Publications
United States	85	558	378
United Kingdom	71	420	198
Switzerland	51	258	114
South Africa	49	191	93

India	50	164	83
Pakistan	36	142	69
Canada	35	141	85
Kenya	47	126	45
Brazil	37	110	36
Uganda	41	97	32
Australia	38	89	65
Ghana	37	85	46
Nigeria	38	84	68
Netherlands	37	81	29
Bangladesh	29	79	38
Tanzania	32	75	38
China	33	73	31
Sweden	29	72	49
Norway	35	62	25
Belgium	38	62	16
DRC	29	61	17
Germany	35	57	15
Malawi	22	55	19
Italy	29	51	11
Philippines	30	51	11
Ethiopia	24	47	41
France	33	45	19
Egypt	30	44	10
New Zealand	29	44	8
Argentina	24	40	9

Within the country collaboration visualization, the United States was the producer of the majority publications (n=378, 29%) in the retrieved dataset. In descending order, the United Kingdom (n=198, 15%), Switzerland (n=114, 8.7%), South Africa (n=93, 7%), and Canada (n=85, 6.5%) were the other major producers of publications. In terms of collaboration, within the top 30 countries with the greatest link strength (Table 5), the United States (n=558), United Kingdom (n=420), Switzerland (n=258), and South Africa (n=191) were also at the top.

Canada (n=141) followed India (n=164) and Pakistan (n=142). Kenya (n=126), Brazil (n=110), Uganda (n=97), Australia (n=89), Ghana (n=85), Nigeria (n=84), the

Figure 6: Collaboration Network of Author Countries (n=116)

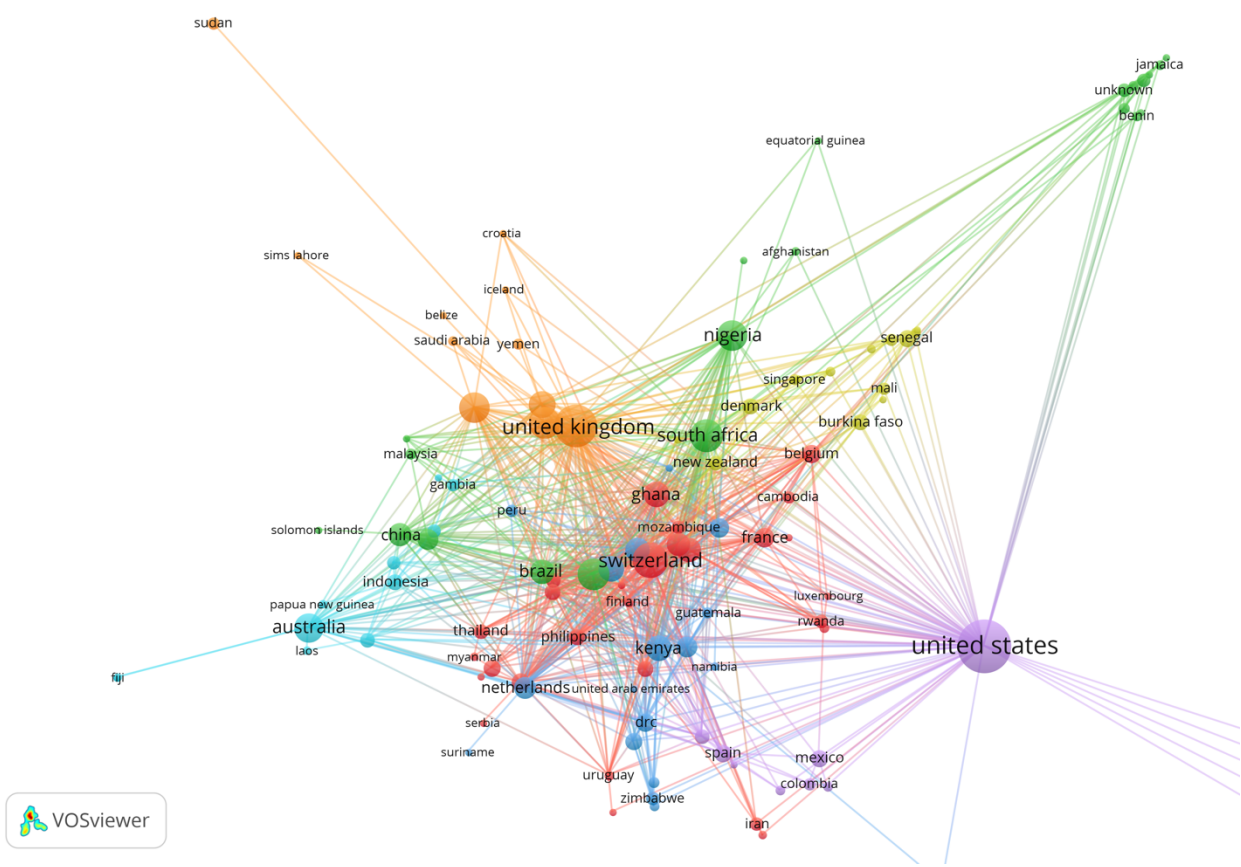


Netherlands (n=81), Bangladesh (n=79), and Tanzania (n=75) were also in the top 30.

A visual analysis of the collaboration network (the size of nodes representing the number of publications and the lines illustrating collaborations) showed a strong cluster of countries with Switzerland at the center (Figure 6). The United States was situated somewhat outside the main cluster and connected with a handful of otherwise unlinked countries. A cluster of African countries was also situated within the larger cluster (Figure 7).

Lastly, Australia was shown outside the major cluster (similar to the United States) and connected with several South East Asian countries. Yet, Singapore and African countries such as Mali, Burkina Faso, and Nigeria were situated more closely to and clustered with South Africa.

Figure 7: Main Cluster of Collaboration Network of Author Countries (n=116)



Discussion

The publication dataset for this research was generated based on a search completed by de Groot et al. (2015) as part of a longitudinal analysis of maternal mortality literature. For the purposes of this research, the search included increased synonymy for maternal mortality and maternal health terms. Terms for the MDGs were also added to narrow retrieved publications to those specifically referencing one or more of the MDGs in relation to maternal mortality and health. Various facets of the resulting data were analyzed via VOSviewer output tables and visualizations. The following section is a discussion of the results found in this research.

To be inclusive of the importance of addressing the needs of transgender reproduction and health, this discussion uses the phrase "women and people who give birth".

1.12 Impact of MDGs and MDG 5 on Maternal Health Research Publication

The findings in this dataset followed and substantiated the previous findings of de Groot et al. (2015) showing a similar substantial yearly increase in the volume of maternal mortality and health publishing. Based on these similar findings, it is highly likely the adoption of MDG 5 and MDGs related to maternal health and mortality as informal science policy led to increased research and publication on the topic. To prove this conclusively, research would need to statistically decouple these increases from the overall increase in research publishing in the 21st century.

In both findings, the increase in publication volume was not explosive as compared to the response to the call for ZIKA research. There are several potential and confounding reasons for this. The gradualness of publication volume increase on this topic may indicate a perception of maternal mortality and health as non-acute issues despite the adoption of MDG 5. Why maternal mortality and health may not be perceived as an acute topic is open for discussion. However, based on the social morays that inhibited various gender equality-based aspects of MDG 5 and the historical emphasis on Western paternalistic interventions (Hulme, 2010b; McPherson, 2016), social analysts may suspect political and, therefore, science policy deprioritization of this issue due to its solely impacting women and people who give birth.

Another reason may be the inherent complexities of the social, economic, and environmental aspects of maternal health problematizing straightforward intervention finding by the biomedical research community. Recognition and acknowledgement of the necessity of addressing barriers to access in maternal health interventions as part of research and publication will require development of more interdisciplinary teams and collaborations (such as place-based collaborations) as well as methods. This may subsequently increase the time to research completion and publication and decrease annual volume.

There are other potential variables including increases and decreases in funding for maternal health research that may likely have influenced these trends. For example, the Bill and Melinda Gates Foundation increased funding support for maternal, neonatal, and child health before and even more substantially after 2009 (Bill and Melinda Gates Foundation, 2009). The 2009 document describing the goals of the Gates Foundation in

relation to maternal, neonatal, and child health directly references MDGs 4 and 5. The document also alludes to unlikelihood of those MDGs being met. Therefore, the Gates Foundation as a major funder of maternal health research may themselves be considered as having been inspired or catalyzed to some extent by the adoption of MDG 5 and related MDGs, equally using the targets and frameworks as foundational perspectives to approaching maternal mortality and health research. Although an analysis of maternal health research was beyond the scope of this research, a brief examination of the grant tracking webpage for the Gates Foundation (<https://www.gatesfoundation.org/How-We-Work/Quick-Links/Grants-Database#q/sortdir=asc>) on March 7, 2020 showed the total number of grants related to Maternal, Neonatal, and Child Health programs peaked in 2015 (57 total awarded grants), then decreased by nearly half in 2016 (26 awarded grants) and fluctuating between 33 and 44 awarded grants thereafter.

After peaking in 2013 (the end year of de Groot et al.'s publication dataset), MDG 5 related maternal health publication volume began to drop off more rapidly than its original growth. The lateness of this peak in the MDG implementation period was an interesting element of these results. Had the adoption of MDG 5 and related MDGs catalyzed an immediate search for novel interventions (as with ZIKA) to prevent maternal mortality and increase maternal health, a rapid increase in the publication volume in the first four to five years would be expected. Counter to this assumption, these results may indicate MDG 5 associated maternal mortality and health publications consisted of summative reporting of trialed interventions near the end of implementation period rather than formative intervention recommendations meant to guide intervention administrators. While the potential emphasis was unexpected, such a body of evidence

could only be useful for informing implementation of the SDGs related to maternal health.

Lastly, it is worth noting the parallel, yet some somewhat later and slower, entry of full-text access publications in the dataset. The lag in the increase in these publications in comparison to the overall results may indicate a barrier in the publishing process. The limitations of accessing published evidence behind a subscription-based paywall is well documented. The prohibitive costs for researchers wishing to publish their work in open access is equally documented (Solomon & Björk, 2012). Therefore, cost might have been a factor in the lag and comparatively small volume of full-text accessible publications. Other potential factors may account for this. However, further research is required to reach any conclusions.

1.13 Comparison of Mined Terms, Author Keywords, and MeSH

A comparison of the terms mined from publication titles and abstracts, author-selected keywords, and applied MeSH terms presented interesting characteristics about the topical nature of the publications in the dataset. References to the Millennium Development Goals were the most frequently occurring terms and keywords in publication titles and abstracts as well as author keywords.

In all three sets, "maternal mortality" was found in the top ten most frequently occurring terms perceivably suggesting an emphasis on interventions addressing MDG 5's first target (to reduce maternal mortality by three quarters between 1990 and 2015) and indicator (reduce the maternal mortality rate). In contrast, term occurrence and synonymy (number of variation terms for a similar concept) for "maternal health" and "reproductive health" were less frequent in all three sets. Terms for contraception and

abortion ("abortion, induced" can be seen in the red cluster of the MeSH map) were very infrequent, if they appeared at all. The delay in adding MDG 5's second target and indicators (September 2005) may account for the greater frequency of maternal mortality over maternal health terms. However, the majority of publications in this dataset were published after 2005. Therefore, a general emphasis on the reduction of pregnancy-related death over preventative health interventions within MDG associated maternal health research is likely. Although less frequent, the emphasis on the first target is also supported by the appearance of terms for skilled birth attendance, health services, facilities and others related to the second indicator for MDG 5's first target, to increase the number of births attended by skilled health personnel.

Between the three sets, specific geographic references such as country or region names were most common in the author-selected keywords. This suggests authors are likely to identify places where research has taken place or been focused on in their selected keywords. Due to frequency calculations, place names appeared less frequently in term text-mined from titles and abstracts. This was likely because authors were more likely to use common concept terms than common place terms in abstract writing. Interestingly, place names were also uncommon in the MeSH maps and table despite a comprehensive list of available place names in the controlled vocabulary. Within this dataset, place names in sub-Saharan Africa were collectively most frequent in occurrence (n=73) but also included India (n=11), Nepal (n=4), and Bangladesh (n=3). There were no appearances of South American, Southeast Asian, or Oceanic place names in the author keywords. In terms of systematic searching practices, this finding is valuable when seeking place-based research.

1.14 Women and Neonatal Health

The results in the terms mined from publication titles and abstracts, author-selected keywords, and MeSH indicated an emphasis on public health aspects of maternal mortality and health. This also aligned with findings by de Groot et al. (2015). However, these emphases in the literature and their association with individual MDG 5 targets and indicators provided an interesting analysis.

Related to pregnancy prevention and contraception, there was a lack of separation between the health of women or people who may give birth and neonate or child health in two (MeSH and author keywords) of the three sets. Simply, there was a perceivable lack of acknowledgement of women outside the state of motherhood. In the MeSH set and visualization in particular, three of the top ten most frequent terms were related to infants and newborns ("infant, newborn", infant, and "infant mortality"). In the author keywords set, the term "maternal and child health" specifically conjoins the two, making women and children an inseparable concept. In each of the three term maps, references to neonatal, infant, or child health are present (at the center of their own cluster (blue) in the text-mined term map) and interrelated with maternal health and mortality. It could be argued this was simply due to the nature of maternity and its necessitation of viewing the health of women and neonates as biomedically interrelated and often interdependent. Yet, contraception and pregnancy prevention are an acknowledged and key part of ensuring both future and continuing maternal health by development researchers and in MDG 5 second target indicators, 5.3 increase the contraceptive prevalence rate, 5.4 reduce adolescent birth rate, 5.6 reduce unmet need for family planning. However, based on the term maps and tables, there is far less emphasis on this aspect of maternal health. This is perhaps because these indicators and the challenge of contraception and pregnancy

prevention are those that are most effected by the social barriers of patriarchal gender roles and sexism. These indicators are also those least addressable by strictly biomedical interventions and will require extensive social and placed-based planning to affect access to contraception and pregnancy prevention. Equally, research literature addressing contraception and pregnancy prevention measures would have required extensive social analysis. As the social facets of maternal health are often unacknowledged in literature (Gil-González et al., 2006; van den Broek & Falconer, 2011), the maternal health publications in this dataset appeared to follow this pattern and interventions that address these indicators were underrepresented despite publications generally coming later in the implementation period after the addition of the second target.

In comparison, the second indicator of the first target (5.2 Increase the number of births attended by skilled health personnel) and third indicator of the second target (5.5 Increase antenatal care coverage), were in far more evidence in the term maps and tables. Similarly, in all three sets "pregnancy" is a frequently occurring term, being in the top 10 in the MeSH and author keyword sets and in the top 20 in the title/abstract terms. This again suggests a focus in the literature on health care beginning at pregnancy and even more so on interventions for birth-related complications leading to maternal death rather than on long-term maternal health or health for women and people who give birth as individuals. Overall, this may indicate that research trends are only selectively responsive to informal policy goals.

1.15 International Collaboration

The collaboration network and table followed the trend of larger publication volume from Western HICs. However, the network visualization provided a deeper

perspective on international author collaboration within this data set. In the visualization, several LMICs impacted by maternal health challenges were centrally located. Similar to the author-keyword place names, a number of the countries with the greatest total collaboration strength from sub-Saharan African as well as India and Bangladesh were represented. Nepal was also a collaborator visible and situated near China in the visualization. A range of South American and Middle Eastern countries were also represented in addition to European and North American countries.

Interesting relationships were also present within the visualized network. Many countries impacted by maternal mortality and poor maternal health were interconnected. For example, Ghana, Mozambique, Tanzania, and Kenya were all closely situated (red cluster) suggesting high collaboration between the countries. To some extent, similar proximity-based geographic collaboration networks were visible. The close situation and clustering of Australia, Papua New Guinea, and Indonesia was unsurprising.

Broader international collaborations appear to have common HIC dominators. The United States had the greatest volume of publications and was located away from the rest of the main cluster in part due to the five countries (Lesotho, Algeria, Austria, Bolivia, and Madagascar) that did not collaborate with authors from other countries in this dataset. At the center of the visualization, Switzerland also appeared as an interconnector in maternal health literature associated with MDG 5, particularly among Southeast Asian countries. It is highly likely Switzerland's positioning and high collaboration was due to the World Health Organization and other agencies being headquartered there.

In this dataset, the majority of publications were co-authored by HIC researchers. However, the visualized network illustrated several collaborations between LMICs. Based on findings by other researchers, these collaborations are likely to have been initiated by HIC researchers. However, the close interrelation between several LMICs equally suggested place-based collaborations may grow out of the original collaborations in the future. In the future, it would be interesting to execute similar analyses on literature associated with the current SDGs and provide a comparison of the changes in collaboration network structures.

1.16 Open Bibliometrics Process

This research trialed an open bibliometrics approach to discovering previously undiscovered public knowledge about maternal health publications associated with MDG 5 via bibliometric analysis. The process of this approach involved identifying both a publication data source and tools that were openly and publicly accessible. In this case, PubMed was identified as the data source and VOSviewer as the analysis tool. Additionally, PubMed2XL was also used to extract data from the PubMed output.

During the execution of this research, the NLM began transitioning from what is now called Legacy PubMed to the new version of the PubMed interface with different retrieval aspects. When the dataset used here was downloaded, it was retrieved as a MEDLINE .txt file whereas now users are able to download a variety of file types. However, none of the file types were ideal for open bibliometrics if the goal was collaboration network analysis. This was because these files often did not contain affiliation data. As of this writing, the MEDLINE .txt. file was not available as an output in the new PubMed interface. In the future, needed affiliation data may be gained through

an API (application programming interface). In the case of this research, PubMed2XL was an open license (via MIT) and was a useful tool for extracting needed data. Unfortunately, the developer stopped supporting the application shortly after this research was completed.

VOSviewer as an analysis and visualization tool proved easy to use and well supported by the creators. Its analyses were somewhat limited and required visual analysis by the research to give meaning to maps and network visualizations. Although outside the scope of this research, the output files were more quantitatively useful and could provide excellent data for statistical analysis. The interface was overall simple and intuitive. Further, VOSviewer visualizations in their interface entirety could be put online to be explored by viewers and stakeholders, increasing its value as an open source tool that furthers open access.

While the data source and tools used proved adequate for this research, significant time and effort was required to clean and operationalize data for the collaboration analysis and visualization in a relatively small dataset. These were not the most valuable aspects of this research. Rather, the comparative analyses of the text-mined terms, author keywords, and MeSH provided ample material for analysis with very little time dedicated to cleaning and operationalization.

Conclusions

This research completed a bibliographic analysis and mapping to find characteristic and trends in maternal mortality and health literature associated with MDG 5. Rather than an explosion of literature referencing MDG 5 and related MDGs soon after their adoption, rapid growth in literature occurred near the end of the MDG implementation period. This suggested the publications in this dataset and in response to MDG 5 were largely summative reporting on interventions. Based on comparative analyses of terms text-mined from publication titles and abstracts, author-selected keywords, and applied MeSH terms several interesting characteristics were discerned. While there was emphasis on public health aspects of maternal health, the literature was still largely concerned with maternal mortality over maternal health per se. Specifically, literature in this dataset focused on the first target of MDG 5 and less so on the second. The second target and its indicators were far more impacted by social barriers to contraceptive access likely reflecting a lack of biomedical attention due to the ineffectiveness of strictly biomedical interventions. This research also illustrated interesting aspects of bibliometric analysis. For example, author keywords were anecdotally more likely to contain references to the countries the research was completed in or focused on than the title and abstract terms or MeSH. An analysis of author country collaborations also showed international collaboration as likely still being directed by HICs but with several developing place-based collaborations growing. Lastly, this

research demonstrated an open bibliometric approach using open data sources and tools yields valuable knowledge.

Limitations

There are several limitations to this research. This includes limited data cleanliness within the given period. Term mapping via text mining of titles and abstracts assumes the accuracy of their descriptiveness relation to their respective articles and texts. For the purposes to this research, keywords, titles, and abstracts were assumed sufficiently representative of the topic of maternal health as a whole if not of their respective publications. It is also impossible to prove the collected data included every publication related to or generated due to the adoption of MDG 5 despite using a systematic search approach. In this same vein and related to article descriptions, not all publications inspired by MDG 5 may have made mention of this in the title, abstracts, or keywords. These publications were not included as part of this analysis. However, the publications that were collected and analyzed for research can be considered a representative subset of maternal health literature produced after the adoption of the MDGs and MDG 5 in particular.

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Appendix A: Sustainable Development Goals

- Goal 1: End poverty in all its forms everywhere
- Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture
- Goal 3: Ensure healthy lives and promote well-being for all at all ages
- Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- Goal 5: Achieve gender equality and empower all women and girls
- Goal 6: Ensure availability and sustainable management of water and sanitation for all
- Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all
- Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
- Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 10: Reduce inequality within and among countries
- Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable
- Goal 12: Ensure sustainable consumption and production patterns
- Goal 13: Take urgent action to combat climate change and its impacts*
- Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

Goal 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Appendix B: Search Strategy

Set #	Search	Results
1 MDGs	(millennium[tw] AND development[tw] AND (goal[tw] OR goals[tw])) OR MDG[tw] OR MDGs[tw]	3,303
2 Maternal/maternity	"Maternal Death"[Mesh] OR "Mothers"[Mesh] OR "Postpartum Period"[Mesh] OR "Postnatal Care"[Mesh] OR "Parturition"[Mesh] OR "Obstetrics"[Mesh] OR "Pregnancy"[Mesh] OR mother[tiab] OR mothers[tiab] OR maternal[tiab] OR maternity[tiab] OR postnatal[tiab] OR "post-natal"[tiab] OR prenatal[tiab] OR "pre-natal"[tiab] OR perinatal[tiab] OR "peri-natal"[tiab] OR antenatal[tiab] OR "ante-natal"[tiab] OR postpartum[tiab] OR "post-partum"[tiab] OR parturition[tiab] OR obstetrics[tiab] OR obstetric[tiab] OR pregnancy[tiab] OR pregnancies[tiab] OR pregnant[tiab] OR impregnate[tiab] OR impregnated[tiab]	1,313,140
3	1 AND 2	1,303

Appendix C: Term Map Thesaurus

label	replace by
accessibility	access
availability	access
African country	Africa
Sub Saharan Africa	Africa
ANC	antenatal care
birth	birth labor
childbirth	birth labor
exclusive breastfeeding	breastfeeding
case	case study
child health service	child health
child death	child mortality
child mortality rate	child mortality
childhood mortality	child mortality
data collection	data
factor	determinant
social determinant	determinant
effective intervention	intervention
health facility	facility
focus group discussion	focus group
financing	funding
unmet need	gap
Bill & Melinda gates foundation	gates foundation
governance	government
policy	health policy
child transmission	HIV aids
HIV	HIV aids
infant mortality rate	infant mortality
infectious disease	infection
institutional delivery	institution
intervention coverage	intervention
depth interview	interview
livebirth	live birth
maternal death	maternal mortality
maternal morbidity	maternal mortality
maternal mortality rate	maternal mortality
maternal mortality ratio	maternal mortality

MMR	maternal mortality
goal	MDG
fourth millennium development goal	MDG4
fifth millennium development goal	MDG 5
MDG	MDGs
millennium development goal	MDGs
millennium development goals	MDGs
united nations millennium development goal	MDGs
measurement	measure
death	mortality
morbidity	mortality rate
mortality	mortality rate
MNCH	mother and newborn health
neonatal care	neonatal health
neonatal death	neonatal mortality
neonatal mortality rate	neonatal mortality
stillbirth	perinatal mortality
newborn care	newborn health
newborn death	newborn mortality
emergency obstetric care	obstetric care
obstetric	obstetric care
AOR	odds ratio
odd	odds ratio
percentage	percent
plan	planning
post	post care
pregnant woman	pregnancy
programme	program
MEDLINE	PubMed
significant reduction	reduction
risk	risk factor
rural area	rural
SDG	SDGs
sustainable development goal	SDGs
facility delivery	skilled care
skilled attendance	skilled care
skilled attendant	skilled care
skilled birth attendance	skilled care
skilled birth attendant	skilled care

august	time period
date	time period
day	time period
December	time period
hour	time period
January	time period
July	time period
June	time period
March	time period
recent year	time period
September	time period
time	time period
year	time period
year period	time period
universal access	access
utilization	use
woman	women

Appendix D: Author Keyword Map Thesaurus

label	replace by
community health workers	community health worker
social determinants of health	determinants
maternal death	maternal mortality
maternal death review	maternal mortality
maternal mortality rate	maternal mortality
maternal mortality ratio	maternal mortality
millennium development goal 5	MDG 5
MDG	MDGs
millennium development goal	MDGs
millennium development goals	MDGs
millennium development goals (MDGs)	MDGs
neonatal deaths	neonatal mortality
skilled birth attendants	skilled birth attendant
sustainable development goals	SDGs
under-5 mortality	under-five mortality

Appendix E: Country Collaboration Network Thesaurus

label	replace by
&	unknown
care	unknown
California	United States
cape	South Africa
Islamabad	Pakistan
Maryland	United States
Massachusetts	United States
PAHO	organization
The World Bank	organization
UNICEF	organization
world bank	organization
USA	united states
health	organization
planning	organization
not available	unknown
Enugu	Nigeria
Paulo	Brazil
Congo	DRC
Democratic Republic Congo	DRC
Russian federation	Russia