BMC Pregnancy and Childbirth

RESEARCH

Open Access

A scoping review of digital technologies in antenatal care: recent progress and applications of digital technologies

Halila Mohamed[1], Aniza Ismail[1*], Rosnah Sutan[1], Rahana Abd Rahman[2] and Kawselyah Juval[3]

Abstract

Introduction Digital health technologies have vastly improved monitoring, diagnosis, and care during pregnancy. As expectant mothers increasingly engage with social media, online platforms, and mobile applications, these innovations present valuable opportunities to enhance the quality of maternal healthcare services.

Objective This review aims to assess the applicability, outcomes, and recent advancement of digital health modalities in antenatal care.

Method We conducted a scoping review by searching four electronic databases (Scopus, Web of Science, PubMed, EBSCOhost), performing manual searches of Google Scholar, and examining the references of relevant studies. Eligible studies included original research published in English between 2010 and 2024 involving the use of digital health technologies for antenatal care, complying with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping review guidelines.

Results One hundred twenty-six eligible articles were identified, with the majority (61.11%) conducted in high-income countries, including the United States, United Kingdom, and Australia. Digital health studies have increased over time, driven by telehealth adoption in affluent nations. Interventions predominantly focused on patient-provider consultations, remote monitoring, and health education, complementing in-person visits or as a substitute when necessary. High levels of acceptance and satisfaction were reported among users. These interventions primarily targeted general maternal care (28.57%), gestational diabetes mellitus (15.07%), and mental health (13.49%) while also addressing gestational weight management, hypertensive disorders, high-risk pregnancies and maternal education. The findings demonstrated positive outcomes in managing clinical conditions, enhancing knowledge, promoting birth preparedness, and improving antenatal care access and utilisation. Additionally, the findings revealed the cost-effectiveness of these approaches in alleviating financial burdens for patients and healthcare systems.

Conclusion Digital health is emerging as a pivotal tool in maternal and child care, fostering positive outcomes and high acceptance among patients and healthcare providers. Its integration into antenatal care ensures the maintenance of standard care quality, with no adverse effects reported despite limited discussions on safety and privacy concerns. As these technologies continue to evolve, they are set to redefine antenatal care by offering more accessible, efficient, and patient-centred solutions, ultimately shaping the future of maternal healthcare delivery.

*Correspondence:
Aniza Ismail
aniza@hctm.ukm.edu.my
Full list of author information is available at the end of the article

Keywords Prenatal care, Gestational, Digital health, Telehealth, Telemedicine, Mobile health, Remote monitoring, Consultation

Introduction

Antenatal care (ANC), or prenatal care, is vital for promoting the health and well-being of pregnant individuals and their unborn children. It plays a critical role in the early detection and management of potential complications, promotes positive maternal and neonatal outcomes and provides essential education and support during pregnancy [1, 2]. Despite its importance, the compliance, effectiveness, and accessibility of ANC services are influenced by various factors, including socio-demographic characteristics, healthcare infrastructure, cultural beliefs, and knowledge [3, 4]. Integrating digital health technologies in ANC service has emerged as a transformative approach to address these challenges, offering novel solutions to improve access, efficiency, and the quality of maternal health services [5].

Digital health technologies have significantly advanced maternal and foetal health outcomes by enabling real-time monitoring, personalised care, and improved access to critical health interventions [6, 7]. By addressing barriers such as geographical distance and resource limitations, these technologies enhance the accessibility, coverage, and utilisation of maternal healthcare services, ensuring pregnancy safety and continuity of care [8]. This impact is particularly evident in low- and middle-income countries (LMICs), where limited infrastructure and geographical barriers often restrict access to traditional healthcare services [9]. Furthermore, the adoption of digital technologies in maternal healthcare not only improves convenience and accessibility but also plays a crucial role in addressing healthcare disparities and promoting equity in maternal health services, ensuring more inclusive and effective care delivery [10].

The adoption of digital technologies in antenatal care has elevated the quality of services by fostering effective communication, delivering personalised care, and enabling timely access to critical information and support [11]. These innovations empower both patients and healthcare providers to make informed decisions, resulting in better health outcomes [12]. Various digital tools support these improvements, each addressing specific maternal healthcare needs. Mobile applications and telehealth platforms enhance communication between patients and healthcare providers, promoting active patient engagement [13–15]. Wearable devices and AI-driven analytics generate real-time insights, facilitating timely interventions and informed clinical decision-making [16]. Additionally, decision support systems streamline workflows, enabling healthcare providers to deliver efficient, targeted care [17]. Together, these technologies contribute to a healthcare system that is increasingly patient-centred, scalable, and adaptable to diverse needs. Advances in information and communication technology (ICT) further underscore the transformative potential of these tools in improving maternal healthcare, particularly in preventive care settings [18, 19].

The COVID-19 pandemic has brought significant changes to the healthcare landscape, with one of the most notable shifts being the rapid adoption of digital health technologies [20]. This trend has profoundly influenced maternal healthcare, where digital interventions have been increasingly utilised to ensure continuity of care and address challenges posed by limited physical access to healthcare services [12]. Even as the pandemic subsides, the use of digital health technologies remains prevalent, gradually becoming an integral and routine part of maternal healthcare practices. [21]. The increasing reliance of reproductive-age women on the Internet, social media, and smartphone applications for prenatal, perinatal, and postnatal health information underscores the growing importance of digital health solutions [22]. These platforms offer a valuable opportunity to enhance maternal care, enabling expectant mothers to navigate their pregnancy journeys with greater confidence and support [23].

There has been a positive association between the use of digital tools in antenatal care and improved maternal and foetal health outcomes [24, 25]. Both the American College of Obstetricians and Gynaecologists (ACOG) and the American College of Nurse-Midwives (ACNM) have recognised the pivotal role of digital health, particularly telehealth, in maternal care, emphasising its potential to shape the future of antenatal services [26–28]. However, the effective use of digital health technologies in obstetric care must be guided by patient preferences and access, considering the complexities of clinical settings and the unique needs of pregnant women [29–31]. Importantly, these digital innovations in antenatal care are intended to complement and strengthen standard care practices, serving as valuable additions rather than substitutions.

While digital health tools hold the potential to enhance antenatal care, their widespread adoption faces notable barriers. These include disparities in digital literacy, inequitable access to reliable internet

connectivity, and ongoing concerns about data security and patient privacy [32–34]. Moreover, it remains crucial to rigorously assess the quality of antenatal care services provided through digital platforms to ensure they meet the established standards of care practice [9]. This review explores advancements in digital healthcare applications for antenatal care, highlighting their practical usefulness and the evolving trends in the usage modalities from 2010 to 2024. By examining the adoption and development of digital health technologies over this period, the review seeks to offer a comprehensive understanding of their growth and impact on antenatal care practices. Furthermore, it highlights the key transition towards telehealth, remote monitoring, and other digital health innovations, which have increasingly become integral components of routine antenatal care.

Objective

This review aims to assess and categorise the characteristics, features, and effectiveness of digital health modalities in antenatal care, focusing on their applicability, outcomes, and recent advancement. It examines the role of digital health technologies in enhancing maternal healthcare services, focusing on their application either as substitutions or complementary enhancements to traditional antenatal care. It delves into the various modalities employed to improve service accessibility, utilisation, and maternal health outcomes, providing insights into their effectiveness and impact on healthcare delivery.

Methods

Overview

This scoping review was conducted in accordance with the methodological framework proposed by Arksey and O'Malley [35] and Levac et al. [36]. The Arksey and O'Malley model outlines six fundamental phases: (1) identifying the research question; (2) searching and identifying relevant studies; (3) selecting the relevant studies; (4) charting the data; (5) collating, summarising, and reporting the results; and (6) consulting with stakeholders (optional). The scoping review methodology was chosen to investigate the current state of digital health technology in ANC provision. The reporting of this scoping review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines [37, 38].

Identifying the research question

This review addressed the following key questions, as shown in Table 1.

Search strategy

A comprehensive search was conducted on November 12, 2024, across four major electronic databases: SCOPUS, Web of Science, PubMed, and Medline/EBSCOHost. To complement this, Google Scholar was utilised to identify additional relevant studies. The search was limited to peer-reviewed articles published in English between January 2010 and November 2024. The primary focus was on studies investigating digital health technologies specifically designed to support antenatal care services. The search strategy was developed using Medical Subject Headings (MeSH) and relevant keywords associated with antenatal care and digital health. Boolean operators "AND" and "OR" were applied to systematically combine keywords, enabling a thorough exploration of literature across both medical and information and communication technology (ICT) fields. This approach ensured the retrieval of a comprehensive and focused body of literature for the review. The search string was as follows:

Table 1 Research questions

Research Question	Rationale
What is the trend in the publication of scientific articles related to digital technology in maternal care?	To observe the publication trends of scientific articles on digital technology in maternal care and identify the countries actively involved in digital health advancements
What digital health technologies have been used to enhance the provision of ANC?	To determine the types and trends of digital health technologies supporting the evolution of ANC over time
Which health domain has attracted considerable attention in the application of digital technology?	To identify the specific ANC health domains that have received significant attention in the application of digital technologies
How do digital health technologies contribute to ANC support?	To explore the functionalities and roles of digital health modalities in facilitating and improving ANC
What are the primary outcomes of digital health technology use in ANC?	To evaluate the outcomes associated with the use of digital technologies in ANC, including effectiveness, acceptance, feasibility, and satisfaction

A. Pregnancy care OR antenatal care OR prenatal care OR perinatal OR prenatal OR during pregnancy OR gestation OR obstetric care OR maternal care
B. Digital health OR digital health care OR Digital Health Technologies OR Digital health intervention
C. eHealth OR mHealth OR mobile health OR Telemedicine OR Telehealth OR Telemonitoring OR Virtual care OR Virtual consultation
D. Acceptability OR Feasibility OR Satisfaction OR Maternal outcome OR Effectiveness OR Safety
E. [A] AND [B] AND [C] AND [D]

Data extraction

Our review focused exclusively on studies utilising digital health technologies relevant to healthcare delivery in ANC. Technologies unrelated to specific health conditions, maternal health or healthcare delivery, were excluded from consideration. No restrictions were imposed regarding study design, methodological approach, or publication venue.

The data extraction process focused on identifying relevant information related to digital health technologies or interventions in antenatal care. Extracted data included the author(s), year of publication, study location, study design, and topic category. Detailed descriptions of the digital health interventions, their purpose, the type of intervention, and clinical outcomes were also recorded. The reviewed digital technologies encompassed innovations such as wearable devices, mobile applications, text reminders, and other technologies related to mHealth, telehealth, telemedicine, and virtual care. These technologies were categorised by their clinical target areas (e.g., hypertension, mental health), purpose (e.g., education, remote monitoring, prevention), mode of delivery (e.g., phone-based interventions, virtual consultations, mobile or web applications), and whether they served as supplementary or substitutive to traditional care.

Duplicates were identified and removed using Endnote 21 software. Two independent reviewers conducted the screening process, beginning with the title and abstract and followed by a full-text review. Reviewer disagreements were resolved through consultation with a third-party supervisor, who acted as an arbitrator to reach consensus. This systematic approach ensured the reliability and validity of the data extracted for subsequent analysis.

Inclusion and exclusion criteria

The eligibility criteria refined the selection according to the review objectives and were based on the inclusion and exclusion criteria and whether they met the participants or population, concept, and context mnemonic categorisation suggested by the Joanna Briggs Institute for Scoping Reviews [39], as shown in Table 2. Studies without accessible full texts or those available only as abstracts were excluded from the review, as abstracts alone often lack sufficient detail necessary for comprehensive data extraction and analysis.

Data analysis

Several temporal trends were identified from the study list, such as the number of studies conducted each year

Table 2 Inclusion and exclusion criteria

Categorisation	Inclusion Criterion	Exclusion Criterion
Population	HCPs and antenatal mothers using digital technologies for pregnancy care	Not related to ANC, that focused on postpartum or postnatal care, family planning or involving partners, spouse, or family
Concept	Involved digital health interventions or tools that primarily used technological platforms to deliver antenatal health services through different digital modalities: websites, computer software, mobile apps, short messaging service (SMS), email, or others	Involved digital technologies for data services or health systems or resource managers, not related to health care provision for pregnant women
Intervention	Wearable devices, mobile apps, websites, mHealth, teleconsultation, virtual care, voice or SMS text reminders	Health management or information systems
Context	Serve to support maternal health in the antenatal period among health providers and patients	Additional reproductive ages including family planning, intrapartum, postpartum period and studies that reported outcomes related to the baby's health
Outcome	Reported on maternal and neonatal outcomes / feasibility / acceptability / satisfaction	Lacked definitive outcome or reporting on data management
Study type	Original research articles, case studies, RCTs, quasi-experimental studies, implementation trials, observational studies, qualitative studies, prospective and retrospective studies	Conference abstracts, editorials, commentaries, letters to the editor, essays, book chapters and books, study protocols, reviews
Language	English	Language other than English

and the digital health technology modalities (text with images, videos, short messaging service [SMS], or others) used by the studies each year. Data characteristics were analysed using descriptive statistics and visualised through tables or charts to provide clarity.

Quantitative data, such as publication frequency, study locations, and adoption trends of digital health technologies, were systematically captured and presented. Qualitative data, such as intervention features and reported outcomes, were grouped and thematically analysed to highlight key findings on effectiveness, feasibility, and patient satisfaction. Findings were further stratified based on clinical conditions (e.g., gestational diabetes, hypertension) and delivery modes (e.g., telemedicine platforms, mobile apps). Given the diversity in study methodologies, types of digital technologies employed, and outcome measures, results were synthesised carefully to ensure meaningful interpretations while addressing the data heterogeneity. While digital tools are designed to benefit both antenatal mothers and healthcare providers, specific data on user populations were not extracted for detailed analysis.

Results

Literature search results

The search strategy retrieved 4,892 studies from selected academic databases, including Scopus, Web of Science (WoS), EBSCOhost MEDLINE, PubMed, and other relevant sources. After removing duplicate records, 4110 studies remained. Titles and abstracts were screened using predefined inclusion and exclusion criteria, narrowing the selection to 337 studies. A subsequent full-text review excluded 211 studies, leaving 126 studies eligible for data extraction. The PRISMA flow diagram (Fig. 1) outlines the selection process of the studies in the analysis, while Table 4 summarises the findings from the final included studies.

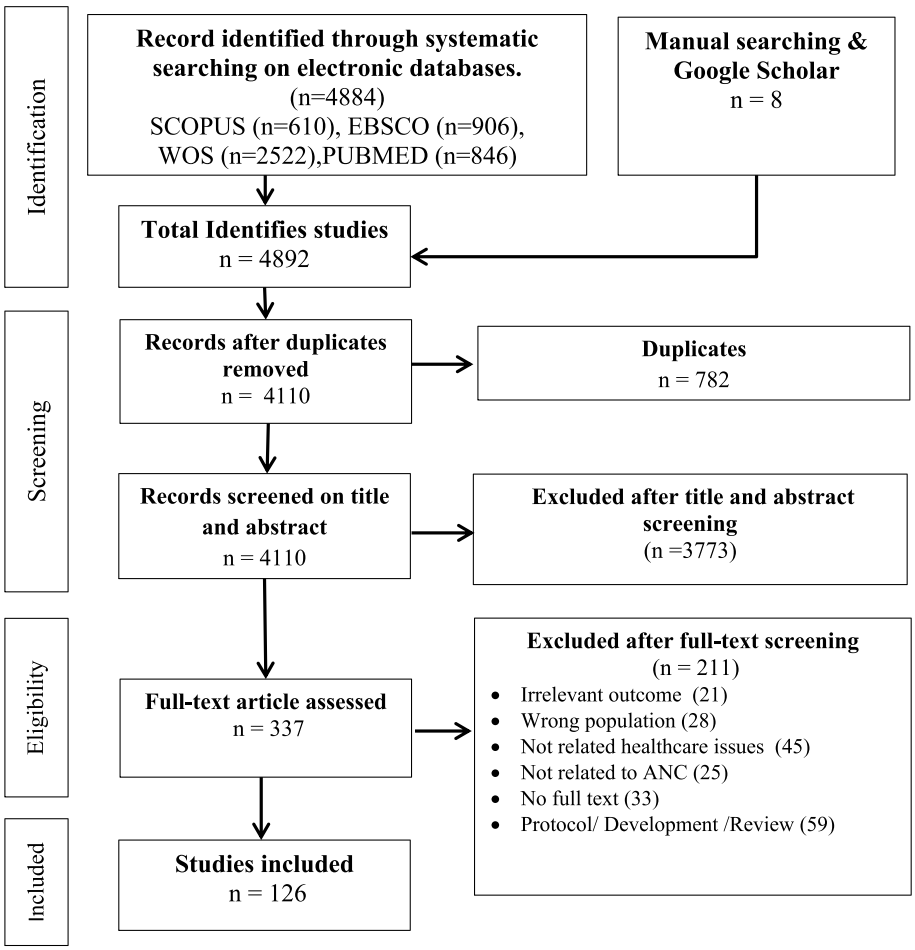

Fig. 1 PRISMA Flow Diagram

Data charting

Characteristics of the included studies

All articles reviewed reported on using digital health technologies or interventions for health-related purposes, specifically targeting antenatal care. The interventions were designed for antenatal mothers or healthcare providers involved in the care. Figure 2 illustrates the publication trends of studies on digital technologies in antenatal care from 2012 to 2024, revealing notable fluctuations in research activity.

Although the search period spans from 2010 to 2024, no publications specifically addressing the utilisation of digital health for healthcare delivery in antenatal care that fulfil the inclusion criteria were identified before 2012. The data reveals a minimal number of publications from 2012 to 2016, followed by a notable peak beginning in 2017. This upward trend continues, with substantial increases in 2018 and 2022, culminating in a significant spike in 2023, which recorded the highest number of studies. The decline in 2024 likely reflects incomplete data for the current year; however, the number of publications remains significantly higher compared to the earlier years. These findings highlight a growing academic interest in digital health technologies in antenatal care, particularly since 2017.

Table 3 summarises the findings and key characteristics of the included studies, highlighting aspects such as geographic distribution, income classification, delivery mediums, clinical conditions addressed, and study designs. The included studies were conducted in 35 countries, with the majority ($n=77$, 61.11%) originating from high-income countries (HICs). The United States contributed the largest number of publications, accounting for 36 studies [43, 45, 53–56, 59, 61, 63, 67, 74, 75, 95, 99, 100, 102, 103, 107, 109, 116, 119, 123, 125–128, 130, 131, 140, 151, 153, 156, 162]. This was followed by Australia with ten publications [80, 83, 88, 90, 91, 98, 108, 129, 136, 154], the United Kingdom with nine studies [79, 81, 85, 110, 120, 121, 124, 146, 155], and the Netherlands with five publications [114, 115, 122, 143, 163]. Other high-income countries (HICs) represented in the studies include Germany [97, 104, 134], Belgium [11, 111, 113], Italy [47, 86], and Spain [76, 77]. Additionally, there was one study each from Canada [58], Sweden [132], France [158], South Korea [78], Japan [69], Israel [82], and Poland [89]. The lower-income countries represented in the studies include Ethiopia [40, 157], Madagascar [44], and Iran [73, 106], collectively contributing to five publications.

The most frequently employed methodological approach was randomised controlled trials (RCTs), accounting for 45 studies [41, 50, 52, 56, 59, 72, 74, 75, 78, 81–84, 96, 99, 101, 104–107, 111, 120–123, 125–135, 142–144, 147, 152, 159, 160, 162, 163]. Cross-sectional studies (CS) represented the second most common design, with 19 studies [11, 44, 48, 49, 53, 55, 57, 58, 61–63, 79, 87, 93, 145, 146, 154, 155]. Similarly, quasi-experimental designs were utilised in 19 studies [45, 47, 65, 66, 73, 76, 90, 91, 94, 95, 102, 108, 112, 136, 141, 148–150, 161]. Other methodological approaches included observational studies [43, 71, 72, 79, 90, 91, 117, 120,1 39, 141, 142, 155, 158, 160] and cohort studies [54, 60, 67, 71, 86, 97, 98, 113, 116, 151, 157]. In addition, four studies utilised a non-randomized single-arm design [85, 100, 103, 109], while three studies employed a pre-and-post interventional approach [40, 42, 119]. While both pre-and-post interventional studies and single-arm non-randomized trials can be categorised under quasi-experimental designs, this analysis adhered strictly to the original terminology used by the authors in their publications. This classification approach ensures consistency, preserves the integrity of the reported methodologies,

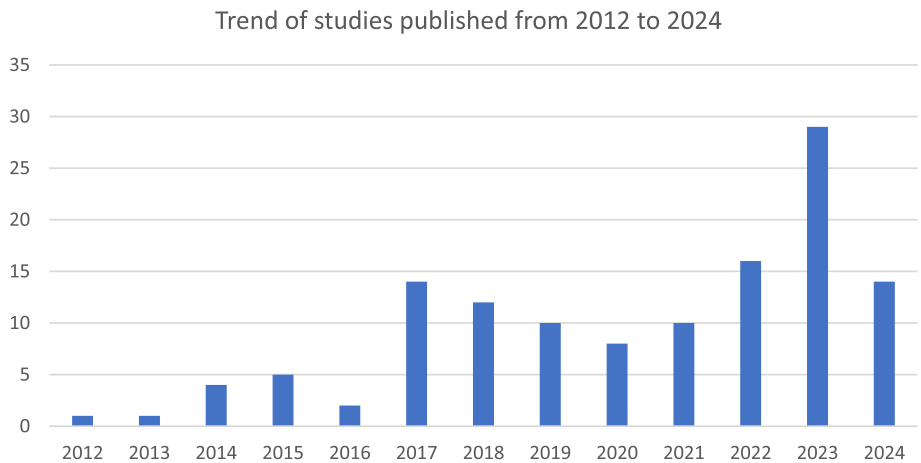

Fig. 2 Publication of Digital Health Technology Studies in Antenatal Care

Table 3 Characteristics of the included study

Category	Studies, n (%)
Region	
The Americas (USA, Canada, Brazil, Columbia)	43 (34.12)
Europe (Netherlands, Germany, UK, France, Italy, Poland, Belgium, Sweden, Spain)	27 (21.42)
The Western Pacific (Australia, China, Japan, South Korea)	16 (12.69)
Southeast Asia (India, Indonesia, Pakistan)	9 (7.14)
The East Mediterranean (Saudi Arabia, Iran, Turkey, Egypt, Iraq, Israel, Palestine)	11 (8.73)
Africa (South Africa, Nigeria, Kenya, Uganda, Tanzania, Ethiopia, Burkina Faso, Madagascar)	20 (15.87)
Income Group	
High-income countries	77 (61.11)
Upper-middle income countries	20 (15.87)
Lower-middle-income countries	24 (19.04)
Low-income-countries	5 (3.96)
Study Design	
Randomized Control Trial	45 (35.71)
Cross Sectional	19 (15.07)
Quasi-Experimental	19 (15.07)
Observational (non-specified)	14 (11.11)
Cohort	11 (8.73)
Qualitative	6 (4.76)
Non-randomized Single Arm Trial	4 (3.17)
Mixed Method	4 (3.17)
Pre and Post Intervention	3 (2.38)
Case Control	1 (0.79)
Clinical condition	
General Maternal Care	36 (28.57)
Gestational Diabetes Mellitus	19 (15.07)
Mental Health Issues	17 (13.49)
Gestational Weight Gain	12 (9.52)
High Risk Pregnancies	9 (7.14)
Maternal Education	9 (7.14)
Hypertension in Pregnancy	9 (7.14)
Smoking Cessation	4 (3.17)
Iron Deficiency Anemia	2 (1.58)
Vaccination	2 (1.58)
Remote Ultrasound Imaging	2 (1.58)
Pre-Anaesthetic Assessment	1 (0.79)
Cardiovascular Health	1 (0.79)
Physical Activity	1 (0.79)
Alcohol Cessation	1 (0.79)
HIV Prevention	1 (0.79)
Purpose of Digital Health	
Complementary to routine care	90 (71.42)
Substitution to routine care	36 (28.57)
Medium	
Teleconsultation (real-time)	32 (25.39)
mHealth	40 (31.74)
mHealth with targeted feedback	41 (32.54)
Teleconsultation (real-time) with mHealth	13 (10.31)

and aligns with the authors' intent. Additionally, case–control designs [114] and qualitative methods [46, 51, 64, 68, 80, 110] were employed in several studies, along with diverse methodological frameworks.

The current study did not specifically analyse the target population, as it included both antenatal mothers and healthcare providers. However, a review of the included studies reveals that antenatal mothers constitute most of the target population and serve as the primary end-users of digital health technologies. In contrast, only a few studies have focused on healthcare providers, primarily in the context of utilising clinical decision support systems (CDSS) and facilitating interfacility consultations and referrals to enhance the delivery of maternal care [40, 42, 44, 47, 50, 53, 66, 77, 135, 138, 142].

Clinical focus areas of digital health interventions

The analysis reveals that digital health solutions are primarily utilised for general maternal care, demonstrating diverse applications [11, 40–68], mainly to enhance maternal health knowledge, improve access to services, and foster greater patient engagement while aiming to increase the utilisation of maternal healthcare services.

Gestational diabetes mellitus (GDM) represents the second most commonly targeted focus of digital health innovations, with tools such as telemonitoring and self-management systems demonstrating significant improvements in glycaemic control [74–92]. Programs like TeleGDM [83, 84], Stay-Active mHealth [85], DiabeTIC [76], and Glucose Buddy [82] have successfully contributed to better glycaemic management and reduced maternal weight gain by incorporating behavioural support and personalised feedback. Furthermore, applications such as GDm-health [81] and CIT [75] have shown high levels of patient satisfaction and adherence to self-monitoring practices, effectively improving compliance and sugar control. The integration of clinical decision support systems [77] further facilitates guideline-based management of diabetic patients, enhancing overall care delivery.

Following GDM, mental health issues such as prenatal anxiety and depression have become a significant focus

in antenatal care. Interventions targeting these concerns often utilise behavioural therapies and self-help resources to help expectant mothers to address psychological challenges [93–109]. Additionally, digital platforms such as iCOPE [98] and the Mobile Mood Tracking and Alert (MTA) application [99] have been effectively employed for mental health screening, enabling the early detection of psychological concerns among antenatal mothers. Comprehensive behavioural support interventions, including MomMoodBooster [107], PUMAS [103], GSH_MBI [101], and HEARTPrep [102], have demonstrated significant efficacy in reducing stress and alleviating depressive symptoms, thereby providing crucial emotional and psychological support during pregnancy. Moreover, real-time teleconsultations [102, 103, 105, 108], whether through group peer support or individualised behavioural counselling, further enhance maternal mental health by fostering engagement, providing tailored guidance, and promoting overall psychological well-being.

Gestational weight gain (GWG) management represents another key area of focus, utilising lifestyle interventions and self-monitoring tools to support healthy weight management during pregnancy [123–134]. Digital applications such as PregChat [123], MOMTech [124], SmartMoms [128], txt4two [129], HealthyMoms [132], and MAMA-DASH [131] integrate educational content, behavioural counselling, and self-monitoring strategies to effectively reduce excessive GWG, improve dietary quality, and promote physical activity. These interventions emphasise personalised health promotion by offering tailored advice on diet and exercise, thereby facilitating improved weight control. Moreover, self-monitoring tools, such as Buddy Healthcare [134], enhance adherence to recommended weight gain guidelines, highlighting the vital role of digital solutions in supporting maternal health. Additionally, the WeChat platform [133] has been shown not only to significantly reduce GWG but also to improve maternal and neonatal outcomes.

Another prominent focus area for digital health interventions is the management of high-risk pregnancies [135–143] and hypertension [110–118]. These conditions are often addressed through remote monitoring systems, which enhance adherence to self-monitoring practices and utilise decision-support tools to facilitate the early detection of complications and improve the quality of care. For instance, wireless remote blood pressure monitoring systems transmit real-time data to healthcare providers, enabling automated feedback or triggering alerts for timely clinical action [111–113, 115, 117]. While applications such as SMARThealth [142], eRegQual [135], and SEWA [138] support the implementation of protocols and guidelines for screening and the early detection of high-risk pregnancies. Additionally, real-time teleconsultations enable timely referrals and provide opportunities for interim consultations between scheduled visits [136, 137].

Digital health technologies have also been used for prenatal education to provide antenatal mothers with comprehensive knowledge and guidance, promoting improved maternal and neonatal outcomes [144–152]. Additionally, specific interventions target concerns such as smoking cessation [119–122], anaemia management [159, 160], and tele-ultrasound imaging [156, 157], facilitating interfacility consultations. Other applications include vaccination information and reminders [153, 154], cardiovascular health monitoring [155] through the continuous tracking of physiological parameters, and virtual pre-anaesthetic assessments [158] tailored for expectant mothers preparing for surgical procedures during pregnancy. These diverse applications underscore the versatility of digital tools in supporting a broad spectrum of health priorities in ANC.

Description of digital technologies

Digital health technologies encompass a wide range of digital solutions. However, a significant challenge lies in the absence of a standardised definition and framework for their application in obstetrics. This lack of uniformity resulted in inconsistencies in how studies classify and assess these interventions. In this review, the identified digital health technologies are categorised into four primary groups, denoting their diverse applications in antenatal care. First, teleconsultations through video or phone calls enable real-time communication between patients and healthcare professionals, improving access to care, particularly in underserved areas [11, 49, 51, 53–58, 61–64, 69, 71, 80, 86, 88, 102, 105, 106, 108, 130, 136, 137, 140, 146, 151, 156–158]. Second, specialised health monitoring applications (mHealth) are primarily used for self-tracking, health monitoring, delivering educational materials or clinical guidelines, and providing reminders to enhance maternal care and patient engagement [40, 42, 48, 60, 65, 66, 68, 70, 72, 87, 96–98, 101, 109, 116, 119–122, 124, 126, 127, 129, 132, 135, 138, 141, 142, 145, 147, 152–155, 160–162]. Third, integrated mHealth applications combine remote monitoring with asynchronous personalised clinical feedback through tools such as text messages, emails, and AI-generated reports. These tools ensure timely responses to patient needs, address specific health concerns, and enhance patient engagement [43–47, 50, 52, 59, 67, 73–79, 81–85, 92, 95, 99, 100, 110–115, 117, 118, 123, 128, 133, 144, 148, 150, 159, 163]. Lastly, a hybrid model integrates mHealth monitoring with real-time teleconsultations, where teleconsultations are conducted following a period of data monitoring to

guide further management decisions [41, 89–91, 93, 94, 125, 131, 134, 139, 143, 149].

mHealth applications serve multiple functions, including monitoring health parameters such as blood glucose, blood pressure, foetal heart rate, and physical activity. Additionally, they deliver health promotion and educational resources, facilitate mental and physical health screenings, and provide reminders for appointments and medication adherence, among other services. These applications enhance healthcare delivery by supporting early detection, patient self-management, and tailored care plans while addressing logistical barriers like geographical distance and limited healthcare infrastructure.

The majority of the reviewed studies primarily focus on digital health interventions targeting antenatal mothers. As previously mentioned, only a small subset of studies ($n=11$) specifically addresses healthcare providers. These studies emphasise interventions that support provider-to-provider consultations for treatment decision-making, including real-time ultrasound consultations and referral systems between community health workers and tertiary centres [40, 42, 44, 47, 50, 53, 66, 77, 135, 138, 142]. In many cases, digital health innovations were compared to either standard care practices or hybrid models that integrate telehealth with conventional methods, providing valuable insights into their effectiveness and potential applicability within healthcare systems.

Figure 3 illustrates the utilisation trends of digital health technologies, specifically mHealth applications and real-time teleconsultations, between 2012 and 2024. For improved visualisation and clarity, mHealth applications with personalised feedback have been grouped under mHealth, while real-time teleconsultations incorporating mobile health (mHealth) applications have been distinctly categorised within the broader domain of teleconsultation. The analysis reveals that mHealth usage followed a fluctuating trend, with a gradual increase from 2012 to 2017, peaking sharply in 2017. Notably, prior to 2019, mHealth was the most used digital health modality in antenatal care. Despite remaining relatively high in 2018 and 2019, the use of mHealth declined in 2020, likely due to the increased reliance on real-time teleconsultation during the COVID-19 pandemic. Afterwards, mHealth usage remained lower until a significant rise was observed in 2023, which marked the highest recorded level, though a decline followed in 2024.

In contrast, the use of real-time teleconsultation exhibited a more consistent upward trajectory starting in 2015. A marked increase occurred between 2019 and 2020, with a sharp peak in 2020 as teleconsultation became a vital tool for maintaining care amidst pandemic-related disruptions. This upward trend persisted, with high usage levels through 2022 and 2023. However, a decline was noted in 2024, possibly reflecting a transition toward hybrid or in-person care models as pandemic-related restrictions eased. Overall, the graph highlights the increasing adoption of both mHealth and teleconsultation in antenatal care, with mHealth showing more pronounced fluctuations and real-time teleconsultation demonstrating steadier growth over time.

Purpose of digital health

The digital health technologies identified were classified into two primary categories based on their intended purpose: as complementary or substitutive interventions to standard antenatal care. Of the 126 studies included, 90 utilised digital health as complementary tools, supplementing routine care by enhancing its efficiency and scope without entirely replacing in-person visits [40–45, 47, 48, 50, 52, 53, 60, 64–68, 70, 72–77, 79, 82–85, 87, 88, 92–105, 107, 109–111, 116,

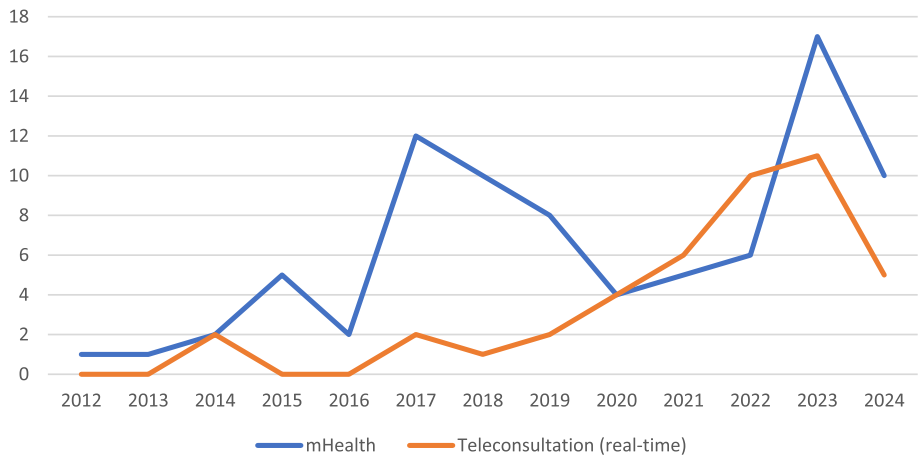

Fig. 3 Digital Health Modalities Utilization Trend in Antenatal Care

135, 138–142, 144–150, 152–155, 159–163]. Meanwhile, 36 studies used digital health as a substitute for conventional care [11, 46, 49, 51, 54–59, 61–63, 69, 71, 78, 80, 81, 86, 89–91, 106, 108, 112–115, 136, 137, 143, 151, 157, 158] entirely replacing specific aspects of routine antenatal visits with telehealth alternatives, thereby significantly reducing the need for physical antenatal visits.

Complementary digital health often integrates digital tools into routine care workflows to enhance the effectiveness and management of antenatal care. Instead of reducing physical visits, these interventions were designed to supplement routine care, providing additional support such as telehealth consultations, health education, or remote monitoring, thereby improving care delivery and patient outcomes. Additionally, these interventions supplemented traditional care by providing digital platforms for education, reminders, and remote monitoring to enhance the quality and accessibility of routine services. Substitutive digital health technologies, on the other hand, primarily aimed to fully replace some aspects of routine antenatal care, offering a more flexible and remote approach to managing maternal health needs.

Figure 4 illustrates the annual distribution of studies categorised based on their use of digital health technologies either as substitution or complementary to routine antenatal care between 2012 and 2024. The chart highlights the trends in the adoption of both complementary and substitution-based digital health interventions in antenatal care over the years, showing a considerable increase in both categories. Complementary interventions supporting traditional care were more prevalent throughout the period, particularly peaking in 2017 and again in 2023. In contrast, substitution-based interventions, which replace conventional in-person care with digital solutions, were minimal before 2018 but began increasing steadily from 2019 onwards. A notable trend is the significant rise in substitution-based interventions in 2020 and 2021, coinciding with the COVID-19 pandemic. This shift likely reflects the necessity of replacing in-person antenatal visits with telehealth alternatives due to pandemic-related restrictions. The peak usage of both types of interventions was observed in 2022 and 2023, with a slight decline in 2024, which may reflect a gradual return to hybrid or in-person care models as restrictions ease. Overall, while the use of digital health for complementary purposes remained consistent, the chart highlights the evolving role of digital health in antenatal care, with substitution-based interventions gaining prominence in recent years.

Table 4 presents a comprehensive summary of studies examining digital health interventions in maternal healthcare. These studies are categorised based on health concerns, study design, description of the digital health solutions, type of intervention, and primary outcomes. The table underscores the wide range of digital health modalities, including teleconsultation, mobile health (mHealth) applications, remote monitoring, health education, and promotion, among others. It highlights their diverse roles, serving either as complementary tools or substitutions within antenatal and maternal care frameworks, thereby reflecting their growing significance in enhancing healthcare delivery and outcomes in this domain.

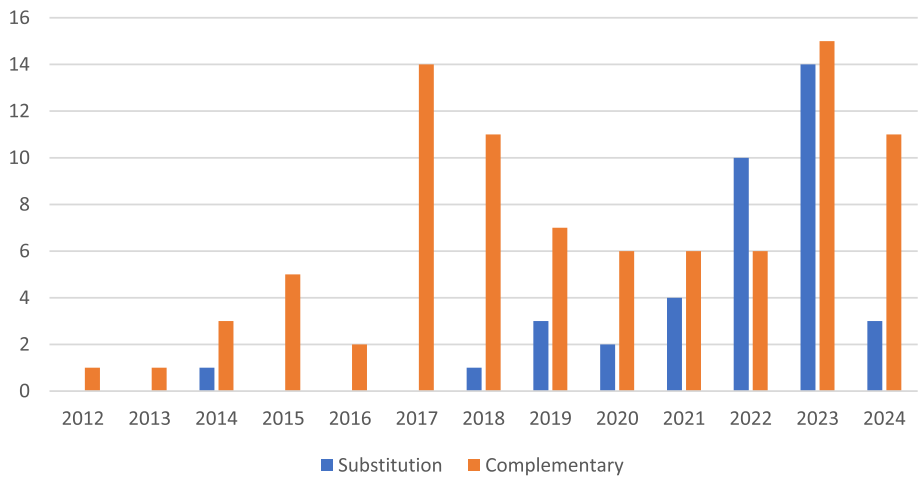

Fig. 4 Purpose of Digital Health in Routine Standard Care

Table 4 Summary of Digital Health Technologies Utilized in Antenatal Healthcare Provision

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
	General maternal care							
1	(Little et al., 2013) Euthopia [40]	PLOS ONE	Pre and post intervention	General Maternal Care	CommCare, a mHealth platform: Smartphone-based decision-support tools, data collection, and analytics dashboard	Health monitoring Clinical decision support	Complementary	Enhanced adherence to standardized maternal healthcare protocols Improved data collection and reporting by Health Extension Workers (HEWs) and midwives Increased empowerment and confidence among healthcare workers in delivering maternal healthcare services
2	(Lund et al., 2014) Tanzania, Africa [41]	BMC Pregnancy and Childbirth	RCT	General Maternal Care	Wired Mothers (mobile phone intervention): automated SMS system providing health education and appointment reminders, and a mobile phone voucher system for direct communication with healthcare providers	Health education Appointment reminders Teleconsultation Emergency care facilitation	Complementary	The intervention significantly improved ANC attendance, with 44% of women in the intervention group attending four or more ANC visits compared to 31% in the control group (OR = 2.39, 95% CI = 1.03–5.55) Better timing and quality of ANC services in the intervention group, including more tetanus vaccinations and malaria preventive treatments, antepartum referral (10% vs 5%)
3	(McNabb et al., 2015) Nigeria [42]	PLOS ONE	Pre and post intervention	General Maternal Care	m4Change ANC mobile application: include mobile decision support application for antenatal care (ANC) services and patient counselling through audio recorded health education	Clinical decision support Health education	Complementary	Improved adherence to guidelines and consistency in healthcare delivery among healthcare workers, ensuring standardization of services Significantly improved the quality of antenatal care (ANC) services: quality score improved from 13.33 (baseline) to 17.15 (endline) out of 25
4	(Marko et al., 2016) United States [43]	JMIR Research Protocols	Prospective Observational (Feasibility study)	General Maternal Care	Babyscripts mobile app: The program uses a mobile app to deliver educational content and remotely monitor blood pressure and weight in low risk pregnancies. Any concerning changes in these measurements are identified and addressed	Health education Health monitoring	Complementary	The Babyscripts system demonstrated feasibility for remote prenatal monitoring, increasing engagement, and timely management of potential complications Remote measurements of weight and blood pressure closely aligned with in-office measurements Patients demonstrated high satisfaction with the system

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
5	(Benski et al., 2017) Madagascar, Africa [44]	Journal of Telemedicine and Telecare	CS (Pilot)	General Maternal Care	Pregnancy And New-born Diagnostic Assessment (PANDA): mHealth system to facilitate the provision of high-quality, standardized ANC in underserved settings (between community level and referral hospital)	Remote consultation : interfacility consultation and referral with health management Clinical decision support	Complementary	Effective Clinical Screening: The system generated alerts for 17% of ANC visits, leading to necessary treatments or referrals High acceptability with 100% satisfaction regarding ANC visits using the PANDA system Improve quality and consistency of care Increase HCPs to ANC recommendation
6	(Bush et al., 2017) United States [45]	Telemedicine and e-Health	Quasi -experimental	General Maternal Care	WYhealth Due Date Plus app: Provide a comprehensive platform for pregnant women to access health information and resources, including direct access to nurse support	Health education and risk identification Appointment reminders Pregnancy tracking	Complementary	Significant association between app use and completion of a prenatal visits at least 6 months before delivery.. ($p = 0.022$) Borderline significant association between app use and reduced incidence of low birth weight. ($p = 0.055$) No significant associations between app use and rates of C-section or NICU admission
7	(Dansharif et al., 2021) Nigeria, Africa [46]	Procedia Computer Science	Qualitative	General Maternal Care	mHealth tools for self-management Winsenga Health e Babies CommCare	Health education Remote foetal monitoring Clinical decision support	Substitution	Benefit: Fewer hospital visits Improve healthcare service
8	(Borsari et al., 2018) Italy [47]	Journal of Immigrant and Minority Health	Quasi -experimental	General Maternal Care	Pregnancy and New-born Diagnostic Assessment (PANDA): mHealth system to facilitate the provision of high-quality, standardized ANC in underserved settings (between community level and referral hospital)	Remote consultation : interfacility consultation and referral with health management Clinical decision support	Complementary	91.9% of patients are satisfied with the system Enabled the identification of a diverse range of high-risk conditions Increase HCPs' care provision to ANC recommendations Provides comprehensive and high-quality antenatal care Facilitates the continuity and interfacility continuation of care
9	(Barron et al., 2018) South Africa [48]	BMJ Global Health	CS	General Maternal Care	MOM Connect: One way text messaging system delivered twice weekly providing health information related to pregnancy and childcare	Health education and promotion	Complementary	High acceptance with 63% registration of all women attending their first ANC appointment to the system High end user satisfaction, Incomplete registration led to missing data Costly with limitation of length to 160 characters
10	(Sulaman et al., 2022) Pakistan [49]	International Journal of Medical Informatics	CS	General Maternal Care	Telemedicine	Teleconsultation	Substitution	Majority (54%) intend to use telemedicine in future

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
11	(Paduano et al., 2022) Tanzania,Africa [50]	International Journal of Environmental Research and Public Health	RCT	General Maternal Care	mHealth system PANDA (Pregnancy And New-born Diagnostic Assessment)	Remote consultation : interfacility consultation and referral with health management Clinical decision support	Complementary	High level of acceptance and satisfaction among patients and HCPs in intervention group Improve quality, access and utilization of ANC visits Increase HCPs to ANC recommendation
12	(Arnaert et al., 2019) West Africa [51]	Digital Health	Qualitative	General Maternal Care	STREAMS (Strengthening Relationships and Enhancing Access to Maternal Services): mHealth supported antenatal care	Teleconsultation	Substitution	Potential to improve mothers' pregnancy awareness and increase their prenatal care attendance Improvement in the patient–provider relationship Increase engagement to ANC services
13	(Musiimenta et al.,2021) Uganda [52]	Digital Health	RCT	General Maternal Care	MatHealth app: Health information via multimedia videos and audios messages Appointment reminders Phone consultation	Teleconsultation Health education Appointment reminders	Complementary	MatHealth app is acceptable and feasible intervention among illiterate women Enabled appropriate maternal health practices, spouse support, clinic visit reminders, and communication with healthcare provider
14	(Bhandari et al., 2020) United States [53]	Telemedicine and eHealth	CS	General Maternal Care	ANGELS program telehealth services : Remote consultations for obstetric patients, clinic appointment and referrals particularly in rural and underserved area	Teleconsultation	Complementary	High levels of satisfaction were reported by both patients and providers with the telehealth services Better access to obstetric care for patients and improved health outcomes
15	(Galle et al., 2021) Belgium [11]	BMJ Global Health	CS	General Maternal Care	Telemedicine for maintaining the provision of maternal healthcare during covid	Teleconsultation	Substitution	More than half (58%) of health professionals use telemedicine Two-fifths of them claimed they had not received any telemedicine guidelines
16	(Duryea et al., 2021) United States [54]	JAMA Network Open	Cohort	General Maternal Care	Audio-only virtual visits : integration of synchronous audio-only virtual visits into prenatal care	Teleconsultation	Substitution	There were no association of adverse perinatal outcomes with the use of audio-only virtual prenatal visits Access and attendance at prenatal visits increased in a vulnerable population during the COVID-19 pandemic The findings indicate that a synchronous, audio-only virtual prenatal care platform in ANC is safe, effective, and legitimate
17	(Hofmann et al., 2022) United States [55]	Maternal and Child Health Journal	CS	General Maternal Care	Telehealth	Teleconsultation	Substitution	Telehealth was discovered to be feasible, appropriate, and acceptable across all providers categories

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
18	(Butler Tobah et al., 2019) United States [56]	American Journal of Obstetric gynaecology	RCT	General Maternal Care	OB Nest: prenatal care model integrated with remote home monitoring devices and nursing support 8 onsite appointments with an obstetric provider.6 virtual visits with a nurse Home monitoring devices (fetal Doppler and sphygmomanometer) Access to an online community of pregnant women	Teleconsultation Remote monitoring	Substitution	Higher satisfaction with integrated care and reduce prenatal stress Fewer number of scheduled visits with clinicians OB Nest saved an average of 2.8 clinician appointments per patient Maternal and fetal outcome are similar in both groups Adherence to ACOG prenatal care service was similar in both groups: standard care is maintained
19	(Wali et al., 2022) Saudi Arabia [57]	Women's Health	CS	General Maternal Care	Phone-based antenatal care	Teleconsultation	Substitution	The use of phone-based ANC during the pandemic showed high level of satisfaction (93.9%)
20	(Zulfeen & Chandrasekaran, 2022) Canada [58]	Elmer Press	CS	General Maternal Care	Virtual prenatal care phone calls and direct video conferencing	Teleconsultation	Substitution	Mothers were less satisfied with virtual prenatal care telehealth services, especially vulnerable patient populations
21	(Marko et al., 2019) United States [59]	JMIR mHealth and uHealth	RCT	General Maternal Care	Babyscripts app The program uses a mobile app to deliver educational content and remotely monitor blood pressure and weight in low risk pregnancies. Any concerning changes in these measurements are identified and addressed	Health education Remote monitoring Remote consultation	Substitution	The use of a mobile app for prenatal care was linked to fewer in-person visits (average of 7.8 in-person visits compared to 10.2 in the control group ($P = .01$)) There's no change in patient or provider satisfaction
22	(Coleman et al., 2020) South Africa [60]	Reproductive Health	Intervention Cohort	General Maternal Care	Sms text messages: One way informative and pregnancy stage-based maternal health information text messages throughout pregnancy	Health education Behavioural counseling	Complementary	Pregnant women are more likely to consistently complete maternal and infant health care and attend ANC visits more often
23	(Futterman et al., 2021) United States [61]	American Journal of Perinatology	CS	General Maternal Care	Telehealth	Teleconsultation	Substitution	Telehealth allows continuation of prenatal care however showed lower overall satisfaction for telehealth use
24	(Jeganathan et al., 2020) United States [62]	AJOG MFM	CS	General Maternal Care	Telehealth in high-risk obstetrical care	Teleconsultation	Substitution	Approximately 87% of patients and 88% of healthcare providers were satisfied with using telehealth for managing high-risk pregnancies Reduced the occurrence of missed and cancelled appointments Improve access to health care

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
25	(Lapadula et al., 2021) United States [63]	Frontiers in Paediatric	CS	Neonatology Prenatal Consultation	Virtual visits through Zoom Pro platform	Virtual consultation	Substitution	Virtual consultations met the expectations of both patients and medical practitioners, resulting in a high level of satisfaction among both parties with virtual visits
26	(Pinheiro dos Santos et al. 2022) Turkey [64]	Frontiers in PH	Qualitative	General Maternal Care	HERA mobile apps (Health Recording App) Health information, health records, reminder	Health education Appointment reminder	Complementary	High acceptance of the mobile apps uses among Syrian refugee in turkey Concern about data security
27	(Alhaidari et al. 2018) Iraq [65]	Journal of Perinatal Medicine	Experimental	General Maternal Care	Weekly messaging system with health information, reminders, and lifestyle advice	Health education Appointment reminder	Complementary	High acceptance and feasible Increase number of ANC visits in intervention group
28	(Sulaman et al., 2022) Pakistan [49]	International Journal of Medical Informatics	CS	General Maternal Care	Telemedicine in obstetric	Teleconsultation	Substitution	The majority (54%) intend to use telemedicine in future 57% did not feel satisfied with telemedicine use
29	(Soni et al., 2023) India [66]	International Journal of Medical Informatics	Quasi -experimental	General Maternal Care	mHealth application: Decision-tree algorithms help guide healthcare workers in their decision-making process	Clinical Decision Support System (Clinical guideline) Appointment reminder	Complementary	Significantly improved the quality of antenatal care in terms of: - attendance of antenatal visits,—thorough history taking (8.26 vs 3.58) and physical examination (4.26 vs 3.66) - appropriate investigation being conducted - comprehensive counselling (6.09 vs 4.33) High level of patient satisfaction
30	(Jahnke et al., 2023) United States [67]	JMIR	Retrospective Cohort	General Maternal Care	MAVEN: Multifaceted digital health platforms providing patient-centred educational materials, care coordination and web-based appointment and communication	Health education Remote consultation	Complementary	Maven significantly reduced in-person visits, including emergency room visits, by improving pregnancy knowledge. It helped 82.5% of users recognize warning signs and 66.1% learn accurate medical information Higher use of digital services was associated with higher odds of avoiding in-person care
31	(Itanyi et al., 2023) Nigeria, Africa [68]	BMC Pregnancy and Childbirth	Qualitative	General Maternal Care	Smart Card with mHealth Apps: Pregnant women's medical information is stored on smart cards, accessible via a mobile app at health facilities, allowing seamless care across multiple facilities	Health information management	Complementary	The patient-held smart card for antenatal services was widely accepted by pregnant women in Nigeria. Many valued its ability to store medical information, reduce clinic waiting times, and facilitate use across multiple health facilities

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
32	(Ishikawa et al., 2023) Japan [69]	JMA Journal	Observational	General Maternal Care	Remote Antenatal Check-ups: cloud-based video communication system for conducting medical interviews and foetal sonography	Teleconsultation	Substitution	Remote antenatal check-ups effectively reduced the need for hospital visits while maintaining safety, with no adverse perinatal events reported during the study Significant improvements in physical, mental, and economic burdens, with high satisfaction levels reported by participants **Burden Reduction**: **-Physical Burden**: 90% of pregnant women reported a reduction in physical burden **-Mental Burden**: 80% reported a reduction in mental burden **-Economic Burden**: 70% reported a reduction in economic burden
33	(Hao et al., 2023) China [70]	JMIR mHealth and uHealth	Retrospective Observational	General Maternal Care	mobile-based prenatal education program	Health education	Complementary	The mobile-based prenatal education program significantly reduced adverse outcomes in pregnant women. Key findings include: Gestational Diabetes Mellitus (GDM): Completing participants had about a 30% lower risk (OR = 0.3043) Postpartum Infections: Significant reduction in risk (OR = 0.1413) Induced Abortion: Lower risk in the completing group (OR = 0.5162) Foetal Intrauterine Distress: Reduced risk (OR = 0.2463) Neonatal Malformations: No cases in the completing group, compared to 17 cases in non-competing participants
34	(Escobar et al., 2023) Colombia [71]	BMC Health Services Research	Retrospective Observational Cohort	General Maternal Care	Telemedicine	Teleconsultation	Substitution	There were no significant differences in maternal death, neonatal complications, or obstetric emergencies between the telemedicine and in person group
35	(Atukunda et al., 2023) Uganda [72]	JMIR Formative Research	RCT	General Maternal Care	SupportMoms-Uganda app: utilizes audio or SMS text messaging to deliver scheduled, customized health-related information and appointment reminder	Health education and promotion Appointment reminders	Complementary	SupportMoms-Uganda app was feasible and acceptable, with over 90% of participants finding it useful and easy to use The app significantly improved attendance at ANC visits and skilled deliveries, with 100% attendance

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
36	(Askari et al.,2023) Iran [73]	Iranian Red Crescent Medical Journal	Quasi- experimental	General Maternal Care	Telehealth: Educational content was delivered through four WhatsApp or phone call sessions, along with ongoing communication	Health education Health promotion	Complementary	Telehealth interventions (WhatsApp and phone calls) significantly increased self-care and self-efficacy while reducing in-person visits during COVID-19. The phone call group showed the highest self-efficacy, followed by WhatsApp, both significantly better than the control group Most participants expressed satisfaction with telehealth services during the pandemic
	Gestational Diabetes Mellitus (GDM)							
37	(Homko et al., 2012) United States [74]	Diabetes Technology and Therapeutics	RCT	GDM	Telemedicine system, includes: Automated reminders and interactive voice response (IVR) technology Transmit blood glucose while enabling asynchronous communication between patients and healthcare providers through an Internet-based platform or a phone system	Remote monitoring Remote consultation Health education	Complementary	No significant differences in maternal glucose control between the telemedicine and control groups Neonatal and pregnancy outcomes were similar between the groups increased system utilization and contact between women with GDM and their healthcare providers
38	(Bartholomew et al., 2015) United States [75]	Clinical Diabetes	RCT	GDM	Cellular Internet Technology (CIT) system: Wireless transmission glucose reading with automated text message feedback, personalized recommendations, and asynchronous communication with healthcare providers	Remote monitoring and consultation Behavioural support	Complementary	Significantly improved self-monitoring blood glucose compliance with higher overall reporting compliance (89.3% vs. 87.6%, $p = 0.049$), fasting compliance (92.9% vs. 91.0%, $p = 0.048$), and 2-h postprandial compliance (88.1% vs. 86.4%, $p = 0.048$) Lower mean 2-h postprandial glucose values Satisfaction scores for the CIT system were significantly higher
39	(Carral et al., 2015) Spain [76]	Diabetes Technology and Therapeutics	Quasi -experimental	GDM	DiabeTIC Web-based telemedicine system **:** patients share glucose readings, insulin dose, and health data while enabling asynchronized communication with healthcare providers to give feedback and adjust treatments remotely	Remote monitoring and consultation Clinical decision support and management	Complementary	Telemedicine group effectively manage glucose control, reducing the number of outpatient visits without compromising maternal or neonatal outcomes: Significantly fewer visits to healthcare facilities No significant differences in mean glycated haemoglobin (HbA1c) levels, delivery timing, caesarean rates or neonatal outcome

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
40	(Caballero-Ruiz et al., 2017) Spain [77]	International Journal of Medical Informatics	Observational (Feasibility study)	GDM	Sinedie (Web-based Clinical Decision Support System): Provides automated diet prescriptions and flags cases requiring insulin therapy, which are reviewed by clinicians	Remote monitoring Personalised dietary recommendation and health education (automated tailored diet prescription)	Complementary	Significant reduction of face-to-face visits required per patient by 88.56% ($p < 0.01$) All patients requiring insulin therapy were correctly identified Improve care efficiency and reduce clinical workload High satisfaction among patient
41	(Sung et al., 2019) Korea [78]	Clinical Therapeutics	RCT—(Pilot)	GDM	Mobile phone application (Huraypositive Inc, Seoul, Korea) : tailored mobile health services for blood glucose monitoring, diet and physical activity. Data were automatically transmitted to a central server via a wireless network	Teleconsultation Remote monitoring and diabetic management	Substitution	Glycaemic control and perinatal outcomes were similar between intervention and control groups The intervention group showed significantly lower insulin resistance, BMI, weight and body fat percentage compared to control group postpartum
42	(Alqudah et al., 2019) United Kingdom [79]	BMC Health Services Research	CS	GDM	mHealth: self-management and remote monitoring and consultation	Remote monitoring Self-management	Complementary	The majority of pregnant women are ready to take care of their condition at home and being remotely monitored by healthcare staff Over 70% found it acceptable to use smartphones for managing health during pregnancy
43	(Kozica-Olenski et al., 2022) Australia [80]	BMC Pregnancy and Childbirth	Qualitative	GDM	Telehealth	Teleconsultation	Substitution	Both women and clinicians viewed telehealth as acceptable for diabetes in pregnancy care and were satisfied with telehealth as an alternative to F2F consultation during pandemic However, telehealth was perceived to reduce the quality of care
44	(Mackillop et al., 2018) United Kingdom [81]	JMIR mHealth and uHealth	RCT	GDM	GDm-health App with website and (SMS) text message: Mobile phone-based real-time blood glucose management system	Teleconsultation Remote monitoring	Substitution	The intervention group had significantly more blood glucose measurements per day compared to the control group No significant difference in glycaemic control between the groups Fewer caesarean deliveries and preterm labour in the intervention group Higher levels of satisfaction in intervention group Similar healthcare cost

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
45	(Miremberg et al., 2018) Israel [82]	American Journal of Obstetrics and Gynaecology	RCT	GDM	Glucose Buddy : A web-based app recorded daily blood glucose data to a research database. Data was entered via a mobile app, and communication occurred through email, with personalized feedback sent to users via email	Teleconsultation Remote monitoring	Complementary	Intervention group: Increased adherence to blood glucose monitoring. (84% vs. 66%, $p < 0.001$) Lower means blood glucose value. (105.1 mg/dL vs. 112.6 mg/dL, $p < 0.001$) Lower rates for fasting sugar (4.7% vs. 8.4%, $p < 0.001$) and 1-h post-prandial (7.7% vs. 14.3%, $p < 0.001$) measurements Treatment with insulin were at lower rate. (13.3% vs. 30.0%, $p = 0.044$) Increased satisfaction with their care
46	(Rasekaba et al., 2018) Australia [83]	Diabetes Research and Clinical Practice	RCT	GDM	TeleGDM Online Health Portfolio (OHP) : web-based patient-controlled health record linking shared data with health professionals	Teleconsultation Remote monitoring	Complementary	Intervention group reached earlier optimum glycaemic control (mean 4.3 weeks vs. 7.6 weeks, $p = 0.0001$) Fewer insulin dose titrations in the intervention group (median 4 vs. 13, $p = 0.04$) No significant differences maternal and neonatal outcome (comparable with standard care) No significant differences in service provider costs between the groups
47	(Al-Ofi et al. 2019) Saudi Arabia [84]	Journal Of International Medical Reasearch	RCT	GDM	TeleGDM: Smartphone - Glucometer and a Glucomail application installed in patients' phones. Any abnormal readings will alert healthcare team for consultation	Teleconsultation Remote monitoring	Complementary	TeleGDM group: Significantly lower 2-h postprandial glucose level than the control group. $p = 0.002$) No difference on fasting sugar level Significant lower weight gain. ($p = 0.03$) More women in reached the recommended range of weight gain at the end of pregnancy

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
48	(Smith et al., 2024) United Kingdom [85]	BMC Pregnancy and Childbirth	Non-randomised Single-arm Trial	GDM and Physical Activity	Stay-Active mHealth application: Supports women with GDM by promoting physical activity through motivational interviewing and digital tools, combined with remote monitoring and personalized advice on diet, exercise, and GDM management	Health education Health promotion Remote monitoring	Complementary	The intervention was found to be feasible and well accepted among women with gestational GDM, with 85% of women rating their care as satisfactory The study had a retention rate of 79% of enrolled participants completing the study Physical activity levels increased significantly after two weeks of motivational interviewing but declined by the end of the study Mean blood glucose levels decreased (6.3 mmol to 5.8 mmol): improve glycaemic control Maternal mean weight gain ave 0.06 kg per week, did not adversely affect weight management No significant adverse neonatal outcomes reported
49	(Montori et al., 2024) Italy [86]	Diabetic Medicine	Cohort Study	GDM	Telemedicine : management of GDM (Cloud-based glucose monitoring, combined with virtual consultations)	Teleconsultation Remote monitoring	Substitution	No statistically significant differences in maternal and neonatal outcomes between the telemedicine and conventional care groups for women with gestational diabetes Telemedicine follow-ups increased maternal satisfaction as women felt more in control and that it suited their lifestyle Reduction in the number of outpatient consultations Telemedicine resulted in optimal glycaemic control and reduced consultation time (65 vs. 97 min)
50	(Duan et al., 2024) China [87]	Digital Health	CS	GDM	mHealth application: Better pregnancy App - designed to prevent GDM by integrating risk prediction, personalized health management, and social support, guided by the Health Belief Model, enhancing their self-management abilities	Health management plans Self-monitoring and management	Complementary	The application demonstrated high acceptability among participants, with an average score of 4.07 out of 5 Has potential to improve awareness and self-management of GDM 98% retention rate among users

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
51	(De Jersey et al., 2024) Australia [88]	Cost Effectiveness and Resource Allocation	Cost-effectiveness Evaluation / Observational	GDM	Living Well during Pregnancy (LWdP) program Telehealth coaching intervention (dietitian-delivered telephone coaching program): designed to prevent gestational diabetes mellitus (GDM) by providing structured lifestyle interventions through telephone coaching	Teleconsultation	Complementary	The LWdP coaching intervention was more cost-effective than routine care for preventing gestational diabetes mellitus (GDM) It demonstrated slightly higher effectiveness (0.894 utility vs. 0.893) compared to routine care while being less costly (AUD 20,828 vs. AUD 20,933) The negative incremental cost-effectiveness ratio (ICER) confirmed it as a dominant strategy for preventing GDM
52	(Cichocka & Gumprecht, 2024) Poland [89]	Journal of Clinical Medicine	Retrospective Analysis/ Observational	GDM	1.Telemedicine Services, which included telephone calls and video consultations 2.Online platform and mobile application for monitoring	Teleconsultation with Remote monitoring	Substitution	No significant differences in pregnancy, neonatal outcomes and GDM management compared to standard in person care High satisfaction with telemedicine visits
53	(Butten et al., 2024) Australia [90]	Practical Diabetes	Quasi -experimental	GDM	MOTHer platform: smartphone application seamlessly integrated with a web-based clinician dashboard, enabling real-time communication and monitoring of blood glucose levels. Also provide GDM educational video	Teleconsultation Healthcare education Remote monitoring	Substitution	The intervention achieved significant cost savings without compromising clinical outcomes. Over 12 months, the healthcare system saved A$17,442, while patients saved an average of A$567 each by reducing the need for face-to-face visits Satisfaction levels were high, with 91.5% of women satisfied with care and 87.1% with the app for managing GDM Significantly reduced the need for face-to-face visits Achieved similar maternal and neonatal outcomes as traditional care
54	(Laurie et al., 2023) Australia [91]	Australian and New Zealand Journal of Obstetrics and Gynaecology	Quasi -experimental	GDM	Digital model of care -Smartphone app-to-clinician portal for glycaemic review and management -Six culturally and linguistically tailored educational videos -Home delivery of equipment and prescriptions	Teleconsultation Remote monitoring, and management of GDM	Substitution	The implementation of a novel digital model of care for GDM demonstrated clinically equivalent maternal and neonatal outcomes compared to traditional care, despite the lack of randomization

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
55	(van Heerden et al., 2023) South Africa [92]	South African Journal of Clinical Nutrition	Mixed- method	GDM	Freestyle Libre 2 CGM (continuous glucose monitoring) patches monitored glucose levels and provided real-time feedback. Data was sent to participants' phones and uploaded to a provider's dashboard for remote monitoring	Remote monitoring	Complementary	The study found that CGM patches were generally acceptable to pregnant women in South Africa, and feasible for short-term use when applied by a trained professional Most participants successfully wearing the first patch for at least 12 of the 14 days
	Mental Health							
56	(Lakshminarayananet al., 2020) India [93]	Asian Journal of Psychiatry	CS	Mental Health	Digital platform training program : improve mental health training and service delivery	Virtual learning and training	Complementary	Improvement in the average score of participants in pre (20%) and post (75%) training with digital platform training
57	(AKSOY DERYA et al., 2021) Turkey [94]	Midwifery	Quasi -experimental	Prenatal distress and pregnancy related anxiety	Interactive education and consultancy provided by phone calls, text messages and a digital education booklet	Health education via virtual learning and communication	Complementary	Tele-education successfully reduced levels of prenatal distress and anxiety compared to control group Prenatal distress significantly decreased, as shown by lower post-test NuPDQ scores (8.75 ± 5.10) Anxiety levels were notably reduced, with lower post-test PRAQ-R2 scores (24.25 ± 4.90)
58	(Bhat et al., 2018) United States [95]	HHS Public Access	Quasi -experimental	Mental Health (Depression)	Perinatal Collaborative Care (CC) program : 2 ways text messaging for behavioural activation, medication reminders, depression information and appointment reminder	Behavioural counselling Health information Appointment reminders	Complementary	Both patients and providers found text messaging to be acceptable and useful when used as adjunct to the conventional physical meetings No substantial correlation observed between certain types of text message content and the improvement of depression
59	(Bogale et al., 2021) Palestine [96]	PLOS ONE	RCT	Fears and worries about birth and parenting	Targeted client communication (TCC) via short message service (SMS) : Health information in pregnancy to alleviate worries among mothers	Health education Appointment reminders	Complementary	Worries in pregnancy: Women in intervention group has less worries related to pregnancies, but it was not statistically significant Satisfaction: No difference between intervention and control groups in women's satisfaction with ANC services
60	(Brusniak et al., 2020) Germany [97]	JMIR mHealth and uHealth	Prospective Cohort	Mental health and physical well being	Digital health app with self-tracking	Health education Self-monitoring	Complementary	User engagement Only 25% of patients could be considered compliant Cultural and socioeconomic background factors is the most influential factors of user's engagement

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
61	(Highet et al., 2021) Australia [98]	Primary Health Care Research & Development	Descriptive Cohort	Mental Health	iCOPE: perinatal mental health digital screening platform	Screening and diagnostic use	Complementary	Screening time, scoring accuracy and reports were efficient with iCOPE platform High user engagement iCOPE demonstrated that the digital screening platform was widely accepted and effective
62	(Hantsoo et al., 2018) United States [99]	HHS Public Access	RCT	Depression	Mobile mood tracking and alert (MTA) mobile application (app): monitored activity, assessed mood, and alerted OB providers of signs of worsening mood	Self-monitoring Self-management support Health communication and referral	Complementary	The use of mobile MTA app has enhanced their self-perceived capability to handle their own health Well accepted and improve mental health service
63	(Ronen et al., 2024) United States [100]	JMIR Formative Research	Non-randomised Single-arm Trial	Mental Health (Prenatal Depression)	Interactive Maternal Group for Information and Emotional Support (IMAGINE) Intervention delivered via the Slack messaging platform for flexible asynchronized communication. Uses SMS, graphics, videos, and mood polls to engage participants and support mental health management	Health education, Health promotion Behavioural support	Complementary	High acceptability and perceived utility among participants, with an uptake rate of 76.9% Despite the positive feedback, no significant changes were observed in depression symptoms, perceived stress, or social support between enrolment and follow-up
64	(X. Zhang et al., 2023) China [101]	Journal of Medical Internet Research	RCT	Mental Health	Digital guided self-help mindfulness training (GSH-MBI) :The program features six modules of animated videos and multimedia content for psychological education, delivered through a WeChat mini program in both video and audio formats	Health education and promotion with self-management	Complementary	GSH-MBI significantly reduced maternal psychological distress, including depression, anxiety, and pregnancy-related anxiety symptoms, compared to the control group at all post-intervention time points Digital GSH-MBIs are effective in improving maternal mental health
65	(Sood et al., 2023) United States [102]	Pediatric Cardiology	Quasi- experimental	Mental Health	HEARTPrep: virtual psychosocial intervention led by licensed clinical psychologists, delivered via a mobile app and telehealth sessions (3–6 live sessions) through the Nemours health system	Teleconsultation	Complementary	High feasibility with 90% enrolment rate and 77% completing the program High acceptability, with mean scores ranging from 3.5 to 3.9 out of 4 Significant improvements in feelings of distress (mean: 3.74), loneliness (mean: 3.84), and preparedness (mean = 3.84) after participating

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
66	(Kalmbach et al., 2023) United States [103]	Sleep Medicine	A Single-Arm Proof of Concept Trail	Mental Health (Insomnia)	Perinatal Understanding of Mindful Awareness for Sleep (PUMAS): Six telemedicine sessions for delivering mindfulness-based strategies and PUMAS app provided guided meditations for patients to practice mindfulness at home	Teleconsultation Health education and promotion	Complementary	PUMAS effectively reduced insomnia, depression, nocturnal cognitive arousal, and sleep effort among participants - 83.3% of patients achieving remission from insomnia - significant decrease in EPDS scores and depressive symptoms - substantial decrease in sleep effort scores High patient engagement (91.7%) and satisfaction with PUMAS
67	(Hassdenteufel et al., 2023) Germany [104]	Psychiatry Research	RCT	Mental Health	Electronic mindfulness-based intervention (eMBI)): audio files, videos, written content, a personal skills box, and interactive worksheets, all of which were integrated into the app to facilitate user engagement and learning	Health education and promotion	Complementary	The eMBI program did not effectively address general depressive or anxiety symptoms, but it showed positive results in reducing pregnancy-related anxiety, improve mindfulness and preventing postpartum depression
68	(Polanczyk et al., 2023) Brazil [105]	Brazilian Journal of Psychiatry	RCT	Mental Health	Motherly Apps & online brief cognitive behavioural therapy (b-CBT)	Teleconsultation Health education (psychoeducation)	Complementary	No significant differences in maternal depression or other mental health outcomes between the intervention and control groups High adherence with a low dropout rate; 93.8% of participants received at least one psychotherapy session
69	(Fatemi et al., 2023) Iran [106]	BMC Pregnancy and Childbirth	RCT	Mental Health	VSIT: virtual Stress Inoculation Training -Virtual SIT: Six fully virtual sessions using WhatsApp for communication and materials -Semi-Attendance SIT: Mix session with face to face	Teleconsultation	Substitution	Both VSIT and semi-attendance SIT effectively reduced anxiety, depression, and stress. However, semi-attendance SIT(hybrid) showed a more significant reduction in anxiety ($P < 0.001$), depression ($P < 0.001$), and psychological distress ($P < 0.001$) compared to VSIT Combination of face-to-face and virtual sessions may be more effective for managing psychological distress in pregnant women compared to fully virtual sessions

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
70	(Danaher et al., 2024) United States [107]	Am J Obstet Gynecol	RCT	Mental Health (Perinatal Depression)	MomMoodBooster2 (MMB2): A variety of multimedia content, offering evidence-based resources to effectively manage depression and anxiety	Health education and promotion	Complementary	The MMB2 group exhibited significantly greater reductions in depression severity and stress compared to the routine care group. (43% of participants showed a significant decrease in depression severity (PHQ-9 scores) compared to 26% in the routine care group.)
71	(Buultjens et al., 2023) Australia [108]	Women and Birth	Quasi- experimental	Mental Health	Telehealth structured online small-group interdisciplinary education (PECS:Perinatal care, education and support)	Teleconsultation Psycho-education and peer support	Substitution	PECS hybrid model of care significantly reduced depression scores over time, compared to the control group (while stress and anxiety scores remained unchanged.) Reduced the number of face-to-face visits
72	(Balsam et al., 2023) United States [109]	JMIR Pediatrics and Parenting	Longitudinal, Single-arm Trial	Mental Health	Headspace mHealth App with Qura Ring (wearable device): A mindfulness meditation app paired with a wearable device to track physiological measures	Behavioural intervention and self-management	Complementary	The Headspace app significantly reduced stress ($P = .005$),general anxiety ($P = .01$), and pregnancy-specific anxiety ($P < .0001$) in pregnant women after the intervention Physiological measures indicated a 13% decrease in low-frequency heart rate variability ($P = .006$), suggesting reduced stress levels
	Hypertension							
73	(Hinton et al., 2017) United Kingdom [110]	BMC Pregnancy and Childbirth	Qualitative	Hypertension	Blood pressure Self-Monitoring (SMBP) providing immediate feedback and guidance through a traffic light system and optional automated SMS responses to manage hypertension and reduce risks during pregnancy	Health education Self-monitoring	Complementary	SMBP in pregnancy was found to be both acceptable and feasible Women felt by self-monitoring, particularly those with previous experience of pre-eclampsia

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
74	(Lanssens et al., 2017) Belgium [111]	JMIR mHealth and uHealth	RCT	Hypertension	Obstetric surveillance via a wireless blood-pressure monitor, weight scale, and activity tracker Predetermined alarm signals were set, if triggered will be managed accordingly	Remote monitoring and decision support system	Complementary	Lower prevalence of preeclampsia (14.58% vs. 43.87%; $p<0.01$) and higher prevalence of gestational hypertension (81.25% vs. 42.86%; $p<0.001$)in the RM group compared to CC Reduced prenatal hospital admissions until delivery in RM (27.08% vs. 62.24%; $p<0.001$) Lower induction rates in RM (25.00% vs. 48.98%; $p=0.03$) and a higher likelihood of spontaneous labour in RM (60.42% vs 31.63%; $p=0.001$)
75	(Musyoka et al., 2019) Kenya [112]	Informative in Medicine unlock	Quasi-experimental	Preeclampsia	24-h ambulatory blood pressure monitoring system : Use of a smartwatch integrated with a mobile apps for 24 h ambulatory blood pressure monitoring, reporting and detection of alert symptoms	Teleconsultation Remote monitoring	Substitution	The study offers practical insight into the adoption of digital health solution to support preeclampsia management The system was efficient in collecting and transmitting blood pressure data High levels of user satisfaction, perceived usefulness, and ease of use
76	(Lanssens et al., 2018) Belgium [113]	European Journal of Obstetrics & Gynecology and Reproductive Biology	Cohort (Retrospective)	Hypertensive disease of pregnancy	Obstetric surveillance via a wireless blood-pressure monitor, weight scale, and activity tracker Predetermined alarm signals were set, if triggered will be managed accordingly	Teleconsultation Remote monitoring	Substitution	Fewer prenatal visits than the CC (mean difference = −1.76, $p<0.01$) Fewer prenatal admissions and hospitalisations until delivery in the RM group Reduced induced labour and higher rates of spontaneous labour in the RM group (50% vs 32.09%, $p<0.01$) Lower prevalence of preeclampsia (19.77% vs 44.19%, $p<0.01$) and a higher prevalence of gestational hypertension in the RM group (69.77% vs 42.79%, $p<0.01$) compared to the CC group More births after 37 weeks in pregnancies in the RM group (91.67% vs. 73.49%, $p<0.01$) Gestational age at delivery was comparable between groups No significant difference in NICU admissions

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
77	(Van den Heuval et al. 2020) Netherlands [114]	Pregnancy Hypertension	Case Control Study	Chronic Hypertension Preeclampsia	SAFE@HOME: digital health platform for telemonitoring blood pressure and symptoms combined with a minimal antenatal visit schedule	Teleconsultation Remote monitoring	Substitution	The usage of a digital platform resulted in a significant reduction in prenatal visits, ultrasounds, and hypertension-related admissions Lower cost per pregnancy and societal cost Perinatal outcomes were similar in both groups
78	(Van den Heuvel et al., 2019) Netherlands [115]	European Journal of O&G and Reproductive Biology	Prospective Observational	Hypertensive disease in pregnancy	SAFE@HOME: telemonitoring platform, with the feature to combine repeated BP measurements monitoring with associated preeclampsia symptom alert and checklist for pregnancy	Teleconsultation Remote monitoring	Substitution	Blood pressure monitoring and symptom checklist compliance rates were 93% and 85%, respectively Most users were satisfied with the system and its usability with higher prenatal care engagement The telemonitoring platform is feasible for patient and HCPs
79	(Zhang et al., 2024) United States [116]	Telemedicine and e-Health	Prospective Cohort	Hypertension	Remote patient monitoring (RPM) for managing maternal hypertension	Remote monitoring	Complementary	RPM for maternal hypertension is feasible and acceptable Positive outcomes were observed, including high patient satisfaction and no maternal or neonatal deaths within 60 days postpartum
80	(D. Jones et al., 2023) United States [117]	Maternal and Child Health Journal	Mixed-method (Pilot)	Hypertension	Cellular-Enabled Blood Pressure (BP) Devices: BodyTrace™ BP devices -equipped with built-in cellular transmission capabilities, enabling real-time sharing of participants' BP readings with healthcare providers	Remote monitoring	Complementary	The device is effective for managing hypertension in pregnant women Participants reported high satisfaction and a strong intention to continue using the device Reduce healthcare access barriers for women in rural areas
81	(Charifson et al., 2024) United States [118]	JMIR mHealth and uHealth	Observational	Hypertension	Delfina Care platform: for remote blood pressure monitoring (RBPM): Connected BP devices that automatically sync measurements to a monitoring platform	Remote monitoring	Complementary	Connected BP devices significantly increase user engagement, leading to 2.13 times more daily measurements and 5.62 times the odds of meeting the two daily measure recommendation. compared to unconnected devices. This increased engagement may enhance monitoring adherence and improve health outcomes

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
	Smoking Cessation							
82	(Abroms et al., 2015) United States [119]	JMIR mHealth and uHealth	Pre and post Intervention (Pilot feasibility)	Smoking Cessation	Quit4baby program: Interactive and automated text messages Quit-smoking support messages tailored for pregnancy Behavioural tips, motivational messages, and reminders for quitting smoking	Health education Behavioural support and counselling	Complementary	The programme is feasible and acceptable High levels of engagement with 100% of participants reading all messages, Abstinence rates: 38% at 2 weeks, 54% at 4 weeks
83	(Naughton et al., 2017) United Kingdom [120]	Addiction	RCT	Smoking Cessation	MiQuit text messaging program: Participants were provided with a 12-week program of automated, interactive text messages tailored to deliver motivational support and guidance for smoking cessation during pregnancy	Health education Behavioural support and counselling	Complementary	5.4% of MiQuit participants achieved validated continuous abstinence compared to 2.0% in the usual care group (OR = 2.7, 95% CI = 0.93–9.35) The incremental cost-per-quitter was estimated at £133.53 (95% CI = −£395.78 to 843.62)
84	(King et al., 2022) United Kingdom [121]	Patient Education and Counseling	RCT (Pilot)	Smoking Cessation	SKIP-IT (SmoKing In Pregnancy – Intervening with Texts): Digital Storytelling interventions: delivers automated text messaging intervention using narratives and images to support smoking cessation among pregnant women	Behavioural counselling Health education Health promotion	Complementary	The intervention group had a lower percentage of non-smokers at follow-up. However, the sample size was insufficient to make conclusive judgment about effectiveness Retention rates were 87% in the intervention group and 77% in the control group Acceptability of the intervention was high The intervention is feasible and acceptable for promoting smoking cessation among pregnant women
85	(Van Dijk et al., 2024) Netherlands [122]	Addictive Behaviour	RCT	Smoking Cessation and Stress Reduction	mHealth application for HRV-BF training targeted at smoking cessation and stress reduction in pregnant women by providing: 1.Personalized Stop-Smoking Plan: Users could create tailored cessation plans 2.Smoking Diary: Users tracked their smoking habits to monitor progress and triggers 3.Stress Reduction Training: Included personalized HRV-biofeedback with paced breathing exercises to manage stress	Patient self-management, behavioural support, and remote monitoring	Complementary	No significant reduction in smoking behaviour or perceived stress in pregnant women, as there were no significant differences in smoking cessation, frequency, or quantity between the intervention and control groups A dose–response effect was observed, suggesting that increased program usage correlated with reductions in smoking frequency and quantity

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
	Gestational Weight Gain (GWG)							
86	(Pollak et al., 2014) United States [123]	Patient Education and Counseling	RCT	Gestational Weight Gain	Preg CHAT: Personalized feedback based on daily steps, sweetened beverage intake, fruit and vegetable consumption, fast food intake, and weight	Health education Behavioural support	Complementary	Preg CHAT group participants gained, on average, six fewer pounds than those in the Txt4Baby group, although the results were not statistically significant ($p=0.24$) No significant differences were observed in physical activity or dietary scores between the groups
87	(Soltani et al., 2015) United Kingdom [124]	Maternal and Child Health Journal	Mixed-method	Gestational Weight Gain	MOMTech: text-messaging-based intervention Combined daily text messages with goal-setting, self-monitoring tools, and antenatal consultations (physical) delivered by a healthy lifestyle midwife	Health education and behavioural support	Complementary	The intervention was deemed acceptable by participants and feasible for clinical implementation Lower mean GWG in the intervention group (5.6 kg vs. 9.74 kg) Fewer participants in the intervention group exceeded the recommended GWG limit (28% vs. 50%)
88	(Chao et al., 2017) United States [125]	Frontiers in Nutrition	RCT	Gestational Weight Gain	Telephone Counseling: weekly session with dietitian Providing personalized guidance and support to help participants adhere to their weight management plans, together with weight monitoring. (Wi-Fi scales)	Teleconsultation (behavioural counselling and dietary management) Remote monitoring	Complementary	No significant difference between the intervention group and the control group in reducing GWG No significant difference in total GWG between the intervention group (15.5 ± 5.3 kg) and the control group (13.3 ± 6.8 kg) Both groups exceed weight gain recommendation (83% in the intervention group vs. 70% in the control group) No significant difference in reported caloric intake between the two groups No significant differences in birth weight, gestational age at delivery
89	(Graham et al., 2017) United States [126]	Journal of Medical Internet Research	RCT	Gestational Weight Gain	Web based intervention providing Blogs, local resources, FAQs, articles, weight gain tracker, diet, and physical activity goal-setting tools, focusing on preventive and supportive care services for managing gestational weight gain	Health education Self-monitoring and behavioural support Resource linkage and accessibility	Complementary	Intervention Arm: Certain usage patterns, like consistent tracking, were associated with reduced total GWG and risk of excessive GWG Control Arm: No significant impact on GWG outcomes Positive impact on GWG for participants with high engagement, particularly in higher-income groups

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
90	(Olson et al., 2017) United States [127]	Obesity	RCT	Gestational Weight Gain	Integrated online and mobile phone behavioural intervention designed to help pregnant women track their gestational weight gain (GWG) and prevent excessive GWG	Health education Self-monitoring and behavioural support	Complementary	Among not-low-income women, consistent GWG tracking resulted in 2.35 kg less weight gain during pregnancy ($p < 0.0001$) and risk of excessive GWG reduced by 27% (RR 0.73, 95% CI: 0.59–0.89, $p = 0.002$) No significant association between consistent tracking and GWC outcomes for low-income women
91	(Redman et al., 2017) United States [128]	JMIR mHealth and uHealth	RCT	Gestational Weight Gain	SmartMoms: mobile app-based system integrating a wireless scale and pedometer for real-time monitoring of weight and activity. It features a personalized weight graph, behavioural tracking tools, and continuous feedback to support weight management during pregnancy	Teleconsultation Health education Behavioural support Self-monitoring and personalised feedback	Complementary	Lower proportion of women exceeding GWG guidelines in SmartMoms groups (56% in-person, 58% remote) vs. control (85%) Remote participants showed higher adherence to intervention protocols (76.5%) compared to in-person (60.8%) The remote intervention was more cost-effective for participants (US $97 vs US $347) and clinics (US $215 vs US $419)
92	(Willcox et al., 2017) Australia [129]	BJOG: An International Journal of Obstetrics and Gynaecology	RCT	Gestational Weight Gain	txt4two mhealth intervention: The use of mobile devices, text messaging, websites, and social media platforms to deliver health information and support	Health education Self-monitoring Behavioural support and counselling	Complementary	The txt4two mHealth intervention was feasible and produced positive outcomes regarding physical activity and GWG. The intervention did not significantly impact dietary intake The intervention group: - gained significantly less weight (7.8 kg) than the control group (9.7 kg, $p = 0.041$) - maintained higher light and moderate physical activity levels than the control group ($p = 0.001$)
93	(Ferrara et al., 2020) United States [130]	Lancet Diabetes Endocrinology	RCT	Gestational Weight Gain	GLOW (Gestational Weight Gain and Optimal Wellness): behavioural lifestyle intervention delivered via telehealth	Teleconsultation and behavioural counselling	Complementary	GLOW intervention is deemed feasible among end users Significant reduction in excess GWG, improve healthy diet and sedentary behaviours, improve markers of insulin resistance among women within the intervention group No difference in perinatal complications between the two groups

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
94	(Van Horn et al., 2018) United States [131]	American Journal of Preventive Medicine	RCT	Gestational Weight Gain	MAMA-DASH diet programme with LOSEIT weight loss smartphone application: multimodal intervention efforts focused on healthier diet and nutritional guideline, modest physical activity and sleep monitoring	Teleconsultation and behavioural counselling Self- monitoring tracker	Complementary	Intervention group: Exhibited a markedly reduced level of total weight gain throughout the 35-week gestational period, with no negative impact on infant health outcomes
95	(Henriksson et al., 2022) Sweden [132]	Scientific Report	RCT	Gestational Weight Gain (main) Diet Quality Physical Activity	HealthyMoms app (6-month mHealth intervention): comprehensive program aimed at promoting healthy weight gain, diet, and physical activity during pregnancy	Health education Health promotion Self-monitoring	Complementary	The HealthyMoms application was associated with reduced GWG, improved dietary quality, and increased physical activity levels as demonstrated by the user engagement Higher engagement (measured by the number of registrations for weight, diet, and physical activity) was associated with: -Lower GWG: Total registrations were linked to lower weight gain during pregnancy -Improved Diet Quality: Increased registrations, especially for physical activity, correlated with better diet quality
96	(Wang et al., 2024) China [133]	BMC Pregnancy and Childbirth	RCT	Gestational Weight Gain	WeChat platform for managing pregnancy weight: personalized and continuous weight management services through a WeChat platform combined with offline consultations	Behavioural counselling through online offline consultation	Complementary	- The intervention group exhibited a significantly lower GWG compared to the control group, ($P < 0.05$) - The rate of appropriate weight gain during pregnancy was 93.30% in the intervention group versus 48.26% in the control group, The intervention group had a lower caesarean section rate, lower incidence of GDM and gestational hypertension, and lower neonatal weight and incidence of macrosomia compared to the control group

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
97	(Téoule et al., 2024) Germany [134]	Archieves of Gynaecology and Obstetrics	RCT	Gestational Weight Gain and Physical Activity	mHealth application: Buddy Healthcare, which facilitates personalized online intervention (virtual health coaching session), educational materials and physical activity tracking	Teleconsultation Health education Self/Remote monitoring	Complementary	The experimental group demonstrated a significant increase in physical activities and daily steps compared to the control group, ($p=0.045$) The intervention group has significantly higher proportion of participants meeting the recommended weight gain guidelines ($p=0.048$), indicating a reduction in excessive gestational weight gain The ratio of women who gained excessively was higher in the control group ($p=0.026$)
	High risk pregnancies							
98	(Venkateswaran et al., 2022) Palestine [135]	The Lancet Digital Health	RCT	High Risk: Anaemia Diabetes Hypertension Foetal Growth Monitoring	eRegQual: Clinical Decision support system : provide real-time, evidence-based guidance to health workers	Clinical guideline for health management	Complementary	Significantly enhanced the quality of antenatal care process, particularly in screening and managing anaemia, hypertension, and gestational diabetes No significant differences in adverse health outcomes were observed, suggesting process improvements did not impact delivery outcomes (Composite adverse health outcome: 21.7% vs. 21.9%.) Similar attendance rates in both groups
99	(Palmer et al., 2021) Australia [136]	The Lancet	Quasi -experimental	High Risk Pregnancies	Telehealth integrated maternal care for low risk and high-risk care models	Teleconsultation Remote monitoring	Substitution	Primary outcomes within integrated care, such as detection and outcomes of foetal growth restriction, pre-eclampsia, and gestational diabetes, were not significantly different Significant reduction in preterm birth among high-risk model while no other significant difference in other outcome measures (stillbirth, neonatal intensive care unit admission) Reduction of in-person consultations by 50% without compromising pregnancy outcomes

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
100	(Escobar et al., 2022) Colombia [137]	BMC Pregnancy and Childbirth	Descriptive Ecological Study	Obstetric Emergencies	Telehealth and education for the care of obstetric emergencies between two hospitals of medium and high complexity	Teleconsultation	Substitution	The use of telehealth and education model significantly reduces perinatal mortality Reduction in blood transfusions due to PPH and eclampsia events in patients
101	(Gupta et al., 2021) India [138]	Journal of Family Medicine and Primary Care	CS Mixed- method	High risk Pregnancies	SEWA applications: System E-approach for Women at risk : designed to identify and manage high-risk pregnancies by providers	Identification and screening of high-risk pregnancies	Complementary	Increase in the identification of pregnant women with high-risk conditions (27.9% from 3.5% in the previous year) The SEWA application represents a feasible and enduring approach to augment the capabilities of healthcare providers in promptly detecting high-risk medical conditions
102	(Valencia et al., 2023) Colombia [139]	International Journal of Medical Informatics	Observational	High-risk Pregnancies	HADA mobile and web Platform (mobile app and web-based dashboard) monitor blood glucose, blood pressure, and weight in real-time through Bluetooth devices, with data shared with healthcare providers and biweekly telemedicine consultations	Remote monitoring Teleconsultation	Complementary	The program achieved good usability and acceptance High user satisfaction, with an overall satisfaction score of 4.76 out of 5 Maternal and neonatal outcomes were comparable to traditional care, with similar caesarean section rates and no unexpected adverse events
103	(Rayford et al., 2023) United States [140]	Telemedicine Report	Retrospective Chart Review/ Observational	High Risk Pregnancies	Telehealth visits: conducted either by combined audio-visual calls or by audio-only calls	Teleconsultation	Complementary	Telehealth visits did not show significant differences in pregnancy outcomes, including mode of delivery ($p=0.2$) and rates of foetal demise, compared to in-person visit ($p=0.12$)
104	(Okonofua et al., 2023) Nigeria,Africa [141]	BMC Pregnancy and Childbirth	Quasi- experimental	Emergency Obstetric Care	The Text4Life mobile apps: connect users to emergency transportation and obstetric care during pregnancy complications	Emergency Care Coordination	Complementary	Text4Life platform effectively increased access to emergency obstetric services in rural Nigeria Out of those who reported complications, 51 (91.1%) were successfully transported to Primary Health Care (PHC) facilities to receive treatment

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
105	(Nagraj et al., 2023) India [142]	JMIR Formative Research	RCT	High Risk Pregnancies	SMARThealth Pregnancy: mobile clinical decision support system enabling providers to screen, refer, and counsel pregnant women at high risk of future cardiovascular diseases	Screening and diagnostic use Health education and counselling	Complementary	Intervention is deemed feasible and acceptable for community health workers (CHWs) to provide home-based care to high-risk pregnant women Enables early detection and timely management of anaemia, GDM, and hypertension, hence lowering the risk of future cardiometabolic disorders
106	(Bekker et al., 2023) Netherlands [143]	The Lancet Digital Health	RCT	High Risk Pregnancies	Home telemonitoring: Participants were provided with cardiotocography and blood pressure devices and had their home measurements digitally sent to care providers for daily review	Teleconsultation Remote monitoring	Substitution	Home telemonitoring: - is as safe and effective as hospital admission, showing non-inferiority in safety and clinical outcomes for managing complicated pregnancies - significantly reduced antenatal costs by 18% due to fewer hospital stays - Mean total costs per participant were €18,691 in the telemonitoring group versus €26,084 in the hospital admission group - higher satisfaction compared to hospital admission
	Education							
107	(Oliveira-Ciabati et al., 2017) Brazil [144]	Reproductive Health	RCT	Maternal Education	PRENACEL: Provides automated, personalized text messages with health education and promotion, appointment reminders, and pregnancy-related information. Users can also ask ANC-related questions through a bi-directional SMS system	Health education Health promotion Patient engagement	Complementary	Improve the coverage of recommended ANC practices: Higher mean ANC scores, with a significant difference ($p < 0.0001$) Higher proportion of women in the PRENACEL group (96.6%) attended six or more ANC visits, compared to 84.8% in the control group ($p = 0.001$) Higher rates of syphilis and HIV testing during ANC
108	(Silva et al., 2019) Brazil [145]	Rev Bras Enferm	CS	Gestational Health Care	e GestAção application : health education on maternal and childcare	Health education and self-monitoring	Complementary	High index of satisfaction of this technology of support to the pregnancy
109	(Shahid & Johnson, 2018) United Kingdom [146]	Evidence-based midwifery	CS	Antenatal Education	Solihull Approach online antenatal course	Health education (virtual course)	Complementary	The online antenatal course reduced parental anxiety, increased intention to breastfeed and improved the relationship with the unborn baby
110	(Basu et al., 2022) India [147]	Short Communication	RCT	Oral care and hygiene practices of pregnant women	mHealth: text messages on oral health promotion	Health education	Complementary	mHealth intervention group showed a significant decrease in missed twice-daily brushing event

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
111	(Masoi & Kibusi, 2019) Tanzania,Africa [148]	Reproductive Health	Quasi- experimental (pre & post with control group)	Knowledge on obstetric and newborns danger signs	Interactive mobile messaging alert system : received health education messages and two-way communication responses on a need basis	Health education and communication	Complementary	The interactive mobile messaging alert system improved women's birth preparedness practice and shown to be effective in enhancing awareness of danger signs in pregnancies
112	(Mohammed &Mohammed, 2022) Egypt [149]	Egyptian Journal of Health Care	Quasi -experimental	Fetal Kick Monitoring	Mobile-assisted education regarding fetal kick monitoring via online session, text messages and illustrative video (Kick counter mobile application)	Teleconsultation Health education	Complementary	Improvements in foetal kick monitoring knowledge and practice among high-risk pregnant women that are statistically significant (p 0.001) and correlate with favourable perinatal outcomes were observed in the study group as compared to the control group
113	(Ochieng' et al., 2024) Kenya, Africa [150]	BMC Pregnancy and Childbirth	Quasi-experimental (pre & post analysis approach)	Antenatal care seeking behaviour and maternal knowledge	PROMPTS (Promoting Mothers through Pregnancy and Postpartum): AI enable SMS-based platform Two-way SMS-based mHealth intervention with informative message and reminders	Health education Health promotion	Complementary	Increase service uptake. Enrolled mothers were 2.28 times more likely to complete four or more antenatal care (ANC) visits compared to unenrolled mothers - increase in knowledge levels regarding pregnancy complications among PROMPTS users, although some decline in knowledge of newborns care practices was observed
114	(Ahlers-Schmidt & Hervey, 2023) United States [151]	Journal of Perinatal Education	Retrospective Cohort	Prenatal Education	Virtual prenatal education through the Baby Talk program	Virtual prenatal education	Substitution	Both formats improved knowledge and intentions for a healthy pregnancy, but the virtual format was less effective in promoting key practices like breastfeeding and safe sleep. Virtual participants were less likely to develop a birth plan, know breastfeeding resources, feel confident in breastfeeding, or plan for safe infant sleep compared to in-person participants
115	(Adam et al., 2023) South Africa [152]	Journal of Medical Internet Research	RCT	Prenatal Education	mHealth intervention: Short, animated storytelling (SAS) videos to improve maternal knowledge and satisfaction during the perinatal period	Health education	Complementary	SAS videos delivered via WhatsApp resulted in a slight increase in maternal knowledge scores, though the increase was not statistically significant High maternal satisfaction associated with the use of SAS videos

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
	Vaccination							
116	(Stockwell et al., 2017) United States [153]	American Journal of Preventive Medicine	Observational	Vaccination	Text messaging platform for vaccine safety monitoring during pregnancy, collect data on health events, and provide health tips, ensuring real-time engagement and effective surveillance	Health surveillance Health education	Complementary	Demonstrated that text messaging is a feasible and effective tool for real-time vaccine safety surveillance during pregnancy (effectively captured health events, pregnancy losses, and live births) Nearly all participants (96.9%) were satisfied with the text message system
117	(Kaufman et al., 2020) Australia [154]	Vaccination in Maternity	CS	Influenza and Pertussis Vaccination	The P3-MumBubVax intervention : SMS text reminder, website, and fact sheets on vaccinations	Health education Appointment reminder	Complementary	Increase maternal and early childhood vaccine uptake and acceptance The P3-MumBubVax intervention is feasible and acceptable in the Australian public antenatal setting
	Cardiovascular health							
118	(Zielinska et al., 2022) United Kingdom [155]	Medicine	CS	Cardiovascular Health (bodyweight, heart rate, blood pressure, activity levels, and sleep patterns)	mHealth Apps – HUMA to record daily measurements Continuous monitoring of physiological parameters indicative of cardiovascular health using smart watch and apps	Remote monitoring of cardiovascular health	Complementary	Remote monitoring of CVS health pregnancy is feasible and could be integrated in routine care Early detection of deviation from baseline health metrics
	Imaging							
119	(Chang Long et al., 2014) United States [156]	Original Research	Retrospective Observational	Ultrasound for high-risk pregnancies	Real-time telemedicine ultrasounds, teleconferencing for community obstetricians, and evidence-based protocols for high-risk pregnancy care	Teleconsultation Diagnostic and clinical support services for high-risk pregnancy care	Substitution	Increased use of comprehensive ultrasounds for high-risk pregnancies (significant at $p < 0.0001$) Shift in the identification of high-risk pregnancies from the second to the first trimester Enhanced prenatal care access, particularly in underserved and rural areas
120	(Jemal et al.,2022) Ethiopia [157]	Journal of Telemedicine and Telecare	Cohort	Ultrasound for ANC	tele-ultrasound platform : consultation bet HCPs in rural clinic and obstetrician in tertiary centre	Teleconsultation : interfacility consultation and referral with health management	Substitution	Antenatal Ultrasound performed supported by obstetrician via tele-ultrasound showed good concordance and was well received by participants and gave rural Ethiopian women better access to antenatal imaging

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
	Pre-Anaesthetic Assessment							
121	(Sassi et al., 2024) France [158]	Indian Journal of Anaesthesia	Prospective Observational	Pre-anaesthetic assessment of antenatal mothers who might require surgical intervention during delivery	TeleO Telemedicine Platform: A secure video telemedicine desktop application, accessible on computers, tablets, and smartphones. It allows secure access through clinician accounts or an email link sent to patients by the secretary	Teleconsultation	Substitution	The study concludes that telemedicine consultations in obstetric anaesthesia are both feasible and effective 88% patients find the teleconsultation acceptable based on the System Use Scale The study found high levels of satisfaction among both patients (85%) and anaesthetists (94%) The intervention saved patients an average of $6 and 60 min, offering notable time and cost benefits even in well-connected areas
	Anaemia							
122	(Sharma et al., 2023) India [159]	European Journal of Obstetrics and Gynaecology and Reproductive Biology	RCT	Iron Deficiency Anaemia	Telephonic Intervention: include text reminders, WhatsApp audio messages, and phone calls to help pregnant women manage iron deficiency anaemia	Telephonic reminders and counselling Health education	Complementary	Adherence to oral Iron-Folic Acid Supplementation (IFAS) improved significantly among anaemic pregnant women, with a 44.9% increase in the experimental group compared to a 13.8% increase in the control group ($P < 0.001$) The experimental group had a statistically significant increase in haemoglobin levels by 0.8 g/dl, compared to 0.2 g/dl in the control group
123	(Arifah et al., 2023) Indonesia [160]	Journal of Education and Health Promotion	RCT	Anaemia	Daily educational messages sent via WhatsApp, designed according to the Capability, Opportunity, Motivation, Behaviour (COM-B) model	Health education	Complementary	Daily educational messages significantly improved knowledge and Iron Folic Acid (IFA) tablet consumption in the intervention group IFA Tablet Consumption: Increased significantly (39.54 ± 3.94 vs. 34.86 ± 8.13, $P = .003$) Knowledge: Significant improvement ($P = .007$) Diet: No significant difference in anaemia prevention diet between groups

Table 4 (continued)

	Author, year, location	Journals	Study design	Health concern	Description of digital technology	Types of intervention	Purpose	Main outcome
	Human Immunodeficiency Virus (HIV)							
124	(Coleman et al., 2017) South Africa [161]	AIDS Care—Psychological and Socio-Medical Aspects of AIDS/HIV	Quasi -experimental	HIV: prevention of mother-to-child transmission (PMTCT)	SMS-based maternal health mHealth system (MAMA South Africa) provide maternal health information, reminders for antenatal and postnatal care, and HIV-related support	Health education and promotion Appointment reminders	Complementary	Significant improvement in ANC visits compared to the control group (5.16 vs. 3.95, $p < 0.001$) 40% increase in the likelihood of attending the recommended four ANC visits was observed (Relative Risk [RR]: 1.41, 95% CI: 1.15–1.72) More likely to have normal vaginal deliveries (RR: 1.10, 95% CI: 1.02–1.19) The risk of delivering a low-birth-weight baby (< 2500 g) was reduced, although not statistically significant (RR: 0.14, 95% CI: 0.02–1.07)
	Physical Activity							
125	(Choi et al., 2016) United States [162]	Maternal and Child Health Journal	RCT	Physical Activity	Mobile app integrated with Fitbit Ultra for tracking physical activity and providing personalized feedback	Health promotion and behavioural support	Complementary	The mHealth PA intervention was feasible and acceptable to motivate pregnant women Both groups increased their physical activity, but the difference between groups was not statistically significant The intervention group reported a significant reduction in the perceived barrier of lack of energy
	Alcohol Cessation							
126	(Van Der Wulp et al., 2014) Netherlands [163]	Journal of Medical Internet Research	RCT	Alcohol Cessation	Internet-based Computer-Tailored Feedback, which provided automated, personalized feedback to pregnant women on their alcohol consumption	Behavioural support and counselling	Complementary	Computer Tailoring: Proven effective in reducing alcohol use and preferable due to its anonymity and scalability Health Counseling: Did not show significant effectiveness

Outcomes

The reviewed studies explored a diverse range of clinical and user-reported outcomes associated with digital health innovations. These outcomes included user acceptance and satisfaction, care engagement, cost-saving, time efficiency, perceived quality of care, and improvements in healthcare delivery. The effectiveness of digital health interventions in maternal healthcare was primarily assessed using various metrics such as glucose levels, blood pressure, weight gain, mental health indicators (e.g., anxiety or depression levels), and knowledge improvement. These metrics were frequently assessed through pre- and post-intervention comparisons or by comparing intervention and control groups, offering a comprehensive understanding of the interventions' impact. Notably, studies conducted in the earlier years of this digital health research span were predominantly pilot or feasibility studies focusing on exploring the practicality and viability of implementing these technologies in maternal healthcare settings.

Digital health innovations demonstrated high acceptability, as evidenced by their successful implementation across multiple applications [44, 50, 52, 55, 66, 72, 79, 80, 85, 87, 92, 98–100, 102, 110, 112, 116, 121, 124, 139, 160]. Examples of effective digital health tools include Smart Cards [68], SupportMoms [72], and interactive mobile messaging systems [95], which have significantly enhanced antenatal care processes. Mental health applications such as iCOPE [98] and the Mobile Mood Tracking and Alert app [99] were widely recognised and accepted for screening and monitoring mental health conditions. Similarly, telehealth interventions like TeleGDM [84, 85] demonstrated strong acceptance among both patients and healthcare providers, particularly in the management of gestational diabetes. High retention rates further underscored the acceptability of these tools, with numerous studies reporting consistent user engagement over time [43, 87, 119]. Moreover, intention-to-use measures revealed positive attitudes toward adopting digital health technologies, indicating sustained user interest and commitment [11, 49]. Interventions such as Babyscripts [43], HealthyMoms [132], and PROMPTS [150] achieved high levels of user engagement, with substantial participation in weight management programs and antenatal care visits. Additionally, continuous monitoring tools, such as Delfina Care, fostered increased daily engagement, thereby enhancing adherence to care protocols [118].

High satisfaction levels were reported across a range of digital health interventions [43, 44, 48–50, 53, 56, 57, 62–64, 66, 69, 80–82, 85, 89, 90, 115–117, 139, 145, 152, 153, 160]. Notable programs, such as ANGELS [53], OB Nest [56], and Glucose Buddy [82], demonstrated particularly high satisfaction rates, especially in providing virtual antenatal care services in remote areas and managing gestational diabetes (e.g., Glucose Buddy). During the COVID-19 pandemic, phone-based antenatal care achieved an impressive satisfaction rate of 93.9% [57]. Furthermore, virtual consultations for pre-anaesthetic assessments reported satisfaction rates of 85% among patients and 94% among healthcare providers [158]. However, some studies highlighted dissatisfaction with these technologies. For instance, one study reported lower overall satisfaction with teleconsultation services [61], while another found that 57% of participants were dissatisfied with their telemedicine experience, particularly among vulnerable populations [49, 58].

Adherence to care plans emerged as a significant outcome in multiple studies utilising digital health technologies [40–42, 45, 47, 50, 54, 56, 60, 62, 65, 66, 72, 75, 82, 128, 130, 144, 150, 161]. This includes adherence to care plan management, lifestyle modifications, regular clinic visits, and consistent health tracking. Digital tools such as mobile applications, teleconsultation platforms, and SMS reminders were shown to enhance adherence rates. For instance, telephonic reminders significantly improved compliance with Iron-Folic Acid Supplementation (IFAS) and improved haemoglobin levels in pregnant women [159, 160]. Digital tools like Cellular Internet Technology (CIT) [75], Glucose Buddy [82] and TeleGDM [84, 85] promoted higher adherence to blood glucose monitoring for gestational diabetes, with notable compliance differences between intervention and control groups. Additionally, appointment reminders increased antenatal care visit attendance [60, 65], reduced missed or cancelled appointments [62], and improved adherence to recommended care practices [50, 56], ultimately enhancing service uptake and continuity of care. Adherence to blood pressure monitoring was also significantly enhanced with digital health interventions like Safe@Home [115] and Delfina Care [118]. Mobile-assisted education on foetal kick monitoring improved adherence to recommended monitoring practices [149], correlating with better perinatal outcomes.

The review highlighted the effectiveness of digital health interventions in reducing the frequency of in-person visits without compromising care quality [56, 59, 67, 69, 77, 90, 111, 112]. Programs like OB Nest [56] demonstrated significant outcomes in reducing the frequency of antenatal visits, saving an average of 2.8 clinician appointments per patient and optimising both time and resource utilisation. Mobile applications such as Maven [67] enhanced remote care by improving pregnancy knowledge, with 82.5% of users recognising warning signs and 66.1% obtaining accurate medical information, significantly reducing both in-person and emergency

room visits. Similarly, other studies demonstrated that digital tools improved adherence to care plans, further minimising the need for in-person consultations [59, 77]. While digital health technologies have reduced the need for in-person visits by facilitating virtual consultations and remote monitoring, the review highlights their significant role in improving antenatal care attendance through appointment reminders and maternal education. These interventions have notably increased compliance among expectant mothers, with many attending four or more ANC visits, particularly in underserved areas. This indicates a substantial improvement in ANC visit compliance and accessibility of maternal healthcare services [54, 60, 65, 66, 72, 144, 150, 161].

The review identified a range of maternal and neonatal outcomes associated with digital health interventions, highlighting their effectiveness and safety in antenatal care. Several studies reported comparable maternal and foetal outcomes between telehealth and conventional care, with no significant differences observed in maternal morbidity and mortality, neonatal complications, or obstetric emergencies [54, 56, 69, 71, 74, 76, 78, 83, 85, 86, 89–91, 114, 135, 136, 140]. Some interventions demonstrated improved maternal health, such as reduced adverse pregnancy outcomes through mobile-based prenatal education programs and remote monitoring [70, 81, 111, 113], and reduced perinatal mortality using telehealth and education models [137]. Additionally, digital health tools for managing gestational diabetes showed lower glucose levels, lower excessive weight gain, and insulin resistance in intervention groups compared to controls [75, 82–86]. While four studies found no significant differences in glycaemic control, they reported improved adherence to glucose monitoring [81], significantly lower insulin resistance [78], increased system utilization [74], and a notable reduction in clinic visits [76]. mHealth applications such as the Cellular Internet Technology [75], Glucose Buddy [82] and Stay-Active mHealth [85] significantly improved glycaemic control and gestational weight gain management.

Interventions addressing hypertension improved outcomes by lowering preeclampsia rates and facilitating the early detection of gestational hypertension [111, 113, 138]. These interventions also led to reduced prenatal hospitalisations, fewer prenatal visits [113, 114], and improved maternal health outcomes, with fewer adverse events [116]. While no significant differences in smoking cessation rates were observed between the intervention and control groups, a reduction in the frequency of smoking among antenatal mothers was reported [121, 122], and abstinence rates were higher in the intervention group [119, 120]. Additionally, the use of mHealth tools incorporating behavioural support and counselling proved effective in reducing alcohol consumption [163]. Mobile applications have also demonstrated utility in vaccination safety surveillance and increasing maternal vaccine uptake [153, 154]. These findings highlight the positive outcomes of digital health interventions on maternal outcomes while ensuring safety and maintaining the quality of care.

Key findings emphasised the effective management of gestational weight gain (GWG) through mHealth applications and other digital tools. Several studies demonstrated that these interventions significantly reduced excessive GWG, improved dietary quality, and encouraged healthier physical activity and sedentary behaviours among pregnant women [124, 126–134]. These positive outcomes were facilitated by health education, behavioural counselling, and personalised coaching, along with real-time tracking and tailored feedback. Digital platforms provided additional tailored support, including interactive nutritional education, personalised meal planning, and real-time feedback. For instance, the HealthyMoms app was particularly impactful, as higher user engagement was linked to reduced GWG and improved diet quality [132]. Similarly, the WeChat platform offered personalised and continuous weight management services, resulting in significantly lower GWG and improved rates of appropriate weight gain during pregnancy compared to control groups [133]. Additionally, the Buddy Healthcare app increased physical activity and improved adherence to recommended weight gain guidelines, showing its utility in reducing excessive GWG [134]. However, other studies [123, 125] reported no significant differences in GWG or physical activity levels between the intervention and control groups. Similarly, the use of mobile applications for tracking physical activity and providing personalised feedback did not yield significant differences between the two groups [162].

Digital prenatal education delivered through mHealth applications and virtual online platforms effectively enhanced knowledge and encouraged healthy pregnancy practices among antenatal mothers, as evidenced by multiple studies [144, 146–152]. These interventions significantly improved maternal understanding of antenatal care, health behaviours, and related topics. However, one study [151] highlighted that while knowledge level increased, the virtual format was less effective in promoting education and fostering deeper engagement.

Several studies demonstrated improved mental health outcomes, such as reduced levels of prenatal distress and anxiety among intervention groups compared to control groups [93, 96, 101, 102, 107, 108]. Interventions like the PUMAS program effectively reduced insomnia, depression, nocturnal cognitive arousal, and sleep effort among participants, showcasing the potential of targeted digital

solutions [103]. However, not all studies reported significant improvements; one study [100] found no marked changes in depression symptoms, perceived stress, or social support between enrolment and follow-up, despite positive feedback on the intervention. A mixed approach combining face-to-face and virtual sessions was found to be potentially more effective in managing psychological distress compared to entirely virtual sessions, indicating the importance of hybrid models for mental health support [106]. Another study using Electronic mindfulness-based intervention (eMBI) [104] reported no significant differences in depressive symptoms among participants but demonstrated promising results in reducing pregnancy-related anxiety.

The adoption of digital health demonstrates significant cost-effectiveness by reducing the need for in-person visits, minimising hospital stays, and lowering overall healthcare expenses. Several studies highlight the financial benefits for healthcare systems and patients, with notable savings achieved without compromising clinical outcomes. For example, telemonitoring and mobile health applications have reduced antenatal costs by up to 18% due to fewer hospital stays, with mean costs per participant being €18,691 in the telemonitoring group compared to €26,084 in the hospital admission group [143]. Similarly, one intervention achieved substantial savings for the healthcare system, amounting to €10,500 annually, while reducing patient expenses by €340 through fewer in-person visits [90]. Additionally, the use of digital health in maternal care was shown to be cost-effective while maintaining similar effectiveness to routine care (€12,705.08 vs. €12,768.13) [88]. Teleconsultation also reduced costs per pregnancy and societal expenses [114] by minimising hospital visits and admissions. Virtual pre-anaesthetic assessments provided significant time and cost savings, reducing expenses by an average of €5.52 and saving 60 min per session, even in well-connected areas [158]. Likewise, remote digital solutions proved to be highly cost-effective in managing gestational weight gain, with lower costs for participants (€91 vs. €324) and clinics (€203 vs. €396) [128]. Other studies reported comparable healthcare costs between digital and traditional care models [81, 83]. These findings highlight the dual advantage of digital health technologies in enhancing antenatal care delivery while alleviating financial burdens for stakeholders.

The use of digital health tools in healthcare enables the provision of comprehensive, high-quality care while strengthening the continuity of services and interfacility collaboration [44, 46, 47, 50, 53, 54, 62, 66, 68, 69, 73, 136, 137, 142, 156, 157]. Patients and providers reported improved access to obstetric services and more efficient antenatal care. Digital tools also addressed critical barriers to care, particularly in underserved and rural areas, fostering a perception of greater accessibility [117, 140, 156, 157]. Platforms such as WhatsApp and phone-based telehealth significantly enhanced participants' sense of self-efficacy, particularly during the COVID-19 pandemic [11, 54, 57, 73]. In addition, virtual care interventions involving real-time teleconsultations not only improved healthcare service delivery by enhancing accessibility but also associated with noticeable reductions in physical, mental, and economic burdens, with participants reporting high levels of satisfaction with these more interactive and comprehensive forms of care [69]. At the same time, the integration of digital health models demonstrated maternal and neonatal outcomes comparable to those of traditional care [69, 71, 74, 76, 81, 83, 85, 86, 89–91, 111, 113, 114]. However, some limitations remain. For instance, one study highlighted patient preferences for in-person visits, attributing this to the lack of adequate teleconsultation tools and insufficient clinic support [55]. Similarly, another study raised concerns that telehealth could potentially diminish the perceived quality of care, underscoring the importance of refining digital tools and strengthening support systems to optimize patient satisfaction and care quality [80]. Adverse perinatal outcomes were also highlighted as essential indicators of the effectiveness of digital health interventions. These included the incidence of obstetric emergencies, caesarean deliveries, preterm labour, hospitalisations, intrauterine distress, congenital malformations, intrauterine growth retardation and neonatal complications [70, 71, 81, 111, 113, 114, 136, 161]. Notably, none of the studies reviewed reported any adverse outcomes associated with using digital health in the provision of care. The outcomes of digital health utilisation in antenatal are comprehensively presented in Table 4 for further reference.

Discussion

This review explores the scope and application of digital health technologies in antenatal care, highlighting their role in enhancing the management and well-being of expectant mothers while advancing maternal care services. The findings emphasise the acceptability, satisfaction, and effectiveness of these technologies, demonstrating their transformative potential in improving antenatal care and maternal health outcomes.

The publication trends reveal a growing interest in leveraging digital health technologies for antenatal care, driven by the widespread adoption of digital tools and the transformative impact of the COVID-19 pandemic. The pandemic served as a catalyst, accelerating the integration of telehealth into standard care practices to ensure continued access to maternal health services amidst

global disruptions. This shift is evident in the marked increase in publications from 2020 onward, with a significant spike in 2023, highlighting the healthcare system's rapid adaptation and the normalisation of digital health solutions. The adoption and utilisation of digital health technologies in antenatal care were relatively limited before 2017, as reflected by the few studies published during that period. However, from 2017 onwards, there was a significant increase in publications, driven by advancements in technology and growing recognition of the potential benefits of digital health.

Despite a slight decrease in publications in 2024, the overall volume remains significantly higher than in earlier years. This suggests that digital health technologies are transitioning from experimental applications to integral components of ANC. This decline may indicate a stabilisation phase as digital health becomes standard practice, highlighting the need for long-term studies to optimise their integration and refine their impact on maternal health outcomes. Addressing gaps in early research remains crucial to fully understanding the trajectory of digital health adoption and its potential to transform ANC services, ensuring their continued evolution to meet the dynamic needs of maternal healthcare.

The utilisation of digital health technologies in ANC has steadily expanded, mirroring trends observed in other healthcare domains, such as chronic disease management [166]. During the pandemic, teleconsultations gained prominence as a solution for maintaining access to care, while mHealth applications were increasingly adopted for continuous health monitoring and education. mHealth applications demonstrated steady growth, peaking in 2023, reflecting their increasing acceptance and integration into antenatal care. This surge is likely driven by their utility in facilitating monitoring, promoting self-care, and supporting self-management to improve health outcomes. In contrast, a decline in teleconsultation usage after 2023 suggests a potential normalisation of in-person visits as pandemic-related restrictions eased. The utilisation pattern in mHealth applications and teleconsultations reflects the growing recognition of digital health as a transformative tool in antenatal care. This trend aligns with the rising number of studies, indicating a parallel increase in research interest and practical implementation.

Digital health tools serve as either complementary or substitutional methods to standard care practice. The shift towards substitution interventions, particularly in 2023, reflects the growing demand for remote care, especially in light of the pandemic ensuring continuity of care amidst restrictions on physical visits. Complementary interventions, on the other hand, are intended to enhance standard antenatal care by integrating digital tools into routine workflows. As healthcare systems transitioned back to normalisation, mHealth applications gained renewed importance, emphasising the value of digital health as a hybrid care model in supporting healthcare providers and empowering patients through additional resources and support mechanisms. These interventions focus on improving accessibility, efficiency, and patient engagement without entirely replacing in-person visits. The complementary nature of these tools signify their value in enhancing standard care. Despite the continued prevalence of complementary interventions, substitution-based approaches have gained considerable traction in recent years, marking a shift toward more flexible and remote antenatal care solutions. The trends indicate a growing integration of both types of interventions in standard routine antenatal care practices. The steady rise in publications focusing on both models shows the versatility of digital health interventions in addressing diverse maternal health needs.

Another significant pattern in the adoption of digital health technologies in the antenatal domain is the increased focus on mental health issues starting in 2020, followed by a growing emphasis on managing high-risk pregnancies in 2022. The use of digital health tools for mental health during 2020 can be attributed to the heightened demand for accessible and scalable solutions in response to the mental health challenges exacerbated by the COVID-19 pandemic. Lockdowns, social isolation, and restricted access to in-person healthcare services likely accelerated the adoption of telehealth and digital mental health interventions. By 2022, the application of digital health technologies for high-risk pregnancies gained momentum, driven by advancements in wearable health devices, remote monitoring systems, and AI-powered decision-making tools. These innovations enabled real-time monitoring of maternal and foetal health, providing clinicians with critical data for timely interventions. Additionally, the growing recognition of the importance of maternal health and the need to mitigate risks associated with high-risk pregnancies have further catalysed the integration of digital health solutions in antenatal care. This trend reinforces the potential of technological advancements to address key healthcare challenges and improve outcomes across diverse clinical areas.

Integrating digital health technologies in ANC has enhanced maternal and neonatal outcomes, improved adherence to care plans, and increased patient satisfaction. The findings of this study are consistent with prior research, further validating the effectiveness of digital health solutions in improving healthcare outcomes across various contexts [167, 168]. Studies involving remote consultations for antenatal care revealed that most participants were satisfied with the reduced need

for physical visits, as this convenience did not compromise care quality.

Other research also highlights that both patients and healthcare providers report high satisfaction levels, which are often associated with positive patient and provider experiences, particularly regarding the convenience offered by these digital health solutions [169, 170]. While digital healthcare offers numerous benefits, the transition to digital systems is fraught with challenges, sometimes resulting in user dissatisfaction. Despite its promise of improved efficiency and accessibility, the adoption of digital health technologies often faces hurdles impacting user satisfaction, including user experience, system functionality, and the broader healthcare environment [171–173].

Digital platforms often integrate multiple modalities within clinical settings to optimise healthcare provision, emphasising the need for hybrid models incorporating digital tools with standard practice to achieve optimal care. The integration of these tools within multimodal care makes it challenging to isolate their individual effects. Most positive outcomes, including improved health metrics and adherence to care plans, result from combining digital tools with standard care practices. These findings underscore the complementary nature of digital health technologies rather than their standalone impact. Therefore, while studies often report positive clinical outcomes associated with mobile app or telehealth use, it is essential to recognise that these results are typically attributed to a comprehensive intervention approach rather than the standalone impact of digital health tools. Even though digital health interventions have shown positive outcomes, some studies suggest that virtual interventions alone may fall short of providing holistic care. They underline the importance of integrating virtual tools with physical visits to ensure comprehensive care and achieve optimal results [106, 151].

Significant improvements in antenatal care delivery are achieved by fostering effective communication between patients and healthcare providers through tools like remote monitoring apps, virtual consultations, and text messaging. Wearable devices and tracking tools empower women to monitor their health, enhancing accessibility and care management.

Various maternal health conditions are increasingly managed through digital health technologies, with the primary focus on general maternal care, mental health, and gestational diabetes. General maternal care remains the most widely targeted, employing tools for education, reminders, and health behaviour reinforcement to enhance accessibility and service delivery. Mental health interventions address critical challenges such as prenatal anxiety and depression, incorporating behavioural therapy and mindfulness platforms to improve psychological well-being. Gestational diabetes management also features prominently, with tools like Glucose Buddy and Stay-Active mHealth demonstrating significant improvements in glycaemic control and weight management. These diverse applications illustrate the versatility of digital health solutions while highlighting the importance of effectively tailoring interventions to address specific maternal health needs.

Teleconsultations offer convenience, cost savings, and improved access to care, making them a practical option for routine follow-ups and less complex cases [164]. In contrast, in-person consultations provide comprehensive physical assessments, emergency care, and stronger patient-physician relationships, which are essential for high-risk pregnancies and complex medical conditions [165]. While teleconsultations address accessibility challenges and provide convenience and flexibility, in-person visits remain indispensable for their thoroughness and ability to manage complex healthcare needs. Therefore, they remain the gold standard in patient care.

Conclusion

Digital health technologies have proven to be transformative in antenatal care by improving maternal and neonatal outcomes, enhancing accessibility, and increasing patient satisfaction. These tools, including mHealth apps, teleconsultations, wearables, and tracking devices, effectively support communication, monitoring, and education. While teleconsultations provide convenience and flexibility, in-person visits remain essential for managing high-risk pregnancies and complex medical conditions, serving as the gold standard in maternal healthcare. Integrating digital interventions with physical visits provides a holistic approach, ensuring comprehensive care and optimising clinical outcomes. Future efforts should address barriers such as infrastructure limitations in low-income settings and ensure data security while continuing to refine these tools for widespread and sustainable implementation.

Limitations

The assessment included peer-reviewed articles from four key databases published in English, excluding studies published in other languages. Many reviewed studies covered antenatal care and the postpartum period, typically extending up to six weeks postpartum, a critical phase for maternal recovery and physiological changes. This overlap may have affected the findings specific to antenatal care. Furthermore, the diversity and heterogeneity of digital health technologies made it challenging to categorise and compare outcomes effectively.

Abbreviations

ANC	Antenatal care
PIH	Pregnancy-induced hypertension
HPT	Hypertension
GDM	Gestational diabetes mellitus
IUGR	Intrauterine growth retardation
GWG	Gestational weight gain
PPH	Postpartum haemorrhage
LMIC	Lower and middle-income countries
HIC	High-income countries
HCP	Health care provider
mHealth	Mobile health
ICT	Information and communication technology
DHI	Digital health intervention
RCT	Randomised controlled trial
CS	Cross-sectional

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12884-025-07209-8.

Supplementary Material 1.

Acknowledgements
None.

Authors' contributions
H.M, R.S: Conceptualisation and study design; search strategy formulation; literature search, titles, abstracts, and full texts screening; analysis planning and data interpretation; manuscript writing. A.I, R.S: Study supervision, including review methodology, data extraction, data analysis, and manuscript writing. All authors (H.M, A.I, R.S, R.A, K.J) read and approved the final version of the manuscript to be published.

Funding
Not applicable.

Data availability
All data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Public Health Medicine, Faculty of Medicine, National University of Malaysia, National University of Malaysia, Jalan Yaacob Latif, Bandar Tun Razak, Cheras, Wilayah Persekutuan, 56000 Kuala Lumpur, Malaysia. [2]Department of Obstetrics and Gynaecology, Faculty of Medicine, National University of Malaysia, Jalan Yaacob Latif, Bandar Tun Razak, Cheras, Wilayah Persekutuan, 56000 Kuala Lumpur, Malaysia. [3]Family Health Development Division, Federal Government Administrative Centre, Ministry of Health, Block E1,E3,E6, E7 and E10, Complex E, Putrajaya 62590, Malaysia.

Received: 26 October 2023 Accepted: 21 January 2025
Published online: 13 February 2025

References

1. Sartika D, Razak A, Arifin MA, Kardi M, Jafar N. Evaluation of the antenatal care service program at the Tojo Una-Una district health office. Pharmacogn J. 2024;16(3):615–23. https://doi.org/10.5530/pj.2024.16.97.
2. Boureka E, Tsakiridis I, Kostakis N, Giouleka S, Mamopoulos A, Kalogiannidis I, Dagklis T. Antenatal Care: A Comparative Review of Guidelines. Obstetr Gynecolog Surv. 2024;79(5):290–303.
3. Kota K, Chomienne MH, Geneau R, Yaya S. Socio-economic and cultural factors associated with the utilization of maternal healthcare services in Togo: a cross-sectional study. Reprod Health. 2023;20(1):109.
4. Raymond VG, Ndalla MM, Tibenderana JR. Antenatal care access in Tanzania: progress, challenges, and recommendations for a healthier maternal and child well-being. IJS Global Health. 2023;6(6): e0370.
5. World Health Organization. WHO Guideline: Recommendations On Digital Interventions For Health System Strengthening: Web Supplement 2: Summary of Findings and GRADE Tables (No. WHO/RHR/19.7). Switzerland (GVA): 2023 WHO; 2019. Available from: https://apps.who.int/iris/handle/10665/324998. Updated 2021.
6. Kusyanti T, Wirakusumah FF, Rinawan FR, Muhith A, Purbasari A, Mawardi F, Puspitasari IW, Faza A, Stellata AG. Technology-based (Mhealth) and Standard/Traditional maternal care for pregnant woman: a systematic literature review. InHealthc. 2022;10(7):1287 MDPI.
7. Cantor AG, Jungbauer RM, Totten AM, Tilden EL, Holmes R, Ahmed A, Wagner J, Hermesch AC, McDonagh MS. Telehealth strategies for the delivery of maternal health care: a rapid review. Ann Intern Med. 2022;175(9):1285–97.
8. Till S, Mkhize M, Farao J, Shandu LD, Muthelo L, Coleman TL. Digital health technologies for maternal and child health in Africa and other Low-and middle-income countries: cross-disciplinary scoping review with Stakeholder consultation. J Med Int Res. 2023;25:e42161.
9. Endehabtu BF, Tilahun B, Gelaye KA, Mengiste SA. Mapping the role of digital health interventions to enhance effective coverage of antenatal care: A scoping review. J Multidisciplin Healthc. 2024;17:71–82. Dove Medical Press Ltd. https://doi.org/10.2147/JMDH.S438097.
10. Rogers CC, Jang SS, Tidwell W, Shaughnessy S, Milburn J, Hauck FR, Valdez RS. Designing mobile health to align with the social determinants of health. Front Digit Health. 2023;5:1193920.
11. Galle A, Semaan A, Huysmans E, Audet C, Asefa A, Delvaux T, Afolabi BB, El Ayadi AM, Benova L. A double-edged sword—telemedicine for maternal care during COVID-19: findings from a global mixed-methods study of healthcare providers. BMJ Glob Health. 2021;6(2): e004575.
12. Van Den Heuvel JF, Groenhof TK, Veerbeek JH, Van Solinge WW, Lely AT, Franx A, Bekker MN. eHealth as the next-generation perinatal care: an overview of the literature. J Med Internet Res. 2018;20(6): e202.
13. Melh G, Tamrat T. Classification of digital health interventions v 1.0. Geneva: WHO. 2018.
14. World Health Organization. Call for innovative health technologies for low-resource settings. Switzerland (GVA): 2023 WHO; 2014. Available from: http://www.who.int/medical_devices/innovation/call_2014/en/. Updated 2014, Cited 20 March 2019.
15. World Health Organization. Global Strategy on Digital Health 2020–2025. Switzerland (GVA): 2023 WHO; 2021. Available from: https://www.who.int/docs/default-source/documents/gs4dhdaa2a9f352b0445bafbc79ca799dce4d.pdf. Updated 2021.
16. Junaid SB, Imam AA, Abdulkarim M, Surakat YA, Balogun AO, Kumar G, Hashim AS. Recent advances in artificial intelligence and wearable sensors in healthcare delivery. Appl Sci. 2022;12(20):10271.
17. Cockburn N, Osborne C, Withana S, Elsmore A, Nanjappa R, South M, Parry-Smith W, Taylor B, Chandan JS, Nirantharakumar K. Clinical decision support systems for maternity care: a systematic review and meta-analysis. EClinicalMedicine. 2024;76. https://doi.org/10.1016/j.eclinm.2024.102822.
18. Shamsabadi A, Dashti M, Ghasemzadeh A, Mehraeen E, Saber Mashhad Taraqi A, Jalali A, Pashaei Z, Pashaei A. Virtual clinic in pregnancy and postpartum healthcare: A systematic review. Health Sci Rep. 2023;6(1):e970.

19. Moise IK, Ivanova N, Wilson C, Wilson S, Halwindi H, Spika VM. Lessons from digital technology-enabled health interventions implemented during the coronavirus pandemic to improve maternal and birth outcomes: a global scoping review. BMC Pregnancy Childbirth. 2023;23(1):195.
20. Paul, J. Innovative healthcare digital transformations during and After the COVID-19 pandemic Crisis. Med Res Arch. 2024;12(5). https://doi.org/10.18103/mra.v12i5.5297.
21. Mapari SA, Shrivastava D, Dave A, Bedi GN, Gupta A, Sachani P, Pradeep U. Revolutionizing Maternal Health: The Role of Artificial Intelligence in Enhancing Care and Accessibility. Cureus. 2024;16(9):e69555.
22. Wallwiener S, Müller M, Doster A, Laserer W, Reck C, Pauluschke-Fröhlich J, Brucker SY, Wallwiener CW, Wallwiener M. Pregnancy eHealth and mHealth: user proportions and characteristics of pregnant women using Web-based information sources—a cross-sectional study. Arch Gynecol Obstet. 2016;294:937–44.
23. Bert F, Gualano MR, Brusaferro S, De Vito E, De Waure C, La Torre G, Manzoli L, Messina G, Todros T, Torregrossa MV, Siliquini R. Pregnancy e-health: a multicenter Italian cross-sectional study on Internet use and decision-making among pregnant women. J Epidemiol Community Health. 2013;67(12):1013–8.
24. DeNicola N, Grossman D, Marko K, Sonalkar S, Tobah YS, Ganju N, Witkop CT, Henderson JT, Butler JL, Lowery C. Telehealth interventions to improve obstetric and gynecologic health outcomes: a systematic review. Obstet Gynecol. 2020;135(2):371.
25. Güneş Öztürk G, Akyıldız D, Karacam Z. The impact of telehealth applications on pregnancy outcomes and costs in high-risk pregnancy: A systematic review and meta-analysis. J Telemed Telecare. 2024;30(4):607–30.
26. American College of Obstetricians and Gynecologists. Implementing telehealth in practice: ACOG Committee opinion summary, number 798. Obstet Gynecol. 2020;135(02):493–4.
27. The American College of Obstericians and Gynecologists. ACOG Gains Ground on Expanding Telehealth. USA (WAS): 2023 ACOG. Available from: https://www.acog.org/en/News/News Articles/2020/08/ACOG Gains Ground on Expanding Telehealth. Updated 2020, cited 19 September 2020.
28. Lowery C, DeNicola N, College A, of Obstetricians and Gynecologists. Implementing telehealth in practice. Obstet Gynecol. 2020;135(2):e73–9.
29. Van Hauwaert R, Mateus AR, Coutinho AL, Rodrigues J, Martins AR, Vilela F, Almeida D. The role of digital health technologies on maternal health literacy: a narrative review. Emerg Technol Health Lit Med Pract. 2024;Chapter 3:47–65.
30. Dalton J. Digital Pathways-The way of the future to promote health literacy. Women and Birth. 2023;36:S43.
31. Pierce P, Whitten M, Hillman S. The impact of digital healthcare on vulnerable pregnant women: A review of the use of the MyCare app in the maternity department at a central London tertiary unit. Frontiers in Digital Health. 2023;5:1155708.
32. Upendra S, Kaur J, Barde S. Digital health appliances for antenatal care among pregnant woman a review," 2023 International Conference on Integration of Computational Intelligent System (ICICIS), Pune, India. 2023. p. 1-5. https://doi.org/10.1109/ICICIS56802.2023.10430321.
33. Ng WY, Lau NY, Lee VV, Vijayakumar S, Leong QY, Ooi SQD, Ho D. Shaping Adoption and Sustained Use Across the Maternal Journey: Qualitative Study on Perceived Usability and Credibility in Digital Health Tools. JMIR Hum Fact. 2024;11:e59269.
34. Samaran, E. Integration of Digital Health Technologies in Maternal and Child Health Management: Opportunities and Challenges. In Join: Journal of Social Science. 2024; 1:4. https://ejournal.mellbaou.com/index.php/join/index
35. Arksey H, O'Malley L. Scoping studies: toward a methodological framework. Int J Soc Res Methodol. 2005;8(1):19–32.
36. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci. 2010;5:1–9.
37. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, Moher D, Peters MD, Horsley T, Weeks L, Hempel S. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467–73.
38. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. Int J Surg. 2021;88: 105906.
39. Peters MD, Godfrey CM, McInerney P, Soares CB, Khalil H, Parker D. The Joanna Briggs Institute reviewers' manual 2015: Methodology for JBI scoping reviews. Joanna Briggs Institute. 2015.
40. Little A, Medhanyie A, Yebyo H, Spigt M, Dinant GJ, Blanco R. Meeting community health worker needs for maternal health care service delivery using appropriate mobile technologies in Ethiopia. PLoS ONE. 2013;8(10):e77563.
41. Lund S, Nielsen BB, Hemed M, Boas IM, Said A, Said K, Rasch V. Mobile phones improve antenatal care attendance in Zanzibar: a cluster randomized controlled trial. BMC Preg Childbirth. 2014;14:1–10.
42. McNabb M, Chukwu E, Ojo O, Shekhar N, Gill CJ, Salami H, Jega F. Assessment of the quality of antenatal care services provided by health workers using a mobile phone decision support application in northern Nigeria: a pre/post-intervention study. PLoS ONE. 2015;10(5): e0123940.
43. Marko KI, Krapf JM, Meltzer AC, Oh J, Ganju N, Martinez AG, Gaba ND. Testing the feasibility of remote patient monitoring in prenatal care using a mobile app and connected devices: a prospective observational trial. JMIR Res Prot. 2016;5(4):e6167.
44. Benski AC, Stancanelli G, Scaringella S, Herinainasolo JL, Jinoro J, Vassilakos P, Schmidt NC. Usability and feasibility of a mobile health system to provide comprehensive antenatal care in low-income countries: PANDA mHealth pilot study in Madagascar. J Telemed Telec. 2017;23(5):536–43.
45. Bush J, Barlow DE, Echols J, Wilkerson J, Bellevin K. Impact of a mobile health application on user engagement and pregnancy outcomes among Wyoming Medicaid members. Telemedicine and e-Health. 2017;23(11):891–8.
46. Dansharif AR, Iyawa GE, Owoseni A, Iyawa R. mHealth for self-management in pregnancy: perceptions of women in low-resource settings. Procedia Computer Science. 2021;181:738–45.
47. Borsari L, Stancanelli G, Guarenti L, Grandi T, Leotta S, Barcellini L, Borella P, Benski AC. An innovative mobile health system to improve and standardize antenatal care among underserved communities: A feasibility study in an Italian hosting center for asylum seekers. J Immigr Minor Health. 2018;20:1128–36.
48. Barron P, Peter J, LeFevre AE, Sebidi J, Bekker M, Allen R, Parsons AN, Benjamin P, Pillay Y. Mobile health messaging service and helpdesk for South African mothers (MomConnect): history, successes and challenges. BMJ Glob Health. 2018;3(2): e000559.
49. Sulaman H, Akhtar T, Naeem H, Saeed GA, Fazal S. Beyond COVID-19: prospect of telemedicine for obstetrics patients in Pakistan. Int J Med Informatics. 2022;158: 104653.
50. Paduano S, Incerti F, Borsari L, Benski AC, Ernest A, Mwampagatwa I, Lilungulu A, Masoi T, Bargellini A, Stornelli F, Stancanelli G. Use of a mHealth System to Improve Antenatal Care in Low and Lower-Middle Income Countries: Report on Patients and Healthcare Workers' Acceptability in Tanzania. Int J Environ Res Public Health. 2022;19(22):15342.
51. Arnaert A, Ponzoni N, Debe Z, Meda MM, Nana NG, Arnaert S. Experiences of women receiving mhealth-supported antenatal care in the village from community health workers in rural Burkina Faso. Africa Digital health. 2019;5:2055207619892756.
52. Musiimenta A, Tumuhimbise W, Pinkwart N, Katusiime J, Mugyenyi G, Atukunda EC. A mobile phone-based multimedia intervention to support maternal health is acceptable and feasible among illiterate pregnant women in Uganda: Qualitative findings from a pilot randomized controlled trial. Digital Health. 2021;7:2055207620986296.
53. Bhandari NR, Payakachat N, Fletcher DA, Sung YS, Eswaran H, Benton T, Lowery CL. Validation of newly developed surveys to evaluate patients' and providers' satisfaction with telehealth obstetric services. Telemedicine and e-Health. 2020;26(7):879–88.
54. Duryea EL, Adhikari EH, Ambia A, Spong C, McIntire D, Nelson DB. Comparison between in-person and audio-only virtual prenatal visits and perinatal outcomes. JAMA Netw Open. 2021;4(4):e215854.
55. Hofmann G, Hampanda K, Harrison MS, Fasano M, Nacht A, Yeoman M. Virtual prenatal and postpartum care acceptability among maternity care providers. Matern Child Health J. 2022;26(7):1401–8.

56. Tobah YS, LeBlanc A, Branda ME, Inselman JW, Morris MA, Ridgeway JL, Finnie DM, Theiler R, Torbenson VE, Brodrick EM, de Mooij MM. Randomized comparison of a reduced-visit prenatal care model enhanced with remote monitoring. Am J Obstet Gynecol. 2019;221(6):638-e1.
57. Wali R, Alhakami A, Alsafari N. Evaluating the level of patient satisfaction with telehealth antenatal care during the COVID-19 pandemic at King Abdul-Aziz Medical City, Primary Health Care Center. Specialized Polyclinic Women's Health. 2022;18:17455057221104660.
58. Zulfeen M, Chandrasekaran N. Virtual Prenatal Care During a Pandemic: How Satisfying Is It to the Caregivers and the Patients? Journal of Clinical Gynecology and Obstetrics. 2022;11(3):62–8.
59. Marko KI, Ganju N, Krapf JM, Gaba ND, Brown JA, Benham JJ, Oh J, Richards LM, Meltzer AC. A mobile prenatal care app to reduce in-person visits: prospective controlled trial. JMIR Mhealth Uhealth. 2019;7(5): e10520.
60. Coleman J, Black V, Thorson AE, Eriksen J. Evaluating the effect of maternal mHealth text messages on uptake of maternal and child health care services in South Africa: a multicenter cohort intervention study. Reprod Health. 2020;17(1):1–9.
61. Futterman I, Rosenfeld E, Toaff M, Boucher T, Golden-Espinal S, Evans K, Clare CA. Addressing disparities in prenatal care via telehealth during COVID-19: prenatal satisfaction survey in East Harlem. Am J Perinatol. 2020;38(01):088–92.
62. Jeganathan S, Prasannan L, Blitz MJ, Vohra N, Rochelson B, Meirowitz N. Adherence and acceptability of telehealth appointments for high-risk obstetrical patients during the coronavirus disease 2019 pandemic. American Journal of Obstetrics & Gynecology MFM. 2020;2(4): 100233.
63. Lapadula MC, Rolfs S, Szyld EG, Hallford G, Clark T, McCoy M, McKnight S, Makkar A. Evaluating patients' and neonatologists' satisfaction with the use of telemedicine for neonatology prenatal consultations during the COVID-19 pandemic. Front Pediatr. 2021;9: 642369.
64. Meyer CL, Surmeli A, Hoeflin Hana C, Narla NP. Perceptions on a mobile health intervention to improve maternal child health for Syrian refugees in Turkey: Opportunities and challenges for end-user acceptability. Front Public Health. 2022;10:1025675.
65. Alhaidari T, Amso N, Jawad TM, Alnakkash U, Khazaal F, Alnaaimi A, Pickles T, Playle R, Istepanian R, Philip N, Gregory JW. Feasibility and acceptability of text messaging to support antenatal healthcare in Iraqi pregnant women: A pilot Study. J Perinat Med. 2018;46(1):67–74.
66. Soni S, Sharma K, Yadav K, Singhal S, Kaur R. Bridging gaps in antenatal care: Implementation of the WHO ANC model using a web-based mobile application at different levels of the healthcare system. Int J Med Informatics. 2023;180: 105277.
67. Jahnke H, Rubin-Miller L, Henrich N, Moss C, Shah N, Peahl A. Association Between the Use of a Digital Health Platform During Pregnancy and Helping Users Avoid Emergency and In-Person Care: Retrospective Observational Study. J Med Internet Res. 2023;25:e43180. https://doi.org/10.219643180.
68. Itanyi IU, Iwelunmor J, Olawepo JO, Gbadamosi S, Ezeonu A, Okoli A, Ogidi AG, Conserve D, Powell B, Onoka CA, Ezeanolue EE. Acceptability and user experiences of a patient-held smart card for antenatal services in Nigeria: a qualitative study. BMC Pregnancy Childb. 2023;23(1):198. https://doi.org/10.1186/s12884-023-05494-9.
69. Ishikawa Y, Nakanishi K, Masuda A, Hayasaka M, Tsumura A, Murakami K, Umazume T, Masuda T, Nishiwaki K, Kato Y. Telemedicine for Pregnant Women on a Japanese Remote Island: A Two-year Report. Jma Journal. 2023;6(4):499–504.
70. Hao J, Yang L, Wang Y, Lan Y, Xu X, Wang Z, Li Z, Ma L, Li J, Zhang S. Mobile prenatal education and its impact on reducing adverse pregnancy outcomes: Retrospective real-world study. JMIR Mhealth Uhealth. 2023;11: e46910. https://doi.org/10.2196/46910.
71. Escobar MF, Gallego JC, Echavarria MP, Fernandez P, Posada L, Salazar S, Alarcon J. Maternal and perinatal outcomes in mixed antenatal care modality implementing telemedicine in the southwestern region of Colombia during the COVID-19 pandemic. BMC Health Serv Res. 2023;23(1):259.
72. Atukunda E, Siedner M, Obua C, Musiimenta A, Ware N, Mugisha S, Najjuma J, Mugyenyi G, Matthews L. Evaluating the feasibility, acceptability, and preliminary efficacy of SupportMoms-Uganda, an mHealth-based patient-centered social support intervention to improve the use of maternity services among pregnant women in rural Southwestern Uganda: Randomized controlled trial. JMIR Formative Research. 2023;7: e36619.
73. Askari S, Bahmaei H, Nasab M, Maniati M, Ghanbari S, Zaherian N, Iravani M. Impact of telehealth on pregnant women's self-care, self-efficacy, and satisfaction during the COVID-19 pandemic: A quasi-experimental study. Iran Red Crescent Medical Journal. 2023;25(10):e2982.
74. Homko CJ, Deeb LC, Rohrbacher K, Mulla W, Mastrogiannis D, Gaughan J, Bove AA. Impact of a telemedicine system with automated reminders on outcomes in women with gestational diabetes mellitus. Diab Technol Therapeut. 2012;14(7):624–9.
75. Bartholomew ML, Soules K, Church K, Shaha S, Burlingame J, Graham G, Zalud I. Managing diabetes in pregnancy using cell phone/internet technology. Clin Diab: Pub Am Diab Assoc. 2015;33(4):169.
76. Carral F, Ayala MDC, Fernández JJ, González C, Piñero A, García G, García C. Web-based telemedicine system is useful for monitoring glucose control in pregnant women with diabetes. Diab Technol Therap. 2015;17(5):349–54.
77. Caballero-Ruiz E, García-Sáez G, Rigla M, Villaplana M, Pons B, Hernando ME. A web-based clinical decision support system for gestational diabetes: Automatic diet prescription and detection of insulin needs. Int J Med Informatics. 2017;102:35–49.
78. Sung JH, Min KP, Park CY. Peripartum management of gestational diabetes using a digital health care service: a pilot, randomized controlled study. Clin Ther. 2019;41(11):2426–34.
79. Alqudah A, McMullan P, Todd A, O'Doherty C, McVey A, McConnell M, O'Donoghue J, Gallagher J, Watson CJ, McClements L. Service evaluation of diabetes management during pregnancy in a regional maternity hospital: potential scope for increased self-management and remote patient monitoring through mHealth solutions. BMC Health Serv Res. 2019;19(1):1–6.
80. Kozica-Olenski SL, Soldatos G, Marlow L, Cooray SD, Boyle JA. Exploring the acceptability and experience of receiving diabetes and pregnancy care via telehealth during the COVID-19 pandemic: a qualitative study. BMC Pregnancy Childbirth. 2022;22(1):932.
81. Mackillop L, Hirst JE, Bartlett KJ, Birks JS, Clifton L, Farmer AJ, Gibson O, Kenworthy Y, Levy JC, Loerup L, Rivero-Arias O. Comparing the efficacy of a mobile phone-based blood glucose management system with standard clinic care in women with gestational diabetes: randomized controlled trial. JMIR Mhealth Uhealth. 2018;6(3): e9512.
82. Miremberg H, Ben-Ari T, Betzer T, Raphaeli H, Gasnier R, Barda G, Bar J, Weiner E. The impact of a daily smartphone-based feedback system among women with gestational diabetes on compliance, glycemic control, satisfaction, and pregnancy outcome: a randomized controlled trial. Am J Obstet Gynecol. 2018;218(4):453-e1.
83. Rasekaba TM, Furler J, Young D, Liew D, Gray K, Blackberry I, Lim WK. Using technology to support care in gestational diabetes mellitus: Quantitative outcomes of an exploratory randomized control trial of adjunct telemedicine for gestational diabetes mellitus (TeleGDM). Diabetes Res Clin Pract. 2018;142:276–85.
84. Al-Ofi EA, Mosli HH, Ghamri KA, Ghazali SM. Management of postprandial hyperglycemia and weight gain in women with gestational diabetes mellitus using a novel telemonitoring system. J Int Med Res. 2019;47(2):754–64.
85. Smith R, Gould R, Kenworthy Y, Astbury N, Smith I, Birks J, Bateman P, Hirst J, Jebb S, Michalopoulou M. A feasibility study using motivational interviewing and a smartphone application to promote physical activity (+Stay-Active) for women with gestational diabetes. BMC Pregnancy Childbirth. 2024;24:360.
86. Montori S, Lugli F, Monesi M, Scutiero G, Forini E, Greco P, Verteramo R. Telemedicine in the treatment of gestational diabetes: An observational cohort study on pregnancy outcomes and maternal satisfaction. J. 2024. https://doi.org/10.1111/dme.15201.
87. Duan B, Zhou Z, Liu M, Liu Z, Zhang Q, Liu L, Liu W. Development and acceptability of a gestational diabetes mellitus prevention system (Better pregnancy) based on a user-centered approach: A clinical feasibility study. Digit Health. 2024;10:20552076241266056.
88. De Jersey S, De S, Keramat S, Chang A, Meloncelli N, Guthrie T, Eakin E, Comans T. A cost-effectiveness evaluation of a dietitian-delivered telephone coaching program during pregnancy for preventing gestational diabetes mellitus. Cost Effectiveness and Resource Allocation. 2024;22:18.

89. Gugliucci A, Many A, Cichocka E, Gumprecht J. The impact of telemedicine during the COVID-19 pandemic on diabetes management and pregnancy outcomes in women with gestational diabetes mellitus (GDM). J Clin Med. 2024;13:5797.
90. Butten K, Laurie JG, Varnfield M, Wilkinson SA. Gestational diabetes mellitus care re-imagined: women's experiences of a major model of care change at a large metropolitan hospital. Practical Diabetes. 2024;41(2):22–8.
91. Laurie J, Wilkinson S, Griffin A, Mcintyre H. GDM care re-imagined: Maternal and neonatal outcomes following a major model of care change for gestational diabetes mellitus at a large metropolitan hospital. Aust N Z J Obstet Gynaecol. 2023;63:681–8. https://doi.org/10.1111/ajo.13691.
92. van Heerden A, Kolozali Ş, Norris SA. Feasibility and acceptability of continuous at-home glucose monitoring during pregnancy: a mixed-methods pilot study. South African Journal of Clinical Nutrition. 2023;36(3):100–7.
93. Lakshminarayanan M, Kathuria N, Mehra S. Delivery of perinatal mental health services by training lay counselors using digital platforms. Asian J Psychiatr. 2020;54: 102277.
94. Derya YA, Altiparmak S, Emine AK, GÖkbulut N, Yilmaz AN. Pregnancy and birth planning during COVID-19: The effects of tele-education offered to pregnant women on prenatal distress and pregnancy-related anxiety. Midwifery. 2021;92:102877.
95. Bhat A, Mao J, Unützer J, Reed S, Unger J. Text messaging to support a perinatal collaborative care model for depression: a multimethod inquiry. Gen Hosp Psychiatry. 2018;52:14–20.
96. Bogale B, Mørkrid K, Abbas E, Abu Ward I, Anaya F, Ghanem B, Hijaz T, Isbeih M, Issawi S, AS Nazzal ZE, Qaddomi S. The effect of a digital targeted client communication intervention on pregnant women's worries and satisfaction with antenatal care in Palestine–A cluster randomized controlled trial. Plos one. 2021;16(4):e0249713.
97. Brusniak K, Arndt HM, Feisst M, Haßdenteufel K, Matthies LM, Deutsch TM, Hudalla H, Abele H, Wallwiener M, Wallwiener S. Challenges in acceptance and compliance in digital health assessments during pregnancy: prospective cohort study. JMIR Mhealth Uhealth. 2020;8(10): e17377.
98. Highet N, Gamble J, Creedy D. Perinatal mental health and psychosocial risk screening in a community maternal and child health setting: evaluation of a digital platform. Primary Health Care Research & Development. 2019;20: e58.
99. Hantsoo L, Criniti S, Khan A, Moseley M, Kincler N, Faherty LJ, Epperson CN, Bennett IM. A mobile application for monitoring and management of depressed mood in a vulnerable pregnant population. Psychiatr Serv. 2018;69(1):104–7.
100. Ronen K, Gewali A, Dachelet K, White E, Jean-Baptiste M, Evans YN, Bhat A. Acceptability and Utility of a Digital Group Intervention to Prevent Perinatal Depression in Youths via Interactive Maternal Group for Information and Emotional Support (IMAGINE): Pilot Cohort Study. JMIR Form Res. 2024;8(1):e0249713.
101. Zhang X, Li Y, Wang J, Mao F, Wu L, Huang Y, Sun J, Cao F. Effectiveness of Digital Guided Self-help Mindfulness Training During Pregnancy on Maternal Psychological Distress and Infant Neuropsychological Development: Randomized Controlled Trial. J Med Internet Res. 2023;25: e41298. https://doi.org/10.2196/41298.
102. Sood E, Nees S, Srivastava S, Ng S, Torres C, Osorio A, Canter K, Braley K, Spradley L, Stein J. Virtually-delivered psychosocial intervention for prenatally diagnosed congenital heart disease: Feasibility and acceptability of HEARTPrep. Pediatr Cardiol. 2023;44(7):1479–86. https://doi.org/10.1007/s00246-023-03209-7.
103. Kalmbach DA, Cheng P, Reffi AN, Ong JC, Swanson LM, Fresco DM, Walch O, Seymour GM, Fellman-Couture C, Bayoneto AD, Roth T, Drake CL. Perinatal Understanding of Mindful Awareness for Sleep (PUMAS): A single-arm proof-of-concept clinical trial of a mindfulness-based intervention for DSM-5 insomnia disorder during pregnancy. Sleep Med. 2023;108:79–89. https://doi.org/10.1016/j.sleep.2023.05.026.
104. Hassdenteufel K, Müller M, Abele H, Brucker S, Graf J, Zipfel S, Bauer A, Jakubowski P, Pauluschke-Fröhlich J, Wallwiener M. Using an electronic mindfulness-based intervention (eMBI) to improve maternal mental health during pregnancy: Results from a randomized controlled trial. Psychiatry Res. 2023;330: 115599. https://doi.org/10.1016/j.psychres.2023.115599.
105. Fatori D, Zuccolo P, Xavier MO, Matijasevich A, Polanczyk GV. Smartphone-assisted online brief cognitive behavioral therapy to treat maternal depression: findings of a randomized controlled trial. Brazilian Journal of Psychiatry. 2023;45(1):50–3.
106. Fatemi A, Nasiri-Amiri F, Faramarzi M, Chehrazi M, Adib H, Pahlavan Z. Comparing the effectiveness of virtual and semi-attendance Stress Inoculation Training techniques in improving the symptoms of anxiety, depression, and stress of pregnant women with psychological distress: A multicenter randomized controlled trial. BMC Pregnancy Childbirth. 2023;23:346. https://doi.org/10.1186/s12884-023-05856-5.
107. Danaher BG, Seeley JR, Silver RK, Tyler MS, Kim JJ, La Porte LM, Cleveland E, Smith DR, Milgrom J, Gau JM. Trial of a patient-directed eHealth program to ameliorate perinatal depression: the MomMoodBooster2 practical effectiveness study. Am J Obstet Gynecol. 2023;228(4):453.e1–3.e10. https://doi.org/10.1016/j.ajog.2022.09.027.
108. Buultjens M, Gill J, Fielding J, Lambert K, Vondeling K, Mastwyk S, Sloane S, Fedele W, Karimi L, Milgrom J. Maternity care during a pandemic: Can a hybrid telehealth model comprising group interdisciplinary education support maternal psychological health? Women and Birth. 2023;36:305–13.
109. Balsam D, Bounds D, Amir M, Rahmani A, Nyamathi A. Evaluating the impact of an app-delivered mindfulness meditation program to reduce stress and anxiety during pregnancy: Pilot longitudinal study. JMIR Pediatrics and Parenting. 2023;6: e53933. https://doi.org/10.2196/53933.
110. Hinton L, Tucker KL, Greenfield SM, Hodgkinson JA, Mackillop L, McCourt C, McManus RJ. Blood pressure self-monitoring in pregnancy (BuMP) feasibility study; a qualitative analysis of women's experiences of self-monitoring. BMC Preg Childbirth. 2017;17:1–9.
111. Lanssens D, Vandenberk T, Smeets CJ, De Cannière H, Molenberghs G, Van Moerbeke A, Gyselaers W. Remote monitoring of hypertension diseases in pregnancy: a pilot study. JMIR mHealth and uHealth. 2017;5(3):e6552.
112. Musyoka FM, Thiga MM, Muketha GM. A 24-hour ambulatory blood pressure monitoring system for preeclampsia management in antenatal care. Informatics in Medicine Unlocked. 2019;16: 100199.
113. Lanssess D, Vonck S, Storms V, Thijs IM, Grieten L, Gyselaers W. The impact of a remote monitoring program on the prenatal follow-up of women with gestational hypertensive disorders. Eur J Obst Gynecol Repr Biol. 2018;223:72–8.
114. Van den Heuvel JF, Lely AT, Huisman JJ, Trappenburg JC, Franx A, Bekker MN. SAFE@ HOME: Digital health platform facilitating a new care path for women at increased risk of preeclampsia–A case-control study. Pregnancy Hypertension. 2020;22:30–6.
115. Van den Heuvel JF, Kariman SS, van Solinge WW, Franx A, Lely AT, Bekker MN. SAFE@ HOME–Feasibility study of a telemonitoring platform combining blood pressure and preeclampsia symptoms in pregnancy care. European Journal of Obstetrics & Gynecology and Reproductive Biology. 2019;240:226–31.
116. Zhang Y, Lin YY, Lal L, Swint JM, Tucker T, Ivory DM, Zhang Y, Chandra S, Collier C. Feasibility of remote blood pressure monitoring for detection and management of maternal hypertension in a predominantly black, rural and medicaid population in Mississippi. Telemedicine journal and e-health : the official journal of the American Telemedicine Association. 2024;30(7):e2096–102. https://doi.org/10.1089/tmj.2023.0426.
117. Jones R, Allison H, Moody H, Peng C, Eswaran H. Use of cellular-enabled remote patient monitoring device for hypertension management in pregnant women: A feasibility study. Matern Child Health J. 2023;27:1191–8. https://doi.org/10.1007/s10995-023-03456-7.
118. Charifson M, Wen T, Zell B, Vaidya P, Rios CI, Fagbohun CF, Fulcher I. Impact of remote blood pressure monitoring device connectivity on engagement among pregnant individuals enrolled in the Delfina care platform: Observational study. JMIR mHealth and uHealth. 2024;12:e55617. https://doi.org/10.2196/55617.
119. Abroms LC, Johnson PR, Heminger CL, Van Alstyne JM, Leavitt LE, Schindler-Ruwisch JM, Bushar JA. Quit4baby: results from a pilot test of a mobile smoking cessation program for pregnant women. JMIR Mhealth Uhealth. 2015;3(1):e3846.

120. Naughton F, Cooper S, Foster K, Emery J, Leonardi-Bee J, Sutton S, Coleman T. Large multi-centre pilot randomized controlled trial testing a low-cost, tailored, self-help smoking cessation text message intervention for pregnant smokers (MiQuit). Addict. 2017;112(7):1238–49.
121. King E, Cheyne H, Abhyankar P, Elders A, Grindle M, Hapca A, Jones C, O'Carroll R, Steele M, Williams B. Promoting smoking cessation during pregnancy: A feasibility and pilot trial of a digital storytelling intervention delivered via text-messaging. Patient Educ Couns. 2022;105(7):2562–72.
122. Van Dijk W, Oosterman M, de Vente W, Jansen I, Blankers M, Huizink AC. Smoking cessation in pregnant women: A randomized controlled trial investigating the effectiveness of an eHealth intervention including heart rate variability-biofeedback training. Addict Behav. 2024;154: 108005.
123. Pollak KI, Alexander SC, Bennett G, Lyna P, Coffman CJ, Bilheimer A, Østbye T. Weight-related SMS texts promoting appropriate pregnancy weight gain: a pilot study. Patient Educ Counsel. 2014;97(2):256–60.
124. Soltani H, Duxbury AM, Arden MA, Dearden A, Furness PJ, Garland C. Maternal obesity management using mobile technology: a feasibility study to evaluate a text messaging-based complex intervention during pregnancy. Journal of obesity. 2015;2015(1): 814830.
125. Chao AM, Srinivas SK, Studt SK, Diewald LK, Sarwer DB, Allison KC. A pilot randomized controlled trial of a technology-based approach for preventing excess weight gain during pregnancy among women with overweight. Front Nutr. 2017;4:57.
126. Graham ML, Strawderman MS, Demment M, Olson CM. Does usage of an eHealth intervention reduce the risk of excessive gestational weight gain? Secondary analysis from a randomized controlled trial. J Med Internet Res. 2017;19(1):e6.
127. Olson CM, Strawderman MS, Graham ML. Association between consistent weight gain tracking and gestational weight gain: Secondary analysis of a randomized trial. Obesity. 2017;25(7):1217–27.
128. Redman LM, Gilmore LA, Breaux J, Thomas DM, Elkind-Hirsch K, Stewart T, Martin CK. Effectiveness of SmartMoms, a novel ehealth intervention for management of gestational weight gain: randomized controlled pilot trial. JMIR mHealth and uHealth. 2017;5(9):e8228.
129. Willcox JC, Wilkinson SA, Lappas M, Ball K, Crawford D, McCarthy EA, Campbell KJ. A mobile health intervention promoting healthy gestational weight gain for women entering pregnancy at a high body mass index: the txt4two pilot randomised controlled trial. Int J Obst Gynaecol. 2017;124(11):1718–28.
130. Ferrara A, Hedderson MM, Brown SD, Ehrlich SF, Tsai AL, Feng J, Galarce M, Marcovina S, Catalano P, Quesenberry CP. A telehealth lifestyle intervention to reduce excess gestational weight gain in pregnant women with overweight or obesity (GLOW): a randomized, parallel-group, controlled trial. Lancet Diabetes Endocrinol. 2020;8(6):490–500.
131. Van Horn L, Peaceman A, Kwasny M, Vincent E, Fought A, Josefson J, Spring B, Neff LM, Gernhofer N. Dietary approaches to stop hypertension diet and activity to limit gestational weight: maternal offspring metabolics family intervention trial, a technology enhanced randomised trial. Am J Prev Med. 2018;55(5):603–14.
132. Henriksson P, Migueles JH, Söderström E, Sandborg J, Maddison R, Löf M. User engagement in relation to effectiveness of a digital lifestyle intervention (the HealthyMoms app) in pregnancy. Sci Rep. 2022;12(1):13793.
133. Wang L, Zou L, Yi H, Li T, Zhou R, Yang J, Wang J, Zhang C, Guo H. The implementation of online and offline hybrid weight management approach for pregnant women based on the Fogg behavior model in Hainan, China: A pilot randomized controlled trial. BMC Pregnancy Childbirth. 2024;24:516. https://doi.org/10.1186/s12884-024-06316-5.
134. Téoule J, Woll C, Ray J, Sütterlin M, Filsinger B. The effectiveness of integrated online health-coaching on physical activity and excessive gestational weight gain: a prospective randomized-controlled trial. Arch Gynecol Obstet. 2024;310:307–14.
135. Venkateswaran M, Ghanem B, Abbas E, Khader KA, Ward IA, Awwad T, Baniode M, Frost MJ, Hijaz T, Isbeih M, Mørkrid K. A digital health registry with clinical decision support for improving quality of antenatal care in Palestine (eRegQual): a pragmatic, cluster-randomized, controlled, superiority trial. The Lancet Digital Health. 2022;4(2):e126-36.
136. Palmer KR, Tanner M, Davies-Tuck M, Rindt A, Papacostas K, Giles ML, Brown K, Diamandis H, Fradkin R, Stewart AE, Rolnik DL. Widespread implementation of a low-cost telehealth service in the delivery of antenatal care during the COVID-19 pandemic: an interrupted time-series analysis. The Lancet. 2021;398(10294):41–52.
137. Escobar MF, Echavarria MP, Vasquez H, Nasner D, Ramos I, Hincapié MA, Pabon S, Kusanovic JP, Martínez-Ruíz DM, Carvajal JA. Experience of a telehealth and education program with maternal and perinatal outcomes in a low-resource region in Colombia. BMC Pregnancy Childbirth. 2022;22(1):1–9.
138. Gupta A, Agrawal R, Gupta A, Guleri R, Bajpayee D, Joshi N, Sarin E, Gupta S, Kumar H. Systems E-approach for women at risk (SEWA)—A digital health solution for detection of high-risk pregnancies. Journal of Family Medicine and Primary Care. 2021;10(10):3712.
139. Valencia SA, Barrientos Gómez J, Gómez Ramirez MC, Luna F, Andrade Caicedo H, Torres-Silva E, Sánchez Díaz E. Evaluation of a telehealth program for high-risk pregnancy in a health service provider institution. Int J Med Informatics. 2023;179: 105234. https://doi.org/10.1016/j.ijmi.2023.105234.
140. Rayford M, Morris J, Phinehas R, Schneider E, Lund A, Baxley S, Wan J, Goedecke P, Levi-D'ancona R. Telehealth utilization in high-risk pregnancies during COVID-19. Telemedicine Reports. 2023;4(1):61–3. https://doi.org/10.1089/tmr.2023.0006.
141. Okonofua F, Ntoimo L, Johnson E, Sombie I, Ojuolape S, Igboin B, Imongan W, Ekwo C, Udenigwe O, Yaya S. Texting for life: A mobile phone application to connect pregnant women with emergency transport and obstetric care in rural Nigeria. BMC Pregnancy Childbirth. 2023;23:139. https://doi.org/10.1186/s12884-023-05899-3.
142. Nagraj S, Kennedy S, Jha V, Norton R, Hinton L, Billot L, Rajan E, Abdul A, Phalswal A, Arora V. A mobile clinical decision support system for high-risk pregnant women in rural India (SMARThealth Pregnancy): Pilot cluster randomized controlled trial. JMIR Formative Research. 2023;7: e44362.
143. Bekker M, Koster M, Keusters W, Ganzevoort W, De Haan-Jebbink J, Deurloo K, Seeber L, Van Den Heuvel F, Zuithoff P. Home telemonitoring versus hospital care in complicated pregnancies in the Netherlands: A randomised, controlled non-inferiority trial (HoTeL). The Lancet Digital Health. 2023;5:e120–4.
144. Oliveira-Ciabati L, Vieira CS, Franzon ACA, Alves D, Zaratini FS, Braga GC, Sanchez JAC, Bonifácio LP, Andrade MS, Fernandes M, Quintana SM, Fabio SV, Pileggi VN, Vieira EM, Souza JP. PRENACEL–a mHealth messaging system to complement antenatal care: a cluster randomized trial. Reproduc Health. 2017;14:1–12.
145. Silva RM, Brasil CC, Bezerra IC, Queiroz FF. Mobile health technology for gestational care: evaluation of the GestAção's App. Rev Bras Enferm. 2019;72:266–73.
146. Rebecca Johnson BA, DClinPsy C. Evaluation of an online antenatal course Understanding pregnancy, labour, birth and your baby by the Solihull Approach. Evidence-Based Midwifery. 2018;16(3):101–106.
147. Basu S, Rajeev A, Garg S, Singh MM. Effect of a text-messaging intervention on oral self-care practices in antenatal women in Delhi, India: A pilot randomized control trial. Indian Journal of Community Medicine: Official Publication of Indian Association of Preventive & Social Medicine. 2022;47(1):133.
148. Masoi TJ, Kibusi SM. Improving pregnant women's knowledge on danger signs and birth preparedness practices using an interactive mobile messaging alert system in Dodoma region, Tanzania: a controlled quasi-experimental study. Reprod Health. 2019;16:1–10.
149. Fathy Mohammed A, Mahmoud MH. Effect of Mobile Assisted Education Regarding Fetal Kick Monitoring on Perinatal Outcomes among High-Risk Pregnant Women during COVID-19 Pandemic. Egyptian Journal of Health Care. 2022;13(1):1868–87.
150. Ochieng' S, Hariharan N, Abuya T, Okondo C, Ndwiga C, Warren C, Wickramanayake A, Rajasekharan S. Exploring the implementation of an SMS-based digital health tool on maternal and infant health in informal settlements. BMC Pregnancy Childbirth. 2024;24:222. https://doi.org/10.1186/s12884-024-06373-7.
151. Ahlers-Schmidt C, Hervey A. COVID-19 impact on group prenatal education: A comparison of virtual and in-person formats. J Perinat Educ. 2023;32(3):135–8.
152. Adam M, Kwinda Z, Dronavalli M, Leonard E, Nguy VK, Tshivhase V, Bärnighausen MT, Pillay Y. Effect of short, animated video storytelling on maternal knowledge and satisfaction in the perinatal period in South Africa: Randomized controlled trial. J Med Internet Res. 2023;25: e47266.

153. Stockwell MS, Cano M, Jakob K, Broder KR, Gyamfi-Bannerman C, Castaño PM, LaRussa PS. Feasibility of text message influenza vaccine safety monitoring during pregnancy. Am J Prev Med. 2017;53(3):282–9.
154. Kaufman J, Attwell K, Tuckerman J, O'Sullivan J, Omer SB, Leask J, Regan A, Marshall H, Lee KJ, Snelling T, Perrett K. Feasibility and acceptability of the multi-component P3-MumBubVax antenatal intervention to promote maternal and childhood vaccination: a pilot study. Vaccine. 2020;38(24):4024–31.
155. Zielinska AP, Mullins E, Lees C. The feasibility of multimodality remote monitoring of maternal physiology during pregnancy. Medicine. 2022;101(26):E29566. https://doi.org/10.1097/MD.0000000000029566.
156. Long MC, Angtuaco T, Lowery C. Ultrasound in telemedicine: its impact in high-risk obstetric health care delivery. Ultrasound Q. 2014;30(3):167–72.
157. Jemal K, Ayana D, Tadesse F, Adefris M, Awol M, Tesema M, Dagne B, Abeje S, Bantie A, Butler M, Nwoke C, Kanyuka Z, Adams SJ, Mendez I. Implementation and evaluation of a pilot antenatal ultrasound imaging programme using tele-ultrasound in Ethiopia. J Telemed Telecare. 2022;30(6):1005–16. https://doi.org/10.1177/1357633X221115746.
158. Sassi K, Tardif E, Lasry L, Manenc L, Guerby P, Minville V. Assessing feasibility and satisfaction in third-trimester pre-anaesthetic teleconsultations: A prospective observational study. Indian J Anaesth. 2024;68(2):183–8. https://doi.org/10.4103/ija.ija72123.
159. Sharma S, Smitha M, Balakrishnan D. Telephonic intervention to combat non-adherence to oral iron-folic acid supplementation in pregnancy: A randomized controlled trial. European Journal of Obstetrics Gynecology and Reproductive Biology: X. 2023;20: 100235.
160. Arifah I, Sekar T, Pambarep A, Khoiriyah L, Anitasari T, Kusumaningrum I, Werdani K, Ngadiyono N. Effectiveness of daily educational message on pregnancy anemia prevention behavior and knowledge: A pilot randomized controlled trial. Journal of Education and Health Promotion. 2023;12:296. https://doi.org/10.4103/jehp.jehp10823.
161. Coleman J, Bohlin KC, Thorson A, Black V, Mechael P, Mangxaba J, Eriksen J. Effectiveness of an SMS-based maternal mHealth intervention to improve clinical outcomes of HIV-positive pregnant women. AIDS Care. 2017;29(7):890–7.
162. Choi J, Lee JH, Vittinghoff E, Fukuoka Y. mHealth physical activity intervention: a randomized pilot study in physically inactive pregnant women. Matern Child Health J. 2016;20:1091–101.
163. van der Wulp NY, Hoving C, Eijmael K, Candel MJ, van Dalen W, De Vries H. Reducing alcohol use during pregnancy via health counseling by midwives and internet-based computer-tailored feedback: a cluster randomized trial. J Med Internet Res. 2014;16(12): e274.
164. Moulaei K, Sheikhtaheri A, Fatehi F, Shanbehzadeh M, Bahaadinbeigy K. Patients' perspectives and preferences toward telemedicine versus in-person visits: a mixed-methods study on 1226 patients. BMC Med Inform Decis Mak. 2023;23(1):261.
165. Crook RL, Iftikhar H, Moore S, Lowdon P, Modarres P, Message S. A comparison of in-person versus telephone consultations for outpatient hospital care. Future Healthcare Journal. 2022;9(2):154–60.
166. Li, Z. (2024). The Impact and Benefits of Digital Health Management Systems on Chronic Disease Management. In BIO Web of Conferences (Vol. 111, p. 03005). EDP Sciences.
167. Rastogi R. Digital Health: A Paradigm Shift in Healthcare Management. 2023.
168. Dave P. How Digital Health is Revolutionizing Healthcare and Contributing to Positive Health Outcomes. Journal of Drug Delivery and Therapeutics. 2024;14(6):287–93.
169. Braun M, Schmidt O, Schultz T, Woehrle H, Sundrup MG, Schöbel C. Experiences with digital care of patients with chronic and acute lung diseases during the SARS-CoV-2 pandemic. Der Internist. 2022;63(3):255–65.
170. Zaresani A, Scott A. Does digital health technology improve physicians' job satisfaction and work–life balance? A cross-sectional national survey and regression analysis using an instrumental variable. BMJ Open. 2020;10(12): e041690.
171. Wannheden C, Stenfors T, Stenling A, von Thiele Schwarz U. Satisfied or frustrated? A qualitative analysis of need satisfying and need frustrating experiences of engaging with digital health technology in chronic care. Front Public Health. 2021;8: 623773.
172. Herrmann, S., Giesel-Gerstmeier, J., Demuth, A., & Fenske, D. (2024). We Ask and Listen: A Group-Wide Retrospective Survey on Satisfaction with Digital Medication Software. Journal of Multidisciplinary Healthcare, 923–936.
173. Kitsios F, Stefanakakis S, Kamariotou M, Dermentzoglou L. Digital Service Platform and Innovation in Healthcare: Measuring Users' Satisfaction and Implications. Electronics. 2023;12(3):662.

Publisher's Note