Human Development Index of the maternal country of origin and its relationship with maternal near miss: A systematic review of the literature

Santiago García-Tizón Larroca1*, Francisco Amor Valera1, Esther Ayuso Herrera1, Ignacio Cueto Hernandez1, Yolanda Cuñarro Lopez1 and Juan De Leon-Luis1,2

Abstract

Background: The reduction in maternal mortality worldwide has increased the interest in studying more frequent severe events such as maternal near miss. The Human Development Index is a sociodemographic country-specific variable that includes key human development indicators such as living a long and healthy life, acquiring knowledge, and enjoying a decent standard of living, allowing differentiation between countries. In a globalised environment, it is necessary to study whether the Human Development Index of each patient’s country of origin can be associated with the maternal near-miss rate and thus classify the risk of maternal morbidity and mortality.

Methods: A systematic review of the literature published between 2008 and 2019 was conducted, including all articles that reported data about maternal near miss in their sample of pregnant women, in addition to describing the study countries of their sample population. The Human Development Index of the study country, the maternal near-miss rate, the maternal mortality rate, and other maternal-perinatal variables related to morbidity and mortality were used.

Results: After the systematic review, eighty two articles from over thirty countries were included, for a total of 3,699,697 live births, 37,191 near miss cases, and 4029 mortality cases. A statistically significant (p <0.05) inversely proportional relationship was observed between the Human Development Index of the study country and the maternal near-miss and mortality rates. The most common cause of maternal near miss was haemorrhage, with an overall rate of 38.5%, followed by hypertensive disorders of pregnancy (34.2%), sepsis (7.5%), and other undefined causes (20.9%).

Conclusions: The Human Development Index of the maternal country of origin is a sociodemographic variable allowing differentiation and classification of the risk of maternal mortality and near miss in pregnant women. The most common cause of maternal near miss published in the literature was haemorrhage.

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Keywords: Maternal near miss, Maternal mortality, Human Development Index, Immigrants

* Correspondence: gineteca@gmail.com
1Maternal Fetal Medicine, Department of Obstetrics and Gynaecology, HGUGM, Calle O'Donnell, 48, Planta 0, 28009 Madrid, Spain
Full list of author information is available at the end of the article
Background
Worldwide, over 1500 women die every day due to complications of pregnancy or childbirth. It is possible that most of these deaths could be prevented if the women were in countries other than their countries of origin. Although the Millennium Development Goal of reducing maternal mortality (MM) by 75% between 1990 and 2015 has not been achieved globally, significant progress has been made; in many countries, maternal health has improved significantly, and the goals for 2030 are to achieve MM rates of less than 70 per 100,000 live births and to increase the proportion of births attended by skilled health personnel [1]. One of the Millennium Development Goals set in 2000 by the member countries of the United Nations is to improve the health of women through multiple interventions, such as promoting access to family planning services and emergency obstetric care by qualified and trained personnel. In this respect, women in low-income countries are especially vulnerable to dying from obstetric causes. The World Health Organization, through its “Global Strategy for Women’s, Children’s and Adolescents’ Health (2016-2030),” is analysing relevant indicators and scores to improve the survival of newborns and pregnant women. Although the world has made substantial progress on these two issues, the decline in maternal and neonatal mortality has recently slowed down. Moreover, in 2017-2019, the Quality of Care Network group supported by the WHO included more countries – such as Ethiopia, Ghana, India, Malawi, Nigeria, Tanzania and Uganda – on its agenda to complete the following tasks:

- Accelerate action by adapting the WHO’s standards for improving the quality of maternal and newborn care in health facilities at the country level.
- Foster learning and generate evidence on quality of care through a learning platform.
- Develop and support institutions and mechanisms that will ensure accountability for quality of care by designing a national accountability framework.

Traditionally, the analysis of maternal deaths has been the approach of choice for evaluating women’s health and the quality of obstetric care. However, due to the success of modern medicine, such deaths have become very rare in developed countries, which has led to an increased interest in analysing so-called “near miss” events. The World Health Organization defines a maternal near miss (MNM) as “a woman who nearly died but survived a complication that occurred during pregnancy, childbirth or within forty-two days of termination of pregnancy”. A MNM is also assumed to be a better indicator than MM alone when designing, monitoring, following-up and evaluating safe motherhood programmes [2]. Year after year, increasingly more authors are interested in publishing MNM events that occur in their countries, and it is necessary to analyse morbidity and mortality data over the past decade to compare situations in different countries.

Haemorrhage, hypertensive disorders of pregnancy, and infections stand out as the direct causes of more than 70% of both MNM and mortality. In all these cases, the lack of care or access to care, the high cost of health care or its poor quality, and the variation among different countries results in 1 million maternal orphans every year, and these children are also more likely to die during the years following their mother’s death.

For years, gross national income per capita has been used to weigh differences among countries; however, in the 1990s, the WHO introduced the Human Development Index (HDI) as a sociodemographic variable to help differentiate countries, thus avoiding reliance on the purely economic value of each nation and trying to classify the world population in homogeneous groups through more comprehensive indicators.

This index has helped the WHO to establish different strategies to end preventable maternal morbidity and mortality; its use is increasingly widespread in the medical literature, where a very high HDI is typical of countries with more resources. Tuncalp is the first author to relate the HDI of the maternal country of origin to severe maternal outcomes such as MNM and MM with data from countries in Africa, Asia, Latin America, and the Middle East. That author describes a significant relationship between mothers from countries with medium and low HDIs; women in those countries are shown to have a risk of maternal complications that is 2-3 times higher than for women from countries with high HDIs [3].

Using the HDI of pregnant women from other countries and assessing the influence of HDI on maternal-perinatal health in our country, Spain, a previous study conducted by our team [4] observed an increased risk of adverse maternal-perinatal events in pregnant women from low-HDI countries compared to women originating from countries with higher HDIs. Similarly, Luque-Fernandez et al. [5], analysing the trend of stillbirth in Spain, showed an increased risk of stillbirth, approximately three times higher, in pregnant women from low-HDI countries. For both authors, incorporating HDI improves the characterisation of the maternal socio-economic level by introducing the HDI of the maternal country of origin and maternal educational attainment to population analysis, producing a fuller analysis compared to those studies that only include the country of origin of immigrant pregnant women.

In this study, we will consider the HDI of the place of publication (as a proxy measure like that used in the study on immigration) and determine the relationship with adverse maternal-perinatal outcomes.
The aim of this study is to conduct a systematic review of the articles published over the last decade reporting severe acute maternal morbidity. We use as a reference the HDI of the country where the study was conducted—which directly reflects the HDI of its population of pregnant women—to analyse its relationship with relevant adverse maternal-perinatal outcomes during pregnancy, childbirth, and the postpartum period, such as MNM and MM.

Methods

Protocol, eligibility criteria, information sources and search strategies

This review was performed according to an a-priori-designed protocol recommended for systematic reviews. PRISMA [6] and MOOSE guidelines were followed [7]. The study was registered in the PROSPERO database (registration number: CRD 42019133464). The systematic literature search was conducted in two electronic databases, PubMed/MEDLINE and EMBASE, utilising combinations of the relevant medical subjects by MeSH terms with the following keywords: “near miss” or “morbidity” and “pregnancy” or “mothers” or “pregnancy outcome”. The search period was between 17/02/2008 and 17/02/2019. A reference database (EndNote X7, Thomson Reuters) was used to incorporate all references.

The inclusion criteria were as follows:

- studies published between 17/02/2008 and 17/02/2019;
- studies conducted with humans;
- studies in English, both the abstract and the main text; and
- studies that included MNM analysis in their study population.

The exclusion criteria were as follows:

- studies with scarce information about the study population, such as country of origin, or studies investigating specific ethnic, racial, or immigrant groups;
- published articles that did not report data on MNM or those on maternal morbidity events not meeting MNM criteria according to the WHO;
- systematic reviews, expert opinions, and intervention studies without quantitative data about the MNM rate; and
- studies conducted on the same patient cohort. In these cases, we selected the most up-to-date patient cohorts and excluded secondary analysis studies on the same sample.

Study selection

Titles and abstracts of the search results were screened by two researchers independently (SGTL and FAV). If the title and abstract did not provide useful information for the review or was irrelevant, the articles were eliminated from the analysis. Potentially eligible studies were assessed in full-text format. Any disagreement on the eligibility of studies was resolved through discussion and joint assessment until consensus was reached between the two researchers.

Data collection and data items

Data were extracted using an appraised extraction form. Each reviewer collected the data independently, and discrepancies between them were resolved by the two authors checking the study against the form. The review authors were not blinded to the journal or author details. Extracted data included the name of the first author and year of publication, first and last year of the study, study period, country or countries where the study was conducted, HDI group to which the study country belongs, and the HDI score of the study country.

The HDI is a summary measure of a country’s average level of achievement in the following major dimensions of human development: living a long and healthy life, being educated, and having a decent standard of living. Life expectancy serves as an indicator of the health dimension; standard of living is measured in terms of gross national income per capita; and education level is evaluated as the average number of years of schooling among adults aged twenty-five years and older and expected number of years of schooling among children [8].

A country obtains a higher HDI score when its population has a higher life expectancy, education level, and gross national income (GNI) per capita; these scores are reported within the annual Human Development Report published by the United Nations Development Programme (UNDP) [9]. The UNDP divides countries into four broad categories of human development: group 1 (very high HDI), group 2 (high HDI), group 3 (medium HDI), and group 4 (low HDI) based on the numerical score obtained, with a minimum of 0 and a maximum of 1.

Other maternal-perinatal variables included in the study were type of study (single- or multi-centre), study design, total number of live births (LBs), number of MNM events in the study, rate of MNM/1000 LBs, number of maternal mortality events, rate of MM/100,000 LBs, percentage of MNM due to haemorrhage, percentage of MNM due to hypertensive disorders of pregnancy, percentage of MNM due to sepsis, percentage of MNM due to other causes, MNM in the immigrant population, MNM by ethnic group, maternal age at MNM, percentage of primiparous mothers in the MNM group, parity in MNM, percentage of births <37 weeks gestation in the MNM group, caesarean section rate in the MNM group, and neonatal near miss.
In the case of multicountry studies, the average HDI score given by the HDI scores of all included countries was calculated.

After data collection, the data were ordered according to the publication year.

Risk of bias assessment and statistical analysis
The risk of bias was assessed independently by both authors, who determined the adequacy of compliance with the inclusion criteria. The items assessed were correct description of MNM cases, complete reporting of proportion and type of near miss in the case group, and adequate description of the country or countries where the study was carried out. We tried to choose strict eligibility criteria to achieve a good number of studies that were as homogeneous as possible and thereby extract concrete and valid conclusions.

The quality of the evidence of the studies included was assessed according to the Grade of Evidence Working Group Criteria [10].

Statistical analyses were carried out using STATA, version 13.1 (Stata Corp., College Station, TX, USA) in its default settings. The results are expressed as rates (%) for dichotomous variables, and we calculated 95% confidence intervals (95% CIs). We tried to perform a quantitative synthesis with pooled relative risks and 95% confidence intervals (95% CI), but a meta-analysis was not feasible given the lack of a control group and the heterogeneity of the available studies.

Results
Figure 1 describes the workflow process. As shown, the initial search identified 4842 articles in the databases. After screening and applying the eligibility and exclusion criteria in the final phase of the records, eighty-two articles were selected. A total of 3,699,697 LBs, 37,191 near miss cases and 4029 mortality cases were reported, representing the population analysed in this systematic review.

Table 1 describes the results obtained in each study for the different variables analysed in the review. Over 90% of the studies were led by different authors; among those who led in publishing, the author who published the most studies in the period included in this analysis of MNM was Jayaratnam, with four. Of all the articles, sixty-two (75.6%) have been published since 2014, and the study by Okusanya et al. [53] (reference) included...
| Authors            | Publication Year | First Year | Last Year | Period Years | Country   | HDI Group | HDI score | Study Type | Study Design               | Total live births | MNM cases | MNM rate |
|--------------------|------------------|------------|-----------|--------------|-----------|-----------|-----------|------------|----------------------------|--------------------|------------|----------|
| Adisasmita et al.  | 2008             | 2003       | 2004      | 1            | Indonesia | 3         | 0.694     | multi-centre | Retrospective longitudinal | 5669              | 763        | 1346     |
| Driul et al.       | 2008             | 1998       | 2008      | 10           | Italy     | 1         | 0.88      | single-centre | Retrospective longitudinal | 18936             | 95         | 5.0      |
| Roost et al.       | 2009             | 2006       | 2007      | 1            | Bolivia   | 3         | 0.693     | single-centre | Retrospective longitudinal | 8136              | 401        | 49.3     |
| Almerie et al.     | 2010             | 2006       | 2008      | 2            | Syria     | 4         | 0.536     | single-centre | Retrospective case-control | 28025             | 901        | 32.1     |
| Shrestha et al.    | 2010             | 2009       | 2009      | 1            | Nepal     | 3         | 0.574     | single-centre | Retrospective longitudinal | 1562              | 36         | 23.0     |
| Souza et al.       | 2010             | 2005       | 2005      | 1            | Multicountry | 0.745     | multi-centre | Retrospective longitudinal | 97095             | 2964       | 34.0     |
| Ali et al.         | 2011             | 2008       | 2010      | 2            | Sudan     | 4         | 0.502     | single-centre | Retrospective cohort      | 9578              | 205        | 21.4     |
| Amaral et al.      | 2011             | 2005       | 2005      | 1            | Brazil    | 2         | 0.759     | single-centre | Retrospective longitudinal | 4491              | 95         | 21.1     |
| Donati et al.      | 2011             | 2004       | 2005      | 1            | Italy     | 1         | 0.88      | multi-centre | Retrospective longitudinal | 539382             | 1259       | 2.3      |
| Jayaratnam et al.  | 2011             | 2009       | 2010      | 1            | Australia | 1         | 0.939     | single-centre | Prospective longitudinal | NR               | 17         | 6.0      |
| Kaye et al.        | 2011             | 2010       | 2010      | 1            | Uganda    | 4         | 0.516     | single-centre | Prospective cohort        | 140               | 21         | 1500     |
| Lobato et al.      | 2012             | 2008       | 2008      | 1            | Brazil    | 2         | 0.759     | single-centre | Retrospective review      | 1163              | 27         | 23.2     |
| Souza et al.       | 2012             | 2009       | 2010      | 1            | Brazil    | 2         | 0.759     | multi-centre | Retrospective longitudinal | 82388             | 770        | 9.3      |
| Adeoye et al.      | 2013             | 2006       | 2007      | 1            | Nigeria   | 4         | 0.532     | multi-centre | Prospective case-control  | 375               | 75         | 2000     |
| Jabir et al.       | 2013             | 2010       | 2010      | 1            | Iraq      | 3         | 0.685     | multi-centre | Cross-sectional           | 25472             | 129        | 5.1      |
| Karolinski et al.  | 2013             | 2008       | 2009      | 1            | Argentina | 1         | 0.825     | multi-centre | Cross-sectional           | 65033             | 518        | 8.0      |
| Nelissen et al.    | 2013             | 2009       | 2011      | 2            | Tanzania  | 4         | 0.538     | single-centre | Prospective longitudinal  | 9136              | 216        | 23.6     |
| Roopa et al.       | 2013             | 2011       | 2012      | 1            | India     | 3         | 0.64      | single-centre | Retrospective longitudinal | 7390              | 131        | 17.8     |
| Shen et al.        | 2013             | 2008       | 2012      | 4            | China     | 2         | 0.752     | single-centre | Retrospective longitudinal | 18104             | 69         | 3.8      |
| Tuncalp et al.     | 2013             | 2010       | 2011      | 1            | Multicountry | 0.649     | multi-centre | Retrospective longitudinal | 314623            | 1667       | 5.3      |
| Authors                  | Publication Year | First Year | Last Year | Period Years | Country        | HDI Group | HDI score | Study Type      | Study Design                        | Total live births | MNM cases | MNM rate |
|-------------------------|------------------|------------|-----------|--------------|----------------|-----------|-----------|----------------|-------------------------------------|-------------------|------------|----------|
| Wahlberg et al. [30]    | 2013             | 1998       | 2007      | 9            | Sweden         | 1         | 0.933     | multi-centre  | Retrospective longitudinal         | 914474            | 2655       | 2.9      |
| Abalos et al. [31]      | 2014             | 2004       | 2008      | 4            | Multicountry   | 0.655     | multi-centre | Cross-sectional | 313030               | 1227               | 3.9        |
| David et al. [32]       | 2014             | 2008       | 2008      | 1            | Mozambique     | 4         | 0.437     | multi-centre  | Cross-sectional         | 27916             | 564        | 202      |
| Galvao et al. [33]      | 2014             | 2011       | 2012      | 1            | Brazil         | 2         | 0.759     | multi-centre  | Cross-sectional/Nested case-control | 16243             | 77         | 4.7      |
| Litorp et al. [34]      | 2014             | 2012       | 2012      | 1            | Tanzania       | 4         | 0.538     | multi-centre  | Cross-sectional         | 13121             | 467        | 35.6     |
| Luexay et al. [35]      | 2014             | 2011       | 2011      | 1            | Laos           | 3         | 0.601     | multi-centre  | Retrospective longitudinal         | 1215              | 11         | 9.1      |
| Lumbiganon et al. [36]  | 2014             | 2015       | 2011      | 1            | Multicountry   | -         | multi-centre | Cross-sectional | 314623               | 2365               | 7.5        |
| Mazhar et al. [37]      | 2014             | 2011       | 2011      | 1            | Pakistan       | 4         | 0.562     | multi-centre  | Retrospective longitudinal         | 13175             | 94         | 7.1      |
| Pacheco et al. [38]     | 2014             | 2011       | 2011      | 1            | Brazil         | 2         | 0.759     | single-centre | Retrospective longitudinal         | 2291              | 24         | 10.5     |
| Pandey et al. [39]      | 2014             | 2011       | 2012      | 1            | India          | 3         | 0.64      | single-centre | Retrospective longitudinal         | 6357              | 633        | 1200     |
| Rocha Filho et al. [40] | 2014             | 2009       | 2010      | 1            | Brazil         | 2         | 0.759     | multi-centre  | Retrospective longitudinal         | 82144             | 770        | 9.4      |
| Assarag et al. [41]     | 2015             | 2012       | 2012      | 1            | Morocco        | 3         | 0.667     | multi-centre  | Retrospective case-control         | 299               | 80         | 26.76    |
| Bashour et al. [42]     | 2015             | 2011       | 2015      | 4            | Multicountry (Egypt, Lebanon, Palestine and Syria) | 0.616     | multi-centre | Cross-sectional | 9063                | 71         | 7.8      |
| Cecatti et al. [43]     | 2015             | 2009       | 2010      | 1            | Brazil         | 2         | 0.759     | multi-centre  | Cross-sectional         | 9555              | 770        | 806      |
| Hassan et al. [44]      | 2015             | 2011       | 2012      | 1            | Palestine      | -         | single-centre | Prospective longitudinal | 1558               | 15         | 9.6      |
| Kulkarni et al. [45]    | 2015             | 2012       | 2013      | 1            | India          | 3         | 0.64      | multi-centre  | Prospective longitudinal         | 19176             | 884        | 46.1     |
| Madeiro et al. [46]     | 2015             | 2012       | 2013      | 1            | Brazil         | 2         | 0.759     | multi-centre  | Cross-sectional / Prospective longitudinal | 5841           | 56         | 9.6      |
| Naderi et al. [47]      | 2015             | 2013       | 2013      | 1            | Iran           | 2         | 0.798     | multi-centre  | Retrospective longitudinal         | 19908             | 501        | 25.2     |
| Oladapo et al. [48]     | 2015             | 2012       | 2013      | 1            | Nigeria        | 4         | 0.532     | multi-centre  | Prospective longitudinal         | 91724             | 1451       | 15.8     |
| Authors                  | Publication Year | First Year | Last Year | Period Years | Country | HDI Group | HDI score | Study Type                  | Study Design                  | Total live births | MNM cases | MNM rate  |
|--------------------------|------------------|------------|-----------|--------------|---------|-----------|-----------|----------------------------|--------------------------|-------------------|------------|-----------|
| Oliveira et al. [49]     | 2015             | 2006       | 2007      | 1            | Brazil  | 2         | 0.759     | single-centre               | Retrospective longitudinal | 19940             | 255        | 12.8      |
| Rulisa et al. [50]       | 2015             | 2011       | 2012      | 1            | Rwanda  | 4         | 0.524     | single-centre               | Retrospective longitudinal | 1739              | 192        | 110.4     |
| Sangeeta et al. [51]     | 2015             | 2012       | 2013      | 1            | India   | 3         | 0.64      | single-centre               | Retrospective longitudinal | 6892              | 27         | 4.0       |
| Soma-Pillay et al. [52]  | 2015             | 2013       | 2014      | 1            | South Africa | 3       | 0.699     | multi-centre               | Retrospective longitudinal | 26614             | 136        | 5.1       |
| Okusanya et al. [53]     | 2016             | 1993       | 2013      | 20           | Nigeria | 4         | 0.532     | single-centre               | Retrospective cross-sectional | 30553             | 116        | 3.8       |
| de Mucio et al. [54]     | 2016             | 2013       | 2013      | 1            | Latin America (12 countries) | 0.723 | multi-centre   | Cross-sectional           |                         |                  |            |
| Domingues et al. [55]    | 2016             | 2011       | 2012      | 1            | Brazil  | 2         | 0.759     | multi-centre               | Retrospective case-control | 23984             | 244        | 10.2      |
| El Ghardallou et al. [56]| 2016             | 2012       | 2012      | 1            | Tunisia | 2         | 0.735     | single-centre               | Retrospective longitudinal | 9957              | 58         | 5.8       |
| Jayaratram et al. [57]   | 2016             | 2014       | 2015      | 1            | Australia | 1       | 0.939     | single-centre               | Prospective longitudinal  | 2080              | 10         | 4.8       |
| Kalisa et al. [58]       | 2016             | 2014       | 2014      | 1            | Rwanda  | 4         | 0.524     | single-centre               | Prospective cohort         | 3979              | 86         | 21.6      |
| Lima et al. [59]         | 2016             | 2009       | 2010      | 1            | Brazil  | 2         | 0.759     | multi-centre               | Retrospective longitudinal | 4617              | 50         | 10.8      |
| Mohammadi et al. [60]    | 2016             | 2012       | 2014      | 2            | Iran    | 2         | 0.798     | multi-centre               | Retrospective case-control | 12965             | 82         | 6.3       |
| Nakimuli et al. [61]     | 2016             | 2013       | 2014      | 1            | Uganda  | 4         | 0.516     | multi-centre               | Prospective cohort         | NR                 | 695        | 8.4       |
| Nansubuga et al. [62]    | 2016             | 2013       | 2013      | 1            | Uganda  | 4         | 0.516     | single-centre               | Retrospective longitudinal | 1557              | 434        | 278.7     |
| Norhayati et al. [63]    | 2016             | 2014       | 2014      | 1            | Malaysia | 2       | 0.802     | multi-centre               | Retrospective longitudinal | 21579             | 47         | 2.2       |
| Parmar et al. [64]       | 2016             | 2012       | 2012      | 1            | India   | 3         | 0.64      | single-centre               | Retrospective longitudinal | 1929              | 46         | 23.9      |
| Rathod et al. [65]       | 2016             | 2011       | 2013      | 2            | India   | 3         | 0.64      | multi-centre               | Retrospective longitudinal | 21992             | 161        | 7.6       |
| Tanimia et al. [66]      | 2016             | 2012       | 2013      | 1            | Papua New Guinea | 4       | 0.544     | single-centre               | Prospective longitudinal  | 13338             | 122        | 9.1       |
| Bolnga et al. [67]       | 2017             | 2014       | 2016      | 2            | Papua New Guinea | 4       | 0.544     | single-centre               | Prospective longitudinal  | 6019              | 153        | 25.4      |
| Goldenberg et al. [68]   | 2017             | 2014       | 2016      | 2            | Multicountry (Congo, | 0.593 | multi-centre | Prospective longitudinal | 122707             | 4866        | 39.7      |
| Authors                  | Publication Year | First Year | Last Year | Period Years | Country                       | HDI Group | HDI score | Study Type       | Study Design     | Total live births | MNM cases | MNM rate |
|-------------------------|------------------|------------|-----------|--------------|-------------------------------|-----------|-----------|-----------------|-----------------|------------------|------------|----------|
| Herklots et al. [69]    | 2017             | 2016       | 2016      | 1            | Tanzania                      | 4         | 0.538     | single-centre   | Cross-sectional | 4125             | 37         | 6.7      |
| Khan et al. [70]        | 2017             | 2009       | 2011      | 2            | India                         | 3         | 0.64      | single-centre   | Retrospective cross-sectional | 20556           | 302       | 14.7     |
| Kiruja et al. [71]      | 2017             | 2015       | 2015      | 1            | Somalia                       | 4         | -         | single-centre   | Retrospective longitudinal | 1385          | 120       | 86.6     |
| Liyew et al. [72]       | 2017             | 2015       | 2016      | 1            | Ethiopia                      | 4         | 0.463     | multi-centre    | Cross-sectional  | 29697           | 238       | 8.0      |
| Mawarti et al. [73]     | 2017             | 2011       | 2012      | 1            | Indonesia                     | 3         | 0.694     | single-centre   | Retrospective longitudinal | 3300           | 86        | 26.0     |
| Mbachu et al. [74]      | 2017             | 2015       | 2015      | 1            | Nigeria                       | 4         | 0.532     | single-centre   | Retrospective longitudinal | 262            | 52        | 198.5    |
| Mekango et al. [75]     | 2017             | 2016       | 2016      | 1            | Ethiopia                      | 4         | 0.463     | multi-centre    | Retrospective longitudinal | 308            | 103       | 334.4    |
| Sayinzoa et al. [76]    | 2017             | 2016       | 2016      | 1            | Rwanda                        | 4         | 0.524     | multi-centre    | Prospective case-control | 5577           | 201       | 36.0     |
| Witteveen et al. [77]   | 2017             |            |           | Multicountry (Netherlands, Tanzania, Malawi) | 0.648 | multi-centre | Prospective cohort | NR                   | 2308           | NR        |         |
| Awowole et al. [78]     | 2018             | 2007       | 2016      | 9            | Nigeria                       | 4         | 0.532     | single-centre   | Retrospective longitudinal | 11242          | 43        | 3.8      |
| Benimana et al. [79]    | 2018             | 2015       | 2015      | 1            | Rwanda                        | 4         | 0.524     | single-centre   | Retrospective longitudinal | NR             | 98        | NR       |
| Chikadaya et al. [80]   | 2018             | 2016       | 2016      | 1            | Zimbabwe                      | 4         | 0.535     | single-centre   | Prospective longitudinal | 11871          | 110       | 9.3      |
| Iwuh et al. [81]        | 2018             | 2014       | 2014      | 1            | South Africa                  | 3         | 0.699     | multi-centre    | Retrospective longitudinal | 19222          | 112       | 5.8      |
| Jayaratnam et al. [82]  | 2018             | 2014       | 2015      | 1            | Australia                     | 1         | 0.939     | single-centre   | Prospective longitudinal | 2773           | 19        | 7.0      |
| Liyew et al. [83]       | 2018             | 2015       | 2016      | 1            | Ethiopia                      | 4         | 0.463     | multi-centre    | Prospective cohort     | 828            | 207       | 2500     |
| Oliveira Neto et al. [84]| 2018             | 2013       | 2015      | 2            | Brazil                        | 2         | 0.759     | single-centre   | Retrospective longitudinal | 8065           | 60        | 7.4      |
| Tura et al. [85]        | 2018             | 2016       | 2017      | 1            | Ethiopia                      | 4         | 0.463     | single-centre   | Retrospective longitudinal | 7404           | 594       | 80.2     |
| Woldeyes et al. [86]    | 2018             | 2015       | 2015      | 1            | Ethiopia                      | 4         | 0.463     | single-centre   | Retrospective longitudinal | 2737           | 138       | 50.4     |
Table 1. Summary of all the studies included in the review with their results (Continued)

| Authors          | Publication Year | First Year | Last Year | Period Years | Country | HDI Group | HDI score | Study Type       | Study Design       | Total live births | MNM cases | MNM rate |
|------------------|------------------|------------|-----------|--------------|---------|-----------|-----------|------------------|-------------------|-------------------|------------|----------|
| Yang et al. [87] | 2018             | 2012       | 2015      | 3            | China   | 2         | 0.752     | single-centre   | Retrospective longitudinal | 14105           | 265      | 18.8     |
| Herklots et al. [88] | 2019         | 2017       | 2018      | 1            | Tanzania | 4         | 0.538     | single-centre   | Prospective longitudinal | 26842           | 256      | 9.5      |
| Jayaratnam et al. [89] | 2019    | 2015       | 2016      | 1            | Timor    | 3         | 0.625     | single-centre   | Prospective longitudinal | 4529            | 39       | 8.0      |
| Oppong et al. [90] | 2019           | 2015       | 2015      | 1            | Ghana    | 3         | 0.592     | multi-centre    | Retrospective longitudinal | 8433            | 288      | 34.2     |
| Zanardi et al. [91] | 2019         | 2009       | 2010      | 1            | Brazil   | 2         | 0.759     | multi-centre    | Retrospective longitudinal | 82388           | 624      | 7.6      |
### Table 1 Summary of all the studies included in the review with their results (Continued)

| Authors            | MM cases | MM rate | MNM Haemorrhage % | MNM Hypertension % | MNM Sepsis % | MNM Others % | MNM immigrants | MNM ethnicity | MNM Maternal age | GI in MNM % | Parity in MNM | GA < 37 weeks in MNM % | Caesarean rate in MNM % | Neonatal near miss |
|--------------------|----------|---------|-------------------|-------------------|-------------|--------------|---------------|---------------|-----------------|--------------|--------------|-----------------------|-----------------------|----------------------|
| Adisasmita et al. [11] | 127      | 2240    | 40.6              | 32.3              | NR          | 16.3         | NR            | NR            | NR              | NR          | NR          | NR                    | NR                    | NR                   |
| Driul et al. [12]   | 1        | 54      | NR                | NR                | NR          | NR          | NR            | NR            | NR              | NR          | NR          | NR                    | NR                    | NR                   |
| Roost et al. [13]   | 15       | 1870    | 48                | 46                | NR          | NR          | NR            | NR            | NR              | NR          | NR          | NR                    | NR                    | NR                   |
| Almerie et al. [14] | 15       | 548     | 34                | 52                | 2.8         | NR          | NR            | NR            | Mean 28.4 years | 28          | 30.5         | NR                    | NR                    | 2.77% shoulder dystocia |
| Shrestha et al. [15] | 5        | 3240    | 41.6              | 27.7              | 19.4        | 8.3         | NR            | NR            | Mean 27 years | 30.5        | G1 NM= 30.5% | NR                    | NR                    | NR                   |
| Souza et al. [16]   | 25       | 26      | NR                | NR                | NR          | NR          | NR            | NR            | NR              | NR          | NR          | NR                    | NR                    | NR                   |
| Ali et al. [17]     | 41       | 4320    | 40.8              | 18                | 21.5        | NR          | NR            | NR            | Mean 255 years | NR          | Mean 3.01 in NM | NR                    | NR                    | NR                   |
| Amaral et al. [18]  | 4        | 89      | 17.9              | 57.8              | 14.3        | 17.8        | NR            | NR            | NR              | NR          | NR          | NR                    | NR                    | 60 perinatal deaths   |
| Donati et al. [19]  | NR       | NR      | 40                | 29                | 3           | 25          | Immigrants OR 3 | NR            | ≥ 35 years 2.8/1000 | NR          | Not specified | NR                    | 70%                  | NR                   |
| Jayaratnam et al. [20] | NR       | NR      | 40                | 12                | NR          | NR          | NR            | NR            | NR              | NR          | NR          | NR                    | NR                    | NR                   |
| Kaye et al. [21]    | NR       | NR      | NR                | NR                | NR          | NR          | NR            | NR            | NR              | NR          | NR          | NR                    | NR                    | NR                   |
| Lobato et al. [22]  | NR       | NR      | 4                 | 80                | NR          | NR          | NR            | NR            | NR              | NR          | Not specified | NR                    | NR                    | NR                   |
| Souza et al. [23]   | 140      | 1700    | NR                | NR                | NR          | NR          | NR            | NR            | NR              | NR          | NR          | NR                    | NR                    | NR                   |
| Adeoye et al. [24]  | NR       | NR      | 45.3              | 37.3              | 18.6        | NR          | NR            | NR            | >40 years 5.3%   | NR          | 1-2 (61.3%); 3-4 (25.3%); 5 or more (13.4%) in NM | NR                    | NR                    | NR                   |
| Jabir et al. [25]   | 16       | 628     | 65.9              | 21                | NR          | NR          | NR            | NR            | NR              | NR          | Not specified | NR                    | 67.83%                | NR                   |
| Karolinski et al. [26] | 34       | 523     | 36.7              | 31.1              | 4.4         | 15.3        | NR            | NR            | >35 years in 21.8%, <20 years in 16.1% | 26.6        | 26.6% P0; 37.5% >P3 in NM | NR                    | 80.1                  | NR                   |
| Nelissen et al. [27] | 32       | 3503    | NR                | NR                | NR          | NR          | NR            | NR            | NR              | NR          | Not specified | NR                    | NR                    | NR                   |
| Authors          | MM cases | MM rate | MMN Haemorrhage % | MMN Hypertension % | MMN Sepsis % | MMN Others % | MMN immigrants | MMN ethnicity | MMN Maternal age | G1 in MMN % | Parity in MMN | GA < 37 weeks in MMN % | Caesarean rate in MMN % | Neonatal near miss |
|------------------|----------|---------|-------------------|-------------------|--------------|--------------|----------------|---------------|-----------------|--------------|----------------|-----------------------------|-----------------------------|------------------|
| Roopa et al.     | 23       | 313.0   | 44.2              | 23.6              | 16           | NR           | NR             | NR            | NR              | 58           | NR            | NR                          | NR                          | NR                |
| Shen et al.      | 3        | 16.0    | 36.1              | 31.7              | NR           | NR           | aOR in Immigrants_mean 28 ± 5 years | NR            | 76.8             | G1 76.8% in NM | NR            | 89.9                        | 40% admission to neonatal ICU | NR                |
| Tuncalp et al.   | 360      | 1144    | NR                | NR                | NR           | NR           | MNM by groups: 0.8% HDI 1-2, 0.5% HDI 3, 1.1% HDI 4 Mean ≥35 years | 10.6%         | NR              | G1 37.3% of the total | NR            | NR                        | NR                          | NR                |
| Wahlberg et al.  | 22       | 24      | NR                | NR                | NR           | Specified by groups of origin Specified by groups of origin | NR            | Specified by groups of origin | NR            | NR                        | NR                          | NR                |
| Abalos et al.    | 204      | 65.2    | NR                | NR                | NR           | NR           | NR             | NR            | NR              | NR            | NR                        | NR                          | NR                |
| David et al.     | 71       | 2540    | 58                | 35.5              | 3.9          | NR           | NR             | NR            | 14-19 (23.6%), 20-24 (27%), 25-29 (26.2%), 30-34 (16.7%), ≥35 (6.6%) | 33.9          | 0 (33.9%); 1 (20.47%); 2-4 (40.6%); ≥5 (4.8%) in NM | NR            | 56.6                        | NR                          | NR                |
| Galvao et al.    | NR       | NR       | NR                | NR                | NR           | 84.4% non white; 15.6% white | < 35 years 73.9%; ≥35 years 26.1% | NR            | Not specified | NR            | 74.5                        | NR                          | NR                |
| Litorp et al.    | 77       | 5870    | 13                | 42                | NR           | NR           | NR             | NR            | Mean 26 years | 43           | NR            | NR                          | 35                          | NR                |
| Luexay et al.    | 2        | 1780    | NR                | NR                | NR           | Lao (70.6%); tribes (18.3%) | Mean 244 years | NR            | NR              | NR            | NR                        | NR                          | NR                |
| Lumbiganon et al.| NR       | NR       | NR                | 8.1               | 28.1         | NR           | NR             | NR            | NR              | NR            | NR                        | NR                          | NR                |
| Mazhar et al.    | 38       | 2990    | 48.5              | 25.8              | NR           | NR           | NR             | NR            | 20-40 years 96.2 % | 37           | G1 37% in NM | 47                          | 49                          | NR                |
| Pacheco et al.   | 3        | 1309    | NR                | NR                | NR           | NR           | NR             | NR            | NR              | NR            | NR                        | Not specified                  | NR                |
| Pandey et al.    | 247      | 46840   | 45.6              | 24.2              | 7.5          | 8.7          | NR             | NR            | NR              | NR            | NR                        | NR                          | NR                |
| Authors          | MM cases | MM rate | MNM Haemorrhage | MNM Hypertension | MNM Sepsis | MNM Others | MM Material | MNM Maternal age | G1 in MNM | Parity in MNM | GA < 37 weeks | MNM Coma | MNM Neonatal near miss |
|------------------|----------|---------|----------------|-----------------|------------|------------|-------------|-----------------|-----------|--------------|---------------|----------|------------------------|
| Rocha Filho et al. [40] | 140      | 170.4   | 43.5           | NR              | NR         | 56.5       | white; 56.9% non white | ≥ 40 years 7% | 24.1% in NM | 72.3         | 89.5     | 10%                     |
| Assarag et al. [41] | NR       | NR      | 39             | 45              | 45.1%      | 23.3%      | NR          | Mean 29.2 years | 50        | NR           | 66            | NR       | 10%                     |
| Bashour et al. [42] | 6        | 66.2    | 100            | 15.4            | 15.4%      | 10%        | 10%         | Egypt 40.7%; Lebanon 60%; Palestine 43.8%; Syria 27.8%; Others 50%; 61.1% | 43.1%     | white; 54.2% non white | 3-4; (Egypt 40.7%); 0; (Lebanon 60%); (Palestine 43.8%); (Syria 27.8%); (Others 50%); 61.1% | 34 | 10%                     |
| Cecatti et al. [43] | 16       | 170.0   | 40.5           | 45.3            | 45.3%      | 26.9%      | NR          | Mean 25.8 years | 4.2       | 4.2%         | NR           | NR       | 10%                     |
| Hassan et al. [44] | NR       | NR      | 16.4           | 4.2             | 4.2%       | 2.5%       | NR          | 41% G1 in NM | NR        | NR           | NR           | NR       | 10%                     |
| Madeiro et al. [45] | 94       | 490.2   | 7.7            | 53.4            | 53.4%      | 30.9%      | NR          | 41% G1 in NM | NR        | NR           | NR           | NR       | 10%                     |
| Naderi et al. [46] | 10       | 171.2   | 100            | 86.1            | 86.1%      | 71.9%      | NR          | 41.5%          | NR        | NR           | NR           | NR       | 10%                     |
| Chatto et al. [47] | 2        | 46.1    | 25             | 31.9            | 31.9%      | 25.7%      | NR          | NR             | NR        | NR           | NR           | NR       | 10%                     |
| Chakrapani et al. [48] | 998      | 10880   | 49             | 20.5            | 20.5%      | 15.5%      | NR          | 41.5%          | NR        | NR           | NR           | NR       | 10%                     |
| Viera et al. [49] | 56       | 2808    | 53.7           | 62.7            | 62.7%      | 45.5%      | NR          | 45% G1 in NM | NR        | NR           | NR           | NR       | 10%                     |
| Vila et al. [50] | 50       | 28752   | 19.3           | 28.6            | 28.6%      | 20.5%      | NR          | 45.5%          | NR        | NR           | NR           | NR       | 10%                     |
| Sangeeta et al. [51] | 8        | 116     | 40.7           | 26              | 26%        | 44.7%      | NR          | 41% G1 in NM | NR        | NR           | NR           | NR       | 10%                     |
| Soma-Pillay et al. [52] | 19    | 714     | 39.5           | 32.4            | 32.4%      | 24.1%      | NR          | NR             | NR        | NR           | NR           | NR       | 10%                     |
| Khokar et al. [53] | 20       | 2420    | 0.6            | 20.24           | 20.24%     | 20.24%     | NR          | NR             | NR        | NR           | NR           | NR       | 10%                     |
| Authors                  | MM cases | MM rate | MNM Haemorrhage | MNM Hypertension | MNM Sepsis | MNM Others | MNM immigrants | MNM ethnicity | MNM Maternal age | GI in MNM | Parity in MNM | GA < 37 weeks in MNM | Caesarean rate in MNM | Neonatal near miss |
|-------------------------|----------|---------|-----------------|------------------|------------|------------|----------------|---------------|-------------------|-----------|----------------|---------------------|-------------------------|---------------------|
| et al. [53]             | NR       | NR      | NR              | NR               | NR         | NR         | NR             | NR            | NR                | NR        | NR            | 29 n=31; 30-34 n=40; 35-39 n=33; 40-44 n=9 | 27; 3 n=35; 4 n=14; 5 |                     |
| de Mucio et al. [54]    | NR       | NR      | NR              | NR               | NR         | NR         | NR             | NR            | NR                | NR        | NR            | Not specified        | 133                     | NR                  |
| Domingues et al. [55]   | NR       | NR      | NR              | NR               | NR         | NR         | NR             | NR            | NR                | NR        | NR            | 46.9                | 40.69%; P1 29.4%; 2.3 18.8%; >4 49% | NR                  |
| El Ghardallou et al. [56]| 1        | 100     | 74.1            | 20.7             | NR         | 25.9       | NR             | NR            | Mean 32 ± 5.2 years, >39 years 12.1% | 36.2      | NR            | NR                  | 66.7                    | 15.4% neonatal death, 48.9% (n=16) ICU admission |
| Jayaratnam et al. [57]  | NR       | 48      | NR              | NR               | NR         | NR         | NR             | NR            | NR                | NR        | NR            | Not specified        | NR                     | No                  |
| Kalina et al. [58]      | 13       | 325.0   | 57              | 31.4             | NR         | NR         | NR             | NR            | NR                | NR        | NR            | Not specified        | NR                     | 43                  |
| Lima et al. [59]        | 10       | 216     | NR              | NR               | NR         | NR         | NR             | NR            | NR                | NR        | NR            | 54.3                | NR                     | NR                  |
| Mohammadi et al. [60]   | 12       | 926     | 35              | 32               | 7          | NR         | NR             | NR            | ≥35 years n=124  | 23        | G1= 184 (23%; G1 in NM) | 48        | 81             | 204 perinatal deaths |
| Nakimuli et al. [61]    | 130      | 503.0   | 26.5            | 22               | 11.8       | NR         | NR             | NR            | ≥25 years 55.7%  | 26.5      | G1= 184 (26.5%) of NM | NR        | 78%            | NR                  |
| Nanzubuga et al. [62]   | NR       | NR      | 55              | 0.2              | 3.5        | 4.1        | NR             | NR            | NR                | NR        | NR            | Not specified        | NR                     | NR                  |
| Norhayati et al. [63]   | 2        | 93      | 80.9            | 21.3             | NR         | 38.3       | NR             | NR            | Mean 33.2(60.8) years, >35years 42.6% | NR        | NR            | Not specified        | NR                     | 63.80%             |
| Parmar et al. [64]      | 18       | 933.0   | NR              | NR               | NR         | NR         | NR             | NR            | NR                | NR        | NR            | 42 NR               | 39% perinatal death   |
| Rathod et al. [65]      | 66       | 300     | 26.7            | 11.8             | 11.5       | NR         | NR             | NR            | NR                | NR        | NR            | NR                  | NR                     |

Table 1 Summary of all the studies included in the review with their results (Continued)
| Authors               | MM cases | MM rate | MNM Haemorrhage % | MNM Hypertension % | MNM Sepsis % | MNM Others % | MNM immigrants | MNM Maternal age | GI in MNM % | Parity in MNM | GA < 37 weeks in MNM % | Caesarean rate in MNM % | Neonatal near miss |
|----------------------|----------|---------|-------------------|-------------------|-------------|--------------|----------------|-----------------|-------------|----------------|-------------------------|-------------------------|-------------------|
| Tanimia et al. [66]  | 9        | 675     | 38                | 32                | 7.4         | NR           | NR             | NR              | NR          | NR            | NR          | NR          | NR          |
| Bolnga et al. [67]   | 10       | 1660    | 42.5              | 22.2              | 16.3        | 3.3          | NR             | NR              | NR          | NR            | NR          | 26.80%      | NR          |
| Goldenberg et al. [68]| 190      | 1550    | 79                | 42                | 75          | NR           | NR             | NR              | NR          | NR            | NR          | NR          | NR          |
| Herklots et al. [69] | 28       | 6788    | 29.7              | 24.3              | 10.8        | 2.7          | NR             | NR              | NR          | <20 years 12.3%; 20-35 years 66.2%; >35 years 21.5% | 20 | P0 20%; P1-4 60%; P>4 20% | NR          | 63 | NR          |
| Khan et al. [70]     | 67       | 3250    | 63.6              | 20.5              | 2.6         | NR           | NR             | NR              | Mean 267 years | 36.4 | G1 (36.4%); G2-3 (50%); G4-6 (13.6%) | NR          | 64.2 | NR          |
| Kiruja et al. [71]   | 18       | 13280   | 36.7              | 55                | 2.5         | 1.7          | NR             | NR              | Mean 295 years | 2.5 | ≥ 7 (29.2%); 5-6 (10.8%); 2-4 (29.2%); 1 (28.3%); 0 (2.5%) | NR | NR | 21.7% perinatal death |
| Liyew et al. [72]    | NR       | NR      | 38                | 53                | 1           | NR           | NR             | NR              | NR          | NR            | NR          | NR          | NR          |
| Mawarti et al. [73]  | 29       | 879     | 5.81              | 95                | 4.5         | NR           | NR             | NR              | NR          | NR            | NR          | NR          | NR          |
| Mbachu et al. [74]   | 5        | 19080   | 24.6              | 28.1              | 1.8         | NR           | NR             | NR              | NR          | NR            | NR          | NR          | NR          |
| Mekango et al. [75]  | NR       | NR      | 44.7              | 38.8              | 9.7         | NR           | NR             | NR              | ≥40 years n= 88 | NR | G1 N=5 | 54.4 | NR | NR          |
| Sayinzoga et al. [76] | 13       | 2331    | 22.9              | 8.5               | 7.5         | 5            | NR             | NR              | ≥35 years 60% | 60 | G1 60% | 34 | 52 | 46.1% perinatal death |
| Witteveen et al. [77] | 126     | NR      | NR                | NR                | NR         | MNM% specified by country of origin | NR | Specified by country | NR          | Specified by country | NR | NR | NR          |
| Awowole et al. [78]  | NR       | NR      | 18                | 40                | 12          | NR           | NR             | NR              | Mean 292 years | NR | Mean 2 | NR | NR | NR          |
| Benimana et al. [79] | NR       | NR      | 23.1              | 21.5              | 27.3        | NR           | NR             | NR              | 16-24 years (28.9%); 25-34 years (52.1%); ≥35 years (19%) | 17.4 | 0 (17.4%); 1-2 (53.7%); ≥3 (28.9%) | NR | NR | NR          |
Table 1 Summary of all the studies included in the review with their results (Continued)

| Authors | MM cases | MM rate | MNM Haemorrhage % | MMN Hypertension % | MNM Sepsis % | MNM Others % | MNM immigrants | MNM ethnicity | MNM Maternal age | GI in MNM % | Parity in MNM | GA < 37 weeks in MNM % | Caesarean rate in MNM % | Neonatal near miss |
|---------|----------|---------|-------------------|-------------------|-------------|-------------|---------------|--------------|-----------------|-------------|---------------|----------------------|----------------------|---------------------|
| Chikadaya et al. [80] | 13 | 1095 | 31.8 | 28.2 | NR | 20 | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Iwuh et al. [81] | 13 | 676 | 33.9 | 44.6 | 11.6 | NR | NR | NR | NR | <18 years 3.6%; 18-34 years 84.8%; ≥35 years 11.6% | 41.1 | 40.1% | 41.1%; P1-4 58%; P5 0.9% | NR | NR | NR |
| Jayaratnam et al. [82] | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Liyew et al. [83] | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Oliveira Neto et al. [84] | 5 | 62 | 64.5 | 25.8 | 6.5 | NR | NR | NR | NR | >35 years 79% | NR | NR | NR | 74 | NR |
| Tura et al. [85] | 28 | 378 | 36 | 45.6 | 21.2 | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Woldeyes et al. [86] | 24 | 8770 | 22.5 | 21 | 10.1 | 5.8 | NR | NR | NR | NR | 41.6 | NR | NR | 25.7 | NR | NR |
| Yang et al. [87] | 10 | 709 | 36.9 | 49 | NR | NR | NR | NR | NR | ≥35 years 2.54% | 22.3 | G1-2 2.33% | 5.36 | NR | 35 perinatal deaths |
| Herklots et al. [88] | 79 | 294 | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Jayaratnam et al. [89] | 30 | 662 | 25 | 25 | NR | NR | NR | NR | NR | NR | 50 | NR | NR | NR | NR | NR |
| Oppong et al. [90] | 62 | 735 | 12.2 | 41 | 11.1 | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR |
| Zanardi et al. [91] | 113 | 1371 | NR | NR | NR | NR | NR | NR | NR | NR | 37 | NR | 63% | 73.9 | 14.2% perinatal death |

García-Tizón Larroca et al. BMC Pregnancy and Childbirth (2020) 20:224

Page 15 of 24
the longest period of data collection, at twenty years. Over 70% of the studies had a follow-up design with retrospective data collection/analysis.

Looking at single-country studies, over thirty-three countries were represented, and seven studies were conducted with populations from several countries; Brazil published more studies than any other country, with thirteen (15.4%), followed by India, with six (7.1%), and Nigeria and Ethiopia, with five each (6%). Regarding the number of studies classified by HDI group, seven belonged to group 1, nineteen to group 2, eighteen to group 3, and twenty-nine to group 4. In only three studies, the HDI score could not be obtained because of the lack of data provided regarding the study country.

Regarding the MM rate, the median was 175 deaths per 100,000/LBs, with six studies reporting a rate above 1000; in relation to the MNM rate, the median was 11 events per 1000 LBs, with nine studies reporting a rate above 100. Regarding MNM, the average of the overall percentage of publications reported the cause to be haemorrhage (38.5%), hypertensive disorders of pregnancy (34.2%), sepsis (7.5%), and other causes (20.9%).

In relation to gestational data, the mean percentage of primiparous women in the total cases of MNM published was 37%. The mean percentage of premature births in the MNM cases was 38%. The mean percentage of caesarean sections in the MNM cases reported in the twenty-eight articles that reported these data was 57.2%.

Of all the articles included in the review, only sixteen presented data on adverse neonatal outcomes; the most commonly described complication was perinatal death, reported in twelve articles.

Finally, 4/82 articles referred to the differential analysis of near-miss ratios in immigrants, and 16/82 provided data on perinatal mortality or morbidity (near miss) in their results.

Figures 2 and 3 show the exponential trend relationship between the HDI score of the study population and the MNM and MM rates. In both, an inversely proportional relationship between the two variables was shown; higher MNM rates and higher MM rates were observed for study countries with lower HDI scores, significantly in both cases:

- Average rate of MNM/country = $331.71e^{-4.572 \text{country HDI}}$ per 1000 live births ($R^2 = 0.2251; p = 0.001$)
- Average rate of MM/country = $47290e^{-8.663 \text{country HDI}}$ per 100,000 live births ($R^2 = 0.4304; p = 0.038$)

In addition, to provide more detail in these figures, Tables 2 and 3 show the MNM and MM rates, respectively, weighted by the number of LBs according to the HDI group of the study population. The articles whose study population belonged to HDI group 1 showed the lowest MNM and MM rates compared to the rest of the groups. Those whose study population belonged to HDI group 3 had the highest MNM rate, 7.6 times higher than that of HDI group 1. Studies whose population was classified as HDI group 4 had the highest MM rate, 98.4 times higher than that of HDI group 1. It should be noted in these tables that the MNM rate for group 4 was lower than that for HDI group 3.

The proportion of each cause of MNM published in each study is shown in Figure 4. This same figure reflects the overall proportions of each type of MNM. The most common cause of MNM in the set of studies selected in this review was haemorrhage, occurring in 38.5% (95% CI, 37.7-39.2) of all cases.

Concerning haemorrhagic causes of MNM, the study by Lobato et al. [22] reported the lowest proportion of this complication, with 3.7%, compared to the study by Madeiro et al. [46], which reported the highest percentage of haemorrhagic causes of MNM, 100% of total cases in their sample.

Regarding hypertensive disorders as a cause of MNM, the studies by Lobato et al. [22], Madeiro et al. [46], and Mawarti et al. [73] predominantly include populations of
pregnant women from countries in HDI groups 2 and 3, with proportions of MNM greater than 80% out of all cases in their respective samples.

Overall, the less common cause of MNM was infection/sepsis, at 7.5%, although the studies by Rulisa et al. [50] and Benimana et al. [79] observed this cause to be responsible for 30.2% and 27.6%, respectively, of total MNM cases. Both studies were conducted in countries belonging to HDI group 4. A total of 83.7% of studies that reported infectious causes of MNM were conducted in countries classified as HDI groups 3 and 4.

**Discussion**

This systematic review of the literature selected eighty-two studies that included over three million live births, over 37,000 MNM cases, and just over 4,000 MM events over the past eleven years, representing over fifty countries.

To our knowledge, this is the most up-to-date review of MNM as an adverse perinatal outcome, and the only one in which the country of origin of the study population has been analysed. In addition, it is the first review that analyses these results in relation to the HDI of each country of publication.

As shown in Table 1, increasingly more studies are publishing MNM results as an indicator for monitoring the quality of maternal health and maternal care. These data will be a valuable contribution to taking necessary action to improve the quality of maternal care.

**MNM as an analysis variable of maternal morbidity and mortality and the importance of the country of origin**

Despite the differences in MM between countries, these events are increasingly infrequent and related to a LB rate on the order of 100,000. As stated above, MNM data collection is increasingly necessary; most of the studies included have been published since 2014, showing the growing interest in considering this variable.

Brazil published the most studies in this period, followed by India, Nigeria and Ethiopia; most studies were published in low-HDI countries, leading to publication bias because, as this study shows, cases of severe maternal morbidity are more prevalent in more disadvantaged countries.

As highlighted in Table 1, only four studies underline the relationship between MNM and migration when analysing maternal origin, where perinatal outcomes were more unfavourable in immigrant groups. However, many studies analysed this variable for MM. In a systematic review that included thirteen studies involving over forty-two million women and 4995 maternal deaths, immigrant women had twice the risk of this complication over native women in Western Europe [92].

As in the results obtained in those four studies regarding both MNM and MM, our results highlight a significant relationship between the HDI of the place of publication and adverse maternal-perinatal outcomes. These results are in line with previous studies by Tunçalp et al. [3] and Luque-Fernández et al. [5] and those reported previously by our team.

These studies highlight the importance of classifying maternal risk by considering not only economic data but also other relevant aspects of human development and capacity for survival in each country, or, in the case of immigrants, their country of origin, specifically in the case of pregnant women from low-income countries where monitoring of pregnancy and childbirth occurs in their countries of origin and when a pregnant woman

| HDI group | Sum of MNM | Sum of livebirths | MNM rate per 1000 livebirths |
|-----------|------------|-------------------|-----------------------------|
| 1         | 4556       | 1542678           | 2.95                        |
| 2         | 4844       | 439728            | 11.01                       |
| 3         | 4265       | 188743            | 22.59                       |
| 4         | 7196       | 352653            | 20.40                       |
| Total     | 20861      | 2523802           | 8.26                        |

| HDI group | Sum of MM | Sum of livebirths | MM rate per 100,000 live births |
|-----------|-----------|-------------------|---------------------------------|
| 1         | 57        | 998443            | 5.7                             |
| 2         | 527       | 398338            | 132.4                           |
| 3         | 841       | 188444            | 446.3                           |
| 4         | 1563      | 277953            | 562.2                           |
| Total     | 2988      | 1863178           | 160.4                           |
Fig. 4 Proportion of each cause of MNM published according to HDI group
Main findings

The present study shows that MNM and MM rates have a significant relationship with maternal country of origin. Specifically, the HDI of the maternal country of origin where the different studies were conducted was significantly related to MNM and MM rates. Thus, we have observed that the lower the HDI score of the maternal country of origin, the greater the risk is of suffering from these 2 severe pregnancy complications.

We must emphasise that HDI group 3 had the highest MNM rate compared to the other groups even though group 4 would be expected to have the worst results for this complication. The reason for this is not explained in our review, although a possible cause could be that HDI group 4 had lower MNM ratios compared to group 3 because cases of severe morbidity in these countries more frequently caused maternal deaths. This hypothesis would explain why HDI group 4 had an overall MM rate higher than Group 3 and other groups.

Thus, the present study allows calculation of the average expected MNM ratios based on the country’s HDI score, as shown in the following examples:

- Average MNM rate in Sweden = 331.71e^{-4.572x0.933} = 4.69 per 1000 LBs
- Average MNM rate in Brazil = 331.71e^{-4.572x0.759} = 10.38 per 1000 LBs
- Average MNM rate in Uganda = 331.71e^{-4.572x0.516} = 31.54 per 1000 LBs

In the same way, if we wanted to calculate the average expected MM rate in a country based on its HDI, we could apply the following formula presented in the results section:

- Average MM rate in Sweden = 47290e^{-8.663x0.933} = 15.02 per 100,000 LBs
- Average MM rate in Brazil = 47290e^{-8.663x0.759} = 67.46 per 100,000 LBs
- Average MM rate in Uganda = 47290e^{-8.663x0.516} = 549.73 per 100,000 LBs

We can observe how the MNM and MM rates increase as the HDI score of the reference country decreases. On the other hand, we see rates of these complications similar to those published by the authors of the studies included in this review. The calculation of these rates is limited by the use of a single explanatory variable such as the HDI score of the country in which the adverse event occurs in the study; therefore, we can observe differences in the results published by other authors, such as the study by Vangen et al. [94] in Norway, which presented an HDI score similar to that of Sweden and a MM rate of 7.2 per 100,000 LBs, half of what was anticipated from our equation.

Estimating these two severe adverse events of pregnancy, childbirth, and the postpartum period can be important for clinicians, enabling them to classify the risk of such events according to the place of maternal origin. Considering previous calculations, a clinician in Sweden can expect that near-miss and mortality rates for a patient attending their hospital from Uganda may be higher than those of a patient from Brazil (if we consider the rates of these countries and how to discriminate between Uganda and Brazil), even if both are immigrants. Obviously, this hypothesis must be confirmed by more studies; surely, the near-miss rate of an immigrant patient in Sweden is lower than that corresponding to their country of origin, but according to our results, it is possible that HDI can help estimate the risk with more accuracy.

The HDI simplifies and captures major sociodemographic characteristics and encompasses various aspects of human development across countries in the form of a common score, as explained above. Therefore, using the HDI, maternal origin can be categorised not only by race and ethnicity but also by income and...
educational level, which provide accurate information regarding poverty and inequality worldwide. According to our systematic review, the excess risk of MNM and MM seems to depend not only on the maternal birthplace but also on the region where the prenatal checkups and delivery took place, other maternal characteristics and the presence of comorbidities. Therefore, taking into account that a significant proportion of MNM and MM cases are avoidable, there should be an initiative to develop and implement epidemiological analysis systems in host countries to identify socio-demographic risk factors – such as indicators of poverty and social impairment – that have a significant impact on the perinatal outcomes of pregnant immigrant women.

This proposal to use HDI as a parameter related to morbidity and mortality rates is another step in calculating these risks by analysing other aspects than just the average income of the maternal country of origin or immigrant status. Previously, other authors showed an increased risk of severe maternal morbidity events during pregnancy, childbirth, and the postpartum period in women from low-income countries, such as those in sub-Saharan Africa and the Caribbean [95–97]. The study published by Blagoeva Atanasova et al. [98] in Spain showed a significantly increased MM risk (four times higher) in immigrant women from South American countries. Similarly, this study highlighted important inequalities in the rate of this complication depending on the place of maternal origin.

Near-miss types by HDI group (Figure 4)

Our review showed that the most common cause of MNM was haemorrhage (38.5% of cases), followed closely by hypertensive disorders of pregnancy.

Overall, we did not observe significant differences in the proportions of MNM types according to the HDI or maternal HDI groups. Thus, although the absolute number and MNM rate are higher in low-HDI countries compared to countries with higher HDI, the proportion of causes of these maternal morbidity events does not differ substantially from one country to another for reasons that are not clear in the literature.

Published studies reflect heterogeneous results in the proportions of MNM, as in a recent multi-centre analysis published by Oppong et al. [90] conducted in Ghana with 8,433 LBs and 288 MNM cases. In this study, the most common cause of MNM was preeclampsia/eclampsia, at 41%, compared to haemorrhage, which was observed in 12.2% of cases. The identification and classification of near-miss cases were performed in this group using the WHO Maternal Near Miss Tool [23].

Tanimia et al. [66], however, in a study conducted in Papua New Guinea with 13,338 LBs and 122 near-miss cases, identified, using the same tool and WHO criteria, haemorrhage as the most common cause of maternal near miss (38%), followed by hypertensive disorders of pregnancy (32%).

The main cause of MM identified by the Global Burden of Disease (GBD) study, which conducted a global and regional review of data from 186 countries during the period of 1990–2015, was obstetric haemorrhage. Other relevant causes of MM were hypertensive disorders of pregnancy, maternal sepsis, obstructed labour, and uterine rupture [99].

There are several reasons why the proportion of MNM cases may differ from one study to another even among countries with similar socio-economic development levels as defined by the HDI. On the one hand, the method used in the collection, definition, and classification of MNM varies from one study to another in both the sources and classification systems of these pregnancy complications. There are several cases in which patients may suffer from several types of near-miss incidents, or one cause of near miss may trigger another, but these situations may not be revealed in the results of the studies included in this review. Furthermore, the description of the study population and hospitals where the conditions were treated in the various studies were not always sufficiently detailed to identify the reason why, in some studies, one cause of near miss was more prevalent than another. In this regard, the maternal HDI given by the country of origin where each study was conducted does not explain the differences found between the studies in the proportion of each type of MNM.

Strengths of the review

This is the most recent and up-to-date systematic review that addresses the importance of characterising pregnant women by their country of origin and investigates a relevant sociodemographic variable, HDI, and its relationship with adverse events such as MNM and MM. From what has been published over the course of a decade, eighty-two articles were collected, describing results from over forty countries, including a large number of patients and maternal morbidity and mortality events.

Limitations of the review

Several limitations are worth considering when interpreting the results of this review. However, there is a lack of uniform criteria for the identification of cases of severe obstetric morbidity or MNM. The identification of cases is complex and varies across studies. Three major criteria have been mentioned in a review conducted by the WHO [100]. The review suggested the use of organ system dysfunction-based criteria supplemented with compatible clinical markers of organ system dysfunction that are feasible for collection in the absence of higher-level amenities-based criteria for identifying all severe morbidity and
investigating the cause as the most reproducible one across similar areas.

Population characteristics in case-control groups were not always well described; in several studies, relevant adjustment variables of perinatal outcomes were not used, such as maternal comorbidities, maternal age, parity, maternal body mass index (BMI), or belonging to ethnic or sociodemographic groups that are more vulnerable to pregnancy complications.

As we have described, very few studies refer to immigrant pregnant women or maternal HDI influencing adverse events during pregnancy, childbirth, and the postpartum period.

To address these limitations, Mengistu et al. [101] have recently published a protocol for the systematic review and meta-analysis of severe maternal morbidity events and MNM, at least in high-income countries.

Finally, we must note the limitations of the HDI. On the one hand, the population in the study country is not homogeneous with regard to origin, education level, or income; these factors are not always perfectly described in national epidemiological publications or data. On the other hand, migration flows are very diverse from one country to another depending on economic, social, political, and geographical factors; therefore, the quantity and characteristics of the immigrant population of a nation can be more or less heterogeneous even within similar territories, as in the European Union. We attempted to divide the patients into groups in a simple manner that was based on maternal HDI; additionally, we obtained as much information as we could regarding the mothers’ social situation, as indicated by their country of origin but this might not be entirely informative.

Conclusions
In summary, this review of the literature highlights the usefulness of identifying the HDI of the maternal country of origin through the HDI of the country of publication. Based on eighty-two articles, the review includes a great variety of countries, patients, and maternal morbidity and mortality events. This variety has allowed us to study the inverse and significant relationship between maternal morbidity and mortality and the HDI of the countries included. This relationship is maintained according to the HDI groups.

The most common causes of MNM described were haemorrhage and hypertensive disorders of pregnancy and, less frequently, infectious complications and sepsis. Overall, there were no significant differences in the proportion of each cause of MNM, the HDI, and HDI groups.

Implications for clinical practice
This study shows that the use of maternal sociodemographic variables, including the HDI, may be useful to categorise the risk of maternal morbidity and mortality. In addition to economic value, the HDI weighs education level and life expectancy – as health and social parameters of pregnant women – according to their origin. The HDI is a variable that is easily accessible and calculated, although it may have limitations influenced by other factors, for example, in the immigrant population, such as time spent in the destination country, baseline health state, or the degree of social integration and family income. More studies are needed to determine the discriminatory value of risk in the immigrant population treated in different countries.

Abbreviations
MM: Maternal mortality; MMN: Maternal near miss; HDI: Human development index; WHO: World Health Organization; GNI: Gross national income; UNDP: United Nations Development Programme; LB: Live births; NR: Non reported; GBD: Global Burden of Disease; BMI: Body mass index

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Authors’ contributions
SGTL and FAV designed the study, reviewed all the studies included and wrote the final manuscript. ICH, EAH and YCL reviewed the final manuscript. JLL designed the study as well and prepared the final manuscript. The author(s) read and approved the final manuscript.

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This is a systematic review of the literature so consent to participate was not required. Ethical approval was not required either.

Consent for publication
Not Applicable

Competing interests
The authors declare that they have no competing interests.

Author details
1Maternal Fetal Medicine, Department of Obstetrics and Gynaecology, HGUGM, Calle O’ Donnell, 48, Planta 0, 28009 Madrid, Spain. 2Department of Public and Maternal-Infant Health, Complutense University, Madrid, Spain.

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