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Abstract

Background: Improving maternal health is a global health priority and requires accurate evaluation of factors affecting maternal health. Geographic information systems have been used to explore maternal health problems.

Aims: The aim of this study was to identify studies that used geographic information systems in the field of maternal health care and to determine maternal health and mortality variables visualized on these systems.

Methods: This was a scoping review in which we systematically searched PubMed and Science Direct for studies that used geographic information systems to evaluate maternal health care. We included all relevant cross-sectional studies published in English between December 1995 and December 2017. We extracted the following information from each study included: study year, region, objectives, type of geographic information system used, variables visualized by the geographic information system, and all other variables examined that related to maternal health.

Results: Of 5240 articles initially retrieved, 40 were included for detailed review. Most of the studies (n = 32) were done in developing countries in Africa, Asia, and Latin America and the

Caribbean. Most of the studies (n = 33) visualized mothers' distance to health facilities and travel time to health care centres on geographic information systems. Other factors examined included antenatal care capacity (n = 4) and capacity of maternal health services (n = 3).

Conclusions: Comprehensive research on the application of geographic information systems in maternal care is lacking. Most studies applied simple descriptive mapping of spatial distribution patterns with a few relevant variables.

Keywords: geographic information system; maternal health; maternal health services; health services research

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Introduction

Maternal health is a globally important health challenge. Maternal health refers to the health of women during pregnancy, childbirth and the postpartum period (1). According to the World Health Organization (WHO) the global maternal mortality rate is unacceptably high and about 810 maternal deaths occur daily around the world with 94% of all maternal deaths occurring in developing countries (2). In 2015, 295 000 women died following pregnancy related complications – most of these deaths were in low-resource settings and most could have been prevented (2).The Sustainable Development Goals (SDGs) now call for an acceleration in progress in order to achieve a global maternal mortality rate of 70 maternal deaths per 100 000 live births, or less, by 2030 (3). Achieving this global goal will require countries to reduce their maternal mortality rate by at least 7.5% each year between 2016 and 2030 (3). Reducing

maternal mortality was introduced globally as an important health priority in the United Nations Millennium Development Goals (4). Precise evaluation of the maternal mortality rate is the first step to reducing this rate.

Extensive implementation of various software and information technology services in recent years has helped health experts to improve health care. These improvements have helped health care professionals work more efficiently and effectively (5,6). Recently, researchers have started to apply geographic information systems (GIS) to explore maternal and newborn health problems (7–9). GIS help to show regional variations and abnormal patterns of health characteristics. Through the use of GIS, researchers can gain insight into the use of health services and expose health problems and environmental risks. This technology can be easily used by non-geographers with basic computer literacy and map-reading skills (10). The use of GIS is a means to effectively link and analyse the range of data necessary to address complex questions in health promotion, public health, community medicine, epidemiology, and other fields (11).

Despite a number of reviews on the use of GIS in maternal health (12–16), to the best of our knowledge, no review has collectively analysed the results of studies to determine maternal health and mortality factors visualized through GIS. Some studies have shown that the application of GIS in maternal health can help decision-making on policies to reduce maternal problems and improve maternal care outcomes (17,18). Therefore, we did a scoping review to identify GIS studies related to maternal health care to determine maternal health and mortality factors (variables) visualized through GIS. We also summarized other variables investigated, but not visualized through GIS, to get a general overview of all evaluated variables in the included studies. The results of our review can be used to help in planning to reduce preventable causes of maternal health problems. Our results can also help determine gaps in the use of these types of data and provide a road map to guide more precise studies on various aspects of maternal health.

Methods

Search terms

We searched for relevant articles in English from 1995 to 2017 using PubMed and Science Direct databases. We used two groups of key search terms. Group A included GIS-related terms: GIS; geographic information system; risk mapping; spatial analysis; spatial data; GPS; and health mapping. Group B included terms related to maternal health: maternal mortality; maternal health; maternal care; pregnancy; delivery; and maternal death. Our search strategy was as follows: first we used “OR” to combine the terms within each group A and B separately. Then, we combined keywords from the two groups using the “AND” operator to find all the studies that used GIS in the field of maternal care. We then limited the search in both databases to humans and studies published in English.

Inclusion and exclusion criteria

The inclusion criteria were: cross-sectional study related to the use of GIS in maternal health care; published between December 1995 and December 2017; in English; and on a human population. The exclusion criteria were: review studies, editorials, commentaries and letters; studies that had not visualized data on GIS; and articles not in English.

Review strategy

Two reviewers independently screened and assessed the titles and abstracts of the retrieved articles. The reviewers met and reached consensus at the end of the screening process. In cases of disagreement, a third independent reviewer was consulted to resolve the disagreement. We compared the results of the independent screenings using the kappa statistic (kappa = 8.6). The reviewers were blinded to each other's decisions to control for assessment bias. We also checked the reference lists of the articles retrieved for other relevant studies. We developed a data collection form and extracted the following information from each paper: study year, region, objectives, GIS application type, variables visualized by GIS, and all other variables examined that related to maternal health. We examined the extraction forms for coverage, clarity and content validity in several meetings. We divided the extracted variables from the studies into two groups: subvariables and variables directly visualized on GIS. Based on expert consensuses and in order to better report on the variables, we classified the subvariables into six categories: (1) maternal factors, (2) socioeconomic factors, (3) health care service factors, (4) ecological determinant factors, (5) environmental factors, and (6) health related factors.

Results

Study selection

In our initial search of the online databases we found 5240 articles (Figure 1). After our first screening of titles and abstracts based on out inclusion and exclusion criteria, we retained 201 eligible articles for further full-text review. Based on this review of full texts, we excluded 161 articles as they did not meet the inclusion criteria, and retained 40 articles for detailed analysis.

Included studies

Of the 40 articles we retained, all were journal papers. Table 1 gives a description of the 40 studies – publication year, objectives, region and data sources. The oldest articles were published in 2004 (57,58). The number of studies investigating the application of GIS for maternal care has increased since 2010. Most of the studies (n = 29) were conducted in developing countries in Africa, Asia, and Latin America and the Caribbean (19–23,26–31,33,34,36,37,39–43,45–50,53,55,58) and 11 were conducted in developed countries in Europe, North America, Australia, New Zealand, and Japan

(24,25,32,35,38,44,51,52,54,56,57). Nearly half of the studies (n = 16) were done in Africa because of its high maternal and infant mortality rates (21,23,26,28,31,36,39–42,46–50,58), nine were done in Asia (19,20,22,27,34,37,43,53,55), 11 in the Americas and the Caribbean (24,25,29,30,32,33,44,45,51,52,54), three in Europe (35,57,56) and one in Oceania (38).

Each study presented data on one country/region, except one study which provided data on four countries (27). Multiple data resources were used to conduct the studies. The source of data in 15 of the studies was national statistics and censuses (Table 1). Other sources of data included, among others, results of other previous surveys (n = 11), interviews with women and health staff (n = 5) health registries (n = 6).

Geographic access to health services was the most common factor examined (n = 22) in the included studies (20,22,25,26,28,30,35,37,39,40,41,43,44–47,49,51,52,56–58). Other common factors examined included antenatal care capacity (19,25,42,55) and capacity of maternal health services (21,48,53).

Most studies (n = 28) used the spatial analysis of the GIS software such as network analysis, buffer, hot spots and Moran techniques (19,22,23,26–29,31–35,37–45,48–50,52,53,55,56). Other studies (n = 10) used spatial mapping (20,21,24,25,30,36,51,54,57,58) and two used spatial modelling techniques (46,47).

Many of the studies that used GIS in maternal health focused on potential geographic access to care on the basis of the spatial distribution of health facilities (27,35–37,44,46,47,51,52,56). Some investigated the effect of geographic access on mortality and care utilization (24,33,49,55). Other studies modelled the availability of and access to emergency obstetric care (22,28,43,50).

The geospatial unit of analysis in 16 studies was the national level (27,28,29,31,35,36,39,40,44,46,48–50,52,56,58). Most of the studies (n = 24) used ArcGIS (Esri, Redlands, California, United States of America) (19–21,24,25,27,31,32,34,36–39,42–47,50,51,53–55) to analyse the data, 10 studies used other types of GIS software – ArcView, QGIS, ArcInfo – (22,26,28–30,35,41,49,56,58), and six did not state which software was used to analyse the data (27,33,40,47,52,57).

Variables extracted from the studies are shown in Table 2 . Many studies visualized the variables: distance to health facilities (n = 16) and travel time to health care centres (n = 17). Other frequently mapped variables were spatial distribution of health services and emergency obstetric care (n = 11). Socioeconomic and sociocultural variables, such as women's educational level (n = 10) and household wealth (n = 9), were often investigated.

Discussion

The findings of our study show that special attention has been paid to geographic access and travel time to health services in published literature on maternal health. Other important reported variables included: maternal age, maternal educational level, household wealth, residential area, distribution of health services, and availability of emergency obstetric care facilities per population.

Determining the distribution of human resources (obstetricians/gynaecologists, maternity nurses and midwives) can show imbalances in the distribution of health personnel. The findings of some research has shown that the educational level of women was strongly correlated with the maternal mortality rate (59–63). The results of our study also showed that mothers' educational level was frequently reported in the included studies. Educational level has a positive influence on autonomy, awareness of health services, the health-seeking behaviour, responsibility and knowledge of self-care and healthy lifestyles (64) and can directly and indirectly contribute to a reduction in maternal mortality. Some believe that education may have a more important role compared to economic indicators, such as income, clean water supply and sanitary sewer access (65). Maternal age was examined as the underlying variable in many of the studies we reviewed, and is a key variable because older women are at a higher risk of death and complications during pregnancy or delivery (66,67). The risk of pregnancy-related death for mothers over 40 years between 1998 and 2005 has been reported to be six times higher compared with teenagers (68,69). Others research has found that young adolescents (