

## **The Role of Digital Health Applications in Improving Maternal Health: A Study of Various Applications in High-Income Countries and Low and Middle-Income Countries (LMIC) - A Systematic Review**

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### **Abstract**

**Background:** Technology can disseminate information from the farthest reaches of the globe and provide information even in high-resource environments. In recent years, digital technology has had a significant impact on healthcare delivery processes, and this trend is expected to continue in the future. Pregnancy and maternal health are crucial stages in a woman's life, and they need accurate information to ensure a smooth delivery. This article provides insight into the impact of digital applications which use mobile or web-based delivery method to deliver information using web or mobile based interface for maternal health.

**Methods:** A literature search from databases such as Cochrane, Embase, Medline, PubMed, and Web of Science was conducted to identify and include peer-reviewed articles published from 2011 to 2021. PRISMA flow chart and Mendeley reference manager were used for article screening.

**Results:** After the screening, nine articles (n = 9) were included for review, with five articles from high-income countries and four from middle-income countries (LMIC) studying effects of mental health information disseminated through digital platforms.

**Conclusion:** Digital health apps provide a promising forum for sharing knowledge during and after pregnancy. Due to the small sample sizes used in previous research, there is an urgent need to examine the viability of digital applications for a larger group effect.

**Keywords:** *mHealth; eHealth; Digital App; Maternal Health*

### **Introduction**

A healthy mother is the foundation of a healthy society. The World Health Organization (WHO) defines Maternal Health as the health of women during pregnancy, childbirth, and the postnatal period [1]. Creating an environment for healthy motherhood requires a pragmatic approach as every pregnancy and birth experience is different. The phase of pregnancy is a transition phase to motherhood, which requires adjusting to uncertainties and anxieties [2]. The conventional methods to empower patients include physician consultations, the use of books, or seeking advice from others [3].

The world is witnessing a boom in mobile internet users, with over 4.8 billion users worldwide in 2019 [4]. This massive upsurge, along with the exponential increase of availability of mobile internet in remote parts of the world, is bringing information to the fingertips

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of many individuals [5]. Digital technologies influence information and communication technology (ICT) practices for conveying health-related messages. TCC (targeted client communication) is a new development in digital interventions for healthcare communication [6]. As the internet becomes the most used platform mothers use to seek information, web based, and mobile applications offers unique and effective ways to assist-pregnant women and mothers with verified information that will empower them with a variety of tools without the need to travel or seek help from unreliable sources [7].

Multiple studies focusing on other digital platforms such as text messages and other interventions of mHealth techniques have been studied in detail, however, a systematic review on the effect of mobile applications for improving maternal health has not been conducted thus far. This paper aims to evaluate the extent, type, impact, and effect of digital applications designed to support maternal health in LMIC and high-income countries.

### Objectives of the Study

To conduct a systematic review of studies which evaluate the effects of digital applications designed to improve maternal health in high-income and low-middle income countries.

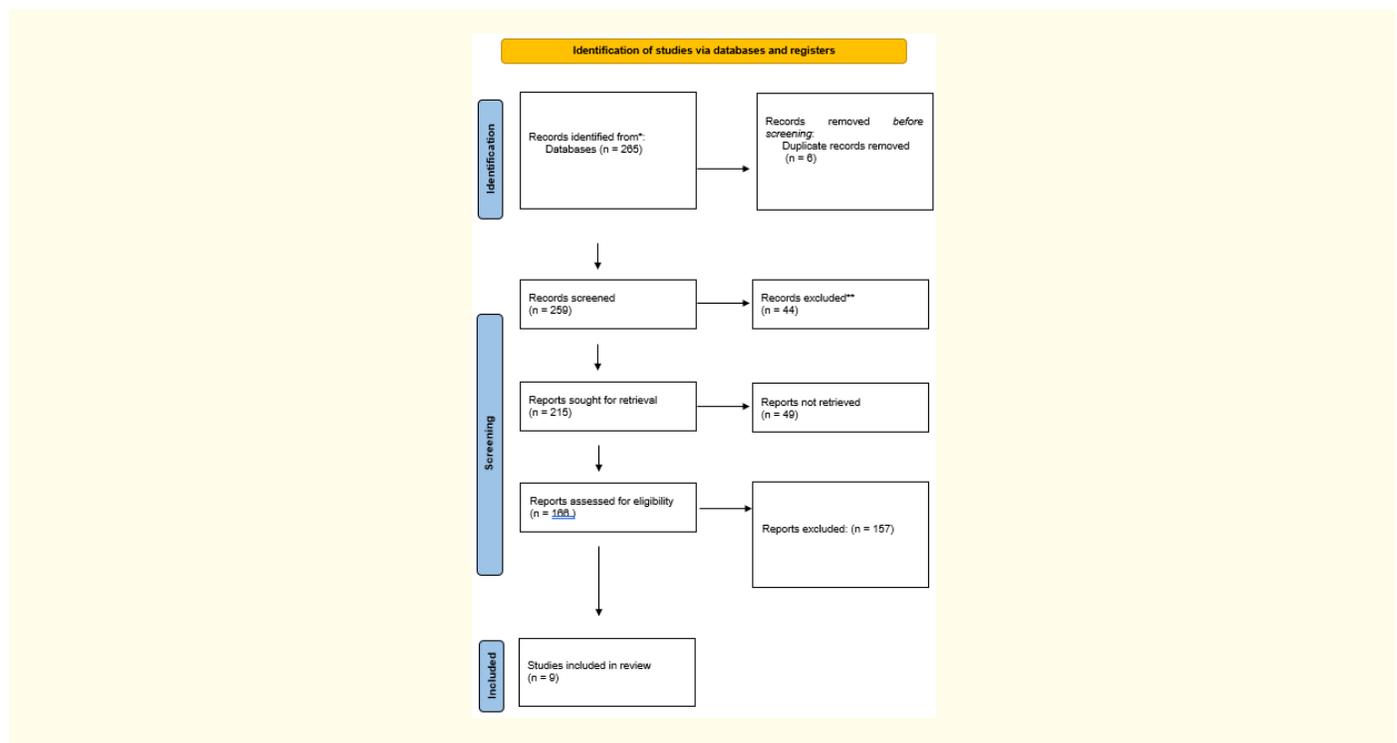
### Methods

**Study design:** This systematic review was conducted using the PRISMA model.

**Search strategy:** A literature search was conducted using the terms “maternal” AND “health” AND “digital” AND “child” OR “mHealth” OR “global” OR “mobile “ OR “eHealth”. The databases included Medline, Embase, Cochrane, Web of Science, and PubMed. The initial search resulted in a total of 265 articles, and this search result was saved for further review in Mendeley reference manager.

**Study selection:** This review’s focus is to examine the use of mobile applications during pregnancy and maternal health. Hence, our inclusion criteria included research utilizing digital applications as an intervention and applications used directly by pregnant women or mothers. Our criteria also included only articles published in English. An initial search provided us with 265 articles, but after eliminating duplicates and initial title and abstract screening, 126 articles were selected for full-text screening. After full-text screening, we selected 9 articles for data abstraction based on our inclusion criteria. The selected studies included both qualitative and quantitative designs and were published in the last ten years to include the most relevant data. Each article review was conducted independently by the six reviewers and reassessed by a second reviewer from the team to verify findings and eliminate conflicts in the selection process.

**Quality assessment:** As the included studies were qualitative, the Effective Public Health EPHPP technique proposed by Helen Thomas and Dr. Donna Ciliska [8] was used for quality assessment. The quality evaluation was done separately by 2 authors, and then a consensus was reached by quality evaluation authors.



Results

Author and Year	Income	Study Type	Sample Size	App Used	Key findings	EHPP
Entsieh, <i>et al.</i> 2015 [9]	LMIC	Focus Group discussions and In-Depth Interviews	29	Mobile Midwife	<p>Mobile Midwife is a reliable and continuous source of help, as well as four main themes:                      1) Consistently grasping pregnancy advice                      2) Partially being caught between nutritional myths                      3) Understanding the need for specialized treatment                      4) Gaining self-confidence to care for their children</p> <p>The women were unaware of the possible adverse effects of malaria on pregnancy before Mobile Midwife educated them on the subject. Interacting with the Mobile Midwife raised awareness of expectant mothers about the value of obtaining skilled assistance from health care centers during pregnancy and childbirth, particularly if complications arise. Their husbands grew interested in the Mobile Midwife messages and frequently assisted their pregnant wives as recommended by Mobile Midwife.</p> <p>The women said that their antenatal attendance had progressed and that they had given birth to their most recent babies at the healthcare facility.</p>	Weak
Goetz, <i>et al.</i> 2017 [3]	High	Web-Based Survey Focus Groups Interviews PRELAX app was used to conduct the survey;	30/37	Pregnancy Apps	<p>Women critiqued the poor quality of existing web-based information sources and mobile apps due to a lack of validated information.                      Pregnant Mothers need individually tailored information. Apps act as a doctor - patient communication platform. There is a need for consumer-friendly web-based and mobile app as well as a concern over the privacy of the information stored                      There was no statistically significant difference between outpatient and inpatient use of an app.                      App use is mainly influenced by socioeconomic background or education.                      Most participant conducted an internet search for information and will not recommend relying on free search.</p> <p>Healthcare professionals should dedicate time to guide women through information provided by the applications to limit any misinterpretation from non-validated resources and limit adverse outcomes.</p>	Weak
Halili, <i>et al.</i> 2018 [10]	High	Focus Groups	13	Smart Moms Canada	<p>Participants agreed that the app provided pregnancy advice, encouragement, and useful pregnancy-related information, especially as a tool for reducing stress and disseminating informal support that health care providers might not have time to provide.</p> <p>Women agreed that the details available in SmartMoms were beneficial and that it placed a stronger emphasis on overall health as well as physical activities.</p> <p>Setting their own goals and engaging with the app in terms of making their own checklists and to-do lists piqued women’s interest.</p> <p>Women mostly used the app to monitor their weight during pregnancy, but they also wanted it to focus more on overall maternal well-being, emphasizing exercise, healthy eating, sleep, and mindfulness.</p>	Strong

<p>Militello, <i>et al.</i> 2021 [11]</p>	<p>High</p>	<p>Survey questions and Exit Semi Structured survey</p>	<p>19</p>	<p>SMILE</p>	<p>The authors used SMILE App which used podcasts to educate perinatal women. The app also collected responses for 2 questions at the end of each podcast and an exit survey to assess the acceptance of the system. The system received 475 responses, with 87.2 percent (414/475) being positive comments. 86.8% of perinatal mothers gave positive feedback for 1<sup>st</sup> question among the 2 questions and average interest in hearing more podcasts was 85.8%. Despite the positive feedback, the number of users per episode was cut in half as the podcasts reached episode 15.</p> <p>The exit survey showed that perinatal were receptive to using voice technology as a potential platform to support health.</p> <p>The study showed that highlighting that hands-free, convenient activities were a strength of voice technology.</p> <p>Although acceptance was good, the participants did not find the podcasts practical.</p> <p>The article findings show that disseminating evidence-based perinatal support via podcasts and curating voice-captured data from perinatal women is feasible in the short term. However, specific areas for improvement have been identified for perinatal interventions utilizing voice technology and further studies are required.</p>	<p>Moderate</p>
<p>Musi-meta <i>et al.</i>, 2020 [12]</p>	<p>LMIC</p>	<p>Mixed method Study-</p>	<p>14</p>	<p>Java App and SQLite database app</p>	<p>Implementing mHealth platforms will relieve patients of transportation burdens, help them share information with their spouses, and feel cared for.</p> <p>They could see its potential use in birth preparedness, identifying danger signs, breastfeeding, and immunization.</p> <p>Pregnant women reported that using a mobile phone-based application could support them in remembering to attend their antenatal appointments by lowering the risk of forgetting.</p> <p>They also stated that the videos and audios information was easily understandable as they were played in their native language and could be replayed as many times as desired. This approach was preferred over the clinic's current approach as the information was tailored to their specific needs.</p> <p>Pregnant women anticipated circumstances in which they might receive information but fail to respond due to a lack of financial resources.</p>	<p>Weak</p>

Sun Y <i>et al.</i> 2021 [13]	LMIC	Survey	168	Smart-phone-based training	<p>Participants in mindfulness training reported significant improvements in depression (group time interaction 2 4=16.2, P=.003) and secondary outcomes (2 4=13.1, P=.01 for anxiety; 2 4=8.4, P=.04 for positive affect) when compared to designated control group participants. Post-intervention, mindfulness training participants reported a lower risk of depressive symptoms (Edinburgh Post-natal Depression Scale [EPDS] score&gt;9) than attention control participants (odds ratio [OR] 0.391, 95 percent CI 0.164-0.930)</p> <p>Following the use of the smartphone-based mindfulness training, screenings for depression were lower.</p> <p>Pregnant women receiving mindfulness training had a 2.471-times greater chance of having a lower EPDS score from baseline to post-intervention when compared to women in the attention control group.</p> <p>In follow-up investigations, the additional benefits of mindfulness training in pregnancy yielded promising results of a low anxiety level and a high positive affect.</p>	Weak
Taki <i>et al.</i> 2019 [14]	High	semi-structured interview	225, 21 for interview	GH APP	<p>Participant characteristics, such as number of previous pregnancies, knowledge, and learning style, affected interest towards the usage of the GH app.</p> <p>Unidirectional push notifications were the main delivery feature that influenced engagement in GH, though the timing of the push message was important. Users perceived the app to be a convenient way to access infant feeding information.</p> <p>Mothers will trust the app if it has a university endorsement and if their doctors advise, but it is expensive to do so. App dysfunction like technical difficulties due to unanticipated upgrades can reduce the interest in using the app</p>	Weak
Van Dijk <i>et al.</i> 2016 [15]	High Income	Short online Follow-up screening surveys every six weeks	N = 1275 (couples contemplating pregnancy) N = 602 (already pregnant)	Web-based smarter pregnancy program - 6 months online coaching 1) SMS and email max 3 interventions per week	<p>1) 64.86% (1218/1878) compliance of participants completing the 6-month program rate was observed 54.7% (range 39.2-73.4%) of participants rated the program usability as positive or very positive. At baseline, 21.57 percent (405/1878) reported adequate vegetable intake, 52.61 percent (988/1878) reported adequate fruit intake, 85.44 percent (1303/1525) reported adequate folic acid use, 86.79 percent (1630/1878) reported no tobacco use, and 64.43 percent (1210/1878) reported no alcohol consumption.</p> <p>The program showed the strongest effectiveness for participating couples. This novel Web-based mHealth platform demonstrates high compliance and usability, and users show improvements in nutrition and lifestyle behaviors.</p>	Weak

Wang <i>et al.</i> 2019 [2]	LMIC	Web-based survey; Focus group interview	535 participated in the cross-sectional Survey 28 women from this agreed to participate in focus group	Pregnancy Apps	<p>Nearly 50% of the women were found to use Pregnancy related smart phone applications in general.</p> <p>Women’s app usage declined from 1<sup>st</sup> trimester to 3<sup>rd</sup> trimester.</p> <p>Women tend to rely on known experienced women within their own family or friends as the pregnancy progressed</p> <p>Most women in this survey (81.5%) used apps for Fetal Monitoring</p> <p>Only 26.2% of women included in this survey used apps for managing diet due to a lack of credible information.</p> <p>Only 50 % recommended using info from apps due to conflicting information regarding food and alcohol consumption.</p> <p>Pregnant individuals believed their doctors over apps.</p> <p>Learning from women experiences shared on web could possibly lead to confusion and anxiety</p> <p>Privacy issues can lead to difficulty in linking apps to hospital data.</p> <p>50% increase in Gestational Weight Gain amongst the included participants and lack of exercise</p>	Weak
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**Discussion**

The maternal health status of any country reflects its progress in terms of improving the health status of the population [16]. Maternal deaths have been referred to as the “tip of the iceberg”, whereas maternal morbidity has been referred to as the bottom. For every woman who dies from pregnancy-related causes, another 20 or 30 suffer from acute or chronic morbidity, sometimes with long-term consequences that impair their ability to function normally [17]. Maternal health improvement is among the top agendas of many countries as it forms a major part of the UN’s Sustainable Development Goals [18]. As a result of the realization that the world’s current digital revolution may hold the key to improve maternal health, several countries have begun to introduce mHealth programs to supplement and improve the current state of the healthcare system [19]. Among the mHealth revolution, mobile apps play a central role in improving maternal health [20]. Hence, conducting a review of related published research makes a vital point in helping improve the mobile apps for maternal health. This review has shown that digital health applications mainly focus on improving aspects of maternal health such as antenatal and postnatal care attendance [9,11], utilization of healthcare facilities [9] and maternal education [2].

The articles included in this review primarily focused on understanding how expecting and new mothers seek information, especially regarding nutrition and the various myths associated with it [2,9]. Many participants complained that the current information available online and offline is unreliable and cannot be trusted, therefore, having an application that provides reliable information will have better acceptance [2].

Digital application usage in LMIC depends mainly on socioeconomic status and education [13]. This is also supported by Goetz., *et al.* [3] in Germany, who found that socioeconomic background and education impacted the application use. In LMICs, there is a spectrum of application use, including smartphone-based training to prevent Maternal Depression [13]. The impact the smartphone platform had on lowering maternal depression shows the potential impact of apps on maternal health. Another impact the apps have on expecting and new mothers is creating awareness regarding the use of hospitals and skilled assistance/midwives [9].

In lieu of the current COVID - 19 pandemic, interventions such as digital applications can play a vital role in keeping mothers connected to the healthcare system. This is critical in many LMICs due to limited healthcare resources currently available. Mobile applications have been shown to be a vital tool to contact and get virtual assistance from doctors, midwives, and other health professionals [12].

A number of studies in LMICs evaluated pregnancy applications to improve maternal health [2,9,21]. The research suggests that mHealth has a positive effect on choosing healthy food during pregnancy, identifying danger signs, supporting breastfeeding, and immunization. The respondents of the studies mentioned concerns with breaches of privacy by sharing personal information, as well as concerns regarding financial constraints of following the nutritional recommendations [13,22]. Study on pregnancy applications found that most women used pregnancy apps for fetal monitoring [2]. This study highlighted that 50% of responding women recommend app information to clarify conflicting information regarding food and alcohol consumption. Provided the design, aesthetic, developmental coding errors, and synchronize difficulties between the app and accessories for the Smart Mom's app being resolved in the upcoming version, women could see the app's future potential for health promotion during pregnancy [10]. Other LMIC studies focused on the "Mobile midwife" app, a reliable and continuous source of help to provide pregnancy education and raise expectant mothers' awareness of the value of obtaining skilled assistance from health care centers during pregnancy and childbirth [9]. This study also signified the positive effect of partner interests on health interventions and maternal health outcomes [9].

The positive effect of the "SMILE" podcast suggested those specific areas need improvement for more interventional support during the perinatal period of women [11]. One unique finding that is identified in the study is that participant women criticized the poor quality of the existing pregnancy applications and invalidated the web-based information [3]. Study participants were also concerned about privacy of the information stored through the mobile app. Most high-income country studies documented that sociodemographic factors, such as maternal education and family income, have an influential effect on maternal health outcomes which was further confirmed through the eminent use of digital health applications [3,10,14]. Study participants responded that expensive apps negatively affect digital health interventions on maternal health outcomes [14]. The Van Dijk study assessed the effect of mHealth on maternal nutrition and lifestyle modification education, and it published the positive outcome of digital behavioral coaching [15]. Like other LMIC studies, one of the high-income country studies showed the positive effect of digital health applications in reducing maternal pregnancy-related stress with plentiful pregnancy advice, encouragement, and information. Many participants had a positive approach in accepting eHealth interventions and including them in routine practices [3].

### **Limitations of the Study**

This review on digital applications used by pregnant women and mothers mainly focuses on health information and promotion. To keep the study focused on outcomes related to digital applications platforms, short messaging services (SMS) have been excluded from this review. The recent surge in digital interventions in healthcare provides encouraging data for integrating these practices in long-term use through various modalities. Although digital applications used by healthcare providers for maternal health are a promising outlet for use, they were not considered to narrow our criteria.

### **Conclusion**

Given the flexibility and agility of digital applications to drive value-based outcomes, there is a need to promote them as an educative tool for improving maternal health worldwide. In addition, digital health applications are a valuable tool for providing accurate and evidence-based information to pregnant women and mothers. Since much of the research has been done in small groups, a larger-scale intervention to evaluate the efficacy of digital platforms are required. The differences in tailored approaches between LMIC and high-income countries were evident during the study. The quality assessment for the studies included, although preliminary, provides encouraging results to pilot them at a larger level. Here, the digital application's goal was mostly customized to meet the requirements of the regional population. In summary, it can be inferred that digital applications can be customized to address individual needs to provide knowledge and assistance to women at a crucial transitional point in their lives.

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