Mobile Health (mHealth) Interventions for Improving Antenatal Care Adherence Among High-Risk Pregnant Women

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Abstract

Antenatal care (ANC) adherence remains a critical determinant of maternal and perinatal outcomes, particularly among women with high-risk pregnancies complicated by hypertensive disorders, gestational diabetes mellitus (GDM), adolescent age, anemia, or prior obstetric complications. Mobile health (mHealth)—the use of mobile and wireless technologies to support healthcare delivery—has emerged as a scalable strategy to improve ANC attendance, self-monitoring, and clinical follow-up in both high- and low-resource settings. This review synthesizes randomized controlled trial (RCT) and systematic review evidence on mHealth interventions for ANC adherence among high-risk pregnant women, spanning short message service (SMS) reminder programs, smartphone applications for gestational diabetes self-management, remote blood pressure monitoring for hypertensive disorders of pregnancy, and mobile clinical decision-support tools for community health workers. Pooled evidence from low- and middle-income countries indicates that SMS-based reminders modestly but significantly increase attendance at four or more ANC visits, skilled birth attendance, and postnatal care uptake, while trials of app-based self-management in gestational diabetes report high engagement and favorable glycemic and neonatal outcomes. Remote blood pressure monitoring appears feasible, safe, and capable of reducing in-

person visit burden and racial disparities in postpartum follow-up, although long-term maternal outcome data remain limited. Across intervention types, effectiveness is shaped by message tailoring, bidirectionality, health worker integration, and digital literacy, while implementation is constrained by infrastructure gaps, cost, data privacy concerns, and sustainability challenges. This review concludes with recommendations for the design, evaluation, and scale-up of future mHealth-based ANC adherence trials, emphasizing standardized adherence metrics, equity-focused recruitment, and integration with existing health information systems.

Keywords: mHealth; antenatal care; high-risk pregnancy; adherence; randomized controlled trial; gestational diabetes; hypertensive disorders of pregnancy; SMS reminders; remote monitoring; maternal health

1. Introduction

1.1 The Global Burden of Maternal Morbidity and the Role of Antenatal Care

Despite a 40% decline in the global maternal mortality ratio between 2000 and 2023—from 328 to 197 deaths per 100,000 live births—maternal mortality remains unacceptably high, with an estimated 260,000 women dying annually from largely preventable causes related to pregnancy and childbirth [1,2]. Ninety-four percent of these deaths occur in low- and lower-middle-income countries, and sub-Saharan Africa and Southern Asia together account for approximately 87% of the global burden [3]. The lifetime risk of maternal death in low-income countries (1 in 66) remains roughly 120-fold higher than in high-income countries (1 in approximately 8,000) [1]. Antenatal care is one of the most consistently recommended platforms for reducing this burden: it enables early detection of complications such as hypertensive disorders, gestational diabetes, anemia, and fetal growth restriction, and provides an entry point for immunization, nutritional supplementation, and birth preparedness counseling. The World Health Organization (WHO) recommends a minimum of eight antenatal contacts to reduce perinatal mortality and improve the overall pregnancy experience, yet as of the most recent global estimates, only about half of pregnant women worldwide receive the recommended minimum number of visits [4]. Modeling work using the Lives Saved Tool suggests that scaling up coverage of key maternal health interventions, including ANC-linked services, to 95% by 2030 could substantially reduce maternal deaths across 126 low- and middle-

income countries (LMICs), though current rates of scale-up remain insufficient to meet Sustainable Development Goal targets [5].

1.2 High-Risk Pregnancy: Definitions and Clinical Significance

"High-risk pregnancy" is a clinical and epidemiological designation applied to pregnancies in which the mother, fetus, or both face an elevated probability of adverse outcomes relative to the general obstetric population. Commonly recognized high-risk categories include hypertensive disorders of pregnancy (chronic hypertension, gestational hypertension, and preeclampsia), gestational and pre-existing diabetes mellitus, adolescent pregnancy, advanced maternal age, multiple gestation, prior adverse obstetric history, chronic kidney disease, autoimmune disease, and severe anemia [15,16,25]. These conditions typically require more frequent monitoring, additional laboratory and ultrasound surveillance, and closer coordination between primary antenatal providers and specialist services than is required in low-risk pregnancy. Because high-risk pregnancies demand a denser schedule of contact with the health system, adherence to recommended visit schedules, self-monitoring regimens (e.g., home blood glucose or blood pressure measurement), and medication or insulin regimens becomes both more clinically consequential and more logistically burdensome for the pregnant woman. It is precisely this combination—higher clinical stakes and higher adherence burden—that has made high-risk pregnancy a natural target population for mHealth-based adherence-support interventions.

1.3 The Rise of Mobile Health as a Maternal Health Intervention

Mobile health, a subset of eHealth, is defined by the WHO as "the use of mobile wireless technologies for public health" [6]. In April 2019, the WHO released its first evidence-based guideline on digital health interventions, explicitly identifying reminders sent to pregnant women to encourage ANC attendance and child immunization return visits as one of the digital interventions already demonstrating positive effects in some contexts [6,7]. The rapid global expansion of mobile phone ownership—including in rural and low-resource settings historically underserved by fixed health infrastructure—has positioned mHealth as an attractive strategy for extending the reach of antenatal and high-risk pregnancy care beyond the walls of the clinic. mHealth interventions relevant to ANC adherence span a spectrum of technical complexity: from simple one-way SMS reminders, to bidirectional

tailored text messaging with behavior-change content, to smartphone applications supporting self-monitoring of glucose or blood pressure, to Bluetooth-enabled remote physiological monitoring platforms, to mobile clinical decision-support tools used by community health workers (CHWs) rather than by pregnant women directly [6,8,15,18,25].

1.4 Rationale and Objectives of This Review

Although numerous individual trials and several systematic reviews have examined discrete mHealth modalities in isolation—SMS reminders in one review, remote blood pressure monitoring in another, gestational diabetes apps in a third—there remains a need for a review that draws these strands together specifically through the lens of ANC adherence among high-risk pregnant women, a population whose adherence needs and clinical stakes differ meaningfully from the low-risk obstetric population typically studied in broader maternal mHealth literature. This review aims to: (1) synthesize RCT and systematic review evidence on mHealth interventions targeting ANC adherence, self-monitoring adherence, and related clinical outcomes among high-risk pregnant women; (2) characterize the theoretical frameworks underpinning intervention design; (3) compare effectiveness and engagement across intervention modalities; (4) identify barriers and facilitators to implementation, with attention to equity and the digital divide; and (5) propose design considerations for future trials in this field.

2. Review Approach

This is a narrative review structured to synthesize the available randomized controlled trial and systematic review literature on mHealth interventions for antenatal care adherence among high-risk pregnant women. Literature was identified through targeted searches of the peer-reviewed and gray literature (including PubMed/MEDLINE-indexed sources, JMIR family journals, Cochrane-affiliated reviews, and WHO/UN agency reports), focusing on studies published through 2026 that reported RCT, pilot RCT, or systematic review/meta-analysis findings on SMS reminders, smartphone applications, remote physiological monitoring, or mobile clinical decision-support tools used in the context of antenatal care, gestational diabetes, or hypertensive disorders of pregnancy. Because the evidence base spans heterogeneous populations (adolescents, women with GDM, women with hypertensive disorders, general antenatal populations in LMICs), study designs, and outcome definitions, a narrative rather

than a quantitative meta-analytic synthesis was chosen, supplemented by tabulated comparison of key trials. This approach mirrors that used in prior overviews of maternal digital health interventions and allows for integration of both quantitative effect estimates reported in existing meta-analyses and qualitative/process findings from individual trials [10,11,15,27].

3. Conceptual and Theoretical Foundations

3.1 Defining Antenatal Care Adherence in the mHealth Context

Within the mHealth literature, "adherence" is used somewhat inconsistently across three related but distinct constructs: (1) health-service adherence, meaning attendance at the recommended number and timing of antenatal visits (frequently operationalized as "ANC4+," or four or more visits, and increasingly as adherence to the WHO's eight-contact model) [4,10]; (2) self-management adherence, meaning consistent engagement in prescribed self-monitoring or self-care behaviors such as home blood glucose testing, home blood pressure measurement, or insulin administration [21,24]; and (3) intervention engagement, meaning the extent to which participants interact with the mHealth tool itself (e.g., responding to two-way SMS messages, opening app modules, syncing a Bluetooth device) [8,20]. A recurring theme across the reviewed trials is that intervention engagement is often used as a proxy for, or moderator of, the other two adherence constructs—for example, the Teen MomConnect trial in South Africa distinguished "high responders" (those replying to ≥ 50% of messages) from low responders when analyzing appointment attendance and knowledge outcomes [8].

3.2 Behavior Change Theories Underpinning mHealth Design

The design of adherence-focused mHealth interventions is frequently informed by established health behavior change theory. The Health Belief Model (HBM) proposes that health behavior is shaped by perceived susceptibility to illness, perceived severity, perceived benefits of action, and perceived barriers to action, with self-efficacy and external "cues to action" (such as an SMS reminder) added in later refinements of the model [36,37]. mHealth reminders operationalize the "cue to action" construct directly, while tailored educational content addresses perceived susceptibility and severity. The Capability, Opportunity, Motivation–Behaviour (COM-B) model and its associated Behaviour Change Wheel framework, developed by Michie and colleagues,

offer a complementary and increasingly popular structure for mHealth intervention design: capability (physical and psychological capacity to perform the behavior), opportunity (physical and social environment enabling the behavior), and motivation (reflective and automatic processes driving the behavior) are each targeted by specific intervention functions such as education, training, environmental restructuring, persuasion, and enablement [35,59,61]. The Teen MomConnect intervention, for example, combined tailored SMS content (targeting capability via knowledge and motivation via risk-perception messaging) with a face-to-face motivational interviewing session (targeting motivation and self-efficacy directly) [8,9]. Similarly, app-based GDM interventions such as the GDM-DH app in Nepal and the SPARK program in Sweden incorporate feedback engines and goal-tracking dashboards explicitly designed to strengthen self-efficacy and behavioral self-regulation, both central COM-B and social-cognitive constructs [18,20].

4. Typology of mHealth Interventions for High-Risk Antenatal Care

4.1 SMS and Text-Message Reminders

The most extensively studied mHealth modality in the maternal health literature remains SMS-based reminders, ranging from simple unidirectional appointment reminders to more elaborate bidirectional, tailored messaging programs. In LMIC settings, several systematic reviews and meta-analyses of RCTs have quantified the effect of SMS reminders on ANC utilization. A 2024 systematic review and meta-analysis pooling evidence on SMS interventions in low- and middle-income countries reported that SMS reminders significantly increased ANC4+ attendance (relative risk [RR] 1.34, 95% CI 1.12–1.60), skilled birth attendance (RR 1.18, 95% CI 1.05–1.33), and postnatal care visit uptake (RR 1.51, 95% CI 1.34–1.71), although substantial heterogeneity was observed across included studies (I^2 ranging from 78% to 96%) [10]. An earlier systematic review and meta-analysis of RCTs focusing specifically on focused ANC visits and skilled birth attendance similarly concluded that SMS reminders exerted a consistently positive effect on both outcomes across LMIC settings [11,15]. A separate meta-analysis reported pooled odds ratios of 1.89 (95% CI 1.49–2.19) for four-or-more ANC visits, 1.63 (95% CI 1.17–2.27) for tetanus toxoid immunization, 1.88 (95% CI 1.18–3.00) for iron supplementation compliance, and 2.54 (95% CI 2.15–2.99) for postnatal care attendance among women receiving mHealth interventions relative to

controls [14]. Outside the maternal health field, a broader systematic review of SMS reminders across health conditions reported a pooled odds ratio of 1.62 (95% CI 1.35–1.94) for appointment attendance across randomized trials, reinforcing that the reminder mechanism generalizes beyond obstetric care [12,13].

Not all SMS-based trials, however, have demonstrated significant effects, particularly when applied to more vulnerable or harder-to-reach subgroups. The Teen MomConnect pilot RCT, which tested a tailored, bidirectional SMS intervention supplemented by a motivational interviewing session among pregnant adolescents and young women in Cape Town, South Africa, found that overall ANC appointment attendance did not differ significantly between intervention and control arms, although knowledge scores improved significantly more among "high-responder" intervention participants than among controls (mean increase 2.1 vs. 0.7 points; $\beta = 1.50$, $P = .045$) [8,9]. The authors attributed the null primary finding partly to low engagement with the two-way messaging component, concluding that more intensive—or more deeply tailored—engagement strategies may be required to influence appointment adherence among adolescent populations specifically [8].

4.2 Smartphone Applications for Self-Monitoring and Self-Management (Gestational Diabetes)

Gestational diabetes mellitus (GDM) has become one of the most active areas of mHealth trial activity in obstetrics, reflecting both the rising global prevalence of GDM and the intensive, daily self-management burden the condition imposes (glucose monitoring, dietary tracking, physical activity, and in some cases insulin administration). Several RCTs and RCT protocols illustrate the range of app-based approaches. The eMOM trial in Finland tested a periodic mobile application incorporating continuous glucose monitoring, an activity tracker, and a food diary used one week per month, without additional human coaching, among women with diet-controlled GDM; daily app-use adherence exceeded 90%, and higher usage correlated with lower fasting and postprandial glucose, lower gestational weight gain, and reduced macrosomia at delivery, with no significant increase in adverse pregnancy complications [21]. The SPARK trial in Sweden, a multicenter two-arm RCT randomizing 412 women with GDM to standard care or a multilingual smartphone app (building on the previously validated HealthyMoms platform), aims to evaluate whether app-supported self-management improves glycemic control and reduces adverse maternal and offspring outcomes [20]. In Nepal, the GDM-DH app protocol describes

a user-centered design and exploratory RCT phase in which self-monitoring adherence, app usability, and glycemic control at six weeks postpartum are the primary feasibility outcomes—the first such LMIC-based GDM app trial identified in this review [18]. The MY GODDESS study in Malaysia similarly tested a feasibility RCT of a mobile app aimed at reducing subsequent risk of type 2 diabetes among women with GDM [19]. Beyond glycemic self-monitoring, the SPAROW trial in Singapore and the TRIANGLE trial in a European cohort both tested app-based behavioral interventions targeting postpartum weight retention and broader lifestyle risk behaviors following a GDM diagnosis, given the well-documented poor compliance with telephone- and face-to-face postpartum weight-management interventions in this population [22,23]. Finally, a randomized trial of a clinical pharmacist-led smartphone application among women with GDM receiving multiple daily insulin injections found significant improvements in medication adherence (measured using the five-item Medication Adherence Report Scale) and insulin injection technique relative to usual care [24].

4.3 Remote Physiological Monitoring: Blood Pressure Surveillance in Hypertensive Disorders of Pregnancy

Hypertensive disorders of pregnancy—including chronic hypertension, gestational hypertension, and preeclampsia—represent a second major focus of high-risk pregnancy mHealth trials, primarily through remote blood pressure monitoring (RBPM) using Bluetooth-enabled, validated home blood pressure devices that transmit readings to clinical teams. A randomized controlled trial comparing remote blood pressure monitoring with office-based monitoring among women at high risk of preeclampsia found that replacing clinic-based surveillance with remote monitoring did not increase adverse outcomes, while reducing the number of in-person contacts and increasing antihypertensive medication uptake, supporting the feasibility and safety of RBPM within structured antenatal pathways [25]. In the postpartum period—a time when hypertensive disorders of pregnancy contribute disproportionately to preventable maternal morbidity and when in-person follow-up attendance is often poor—a multisite RCT comparing remote monitoring through a web-enabled smartphone platform against in-office blood pressure checks found that remote monitoring eliminated a previously observed racial disparity in postpartum blood pressure ascertainment between Black and White patients, in addition to improving overall follow-up rates [26]. A systematic review and meta-analysis of RBPM in women at risk of or diagnosed with hypertensive

disorders of pregnancy, encompassing 18 studies and more than 28,000 patients, found that antenatal RBPM reduced antenatal outpatient visits and hospital admissions (both all-cause and hypertension-specific), and that postpartum RBPM increased the likelihood of blood pressure ascertainment or professional follow-up within ten days of delivery (odds ratio 5.60, 95% CI 1.52–20.69) relative to conventional clinic-based monitoring, although the authors noted substantial study heterogeneity and a continued paucity of high-quality maternal and fetal outcome data [29,30]. The REMOTE CONTROL trial, a pragmatic unblinded RCT, was designed specifically to compare RBPM against face-to-face clinic monitoring in high-risk pregnant women in a 1:1 allocation, reflecting the ongoing need for adequately powered trials with clinical—not merely process—outcomes [31].

4.4 Mobile Clinical Decision Support for Community Health Workers

A distinct but complementary mHealth modality targets not the pregnant woman directly, but the community health worker (CHW) or frontline provider who delivers her antenatal care, particularly in rural low-resource settings where CHWs—such as Auxiliary Nurse Midwives (ANMs) and Accredited Social Health Activists (ASHAs) in India—provide the majority of antenatal and postnatal contact. The SMARThealth Pregnancy program, a pilot cluster RCT conducted in rural India, developed a mobile clinical decision-support tool to help CHWs screen, refer, and counsel pregnant and postpartum women at elevated risk of future cardiovascular disease due to hypertensive disorders of pregnancy or gestational diabetes [15,16]. The trial achieved high fidelity to intervention protocols (100% prior to the COVID-19 pandemic), minimal loss to follow-up (2% at six weeks postpartum), and preliminary evidence of improved anemia detection and management, alongside qualitative reports of improved CHW self-efficacy and professional recognition [15]. Because more than half the study population in this trial was affected by moderate-to-severe anemia at baseline, the SMARThealth Pregnancy model illustrates how mHealth-supported task-sharing with CHWs can extend high-risk pregnancy screening and follow-up capacity in settings where specialist obstetric services are scarce [15,16].

4.5 Tailored Interventions for Vulnerable Subgroups

Adolescent pregnancy constitutes a distinct high-risk category due to elevated rates of pregnancy-related complications and characteristically lower rates of antenatal engagement relative to adult pregnant women [8,9].

The Teen MomConnect intervention, adapted from South Africa's national MomConnect mHealth program, represents one of the few RCTs to specifically tailor mHealth content and delivery for pregnant adolescents and young women, combining SMS-based behavior change content with in-person motivational interviewing [9]. Although appointment attendance did not differ significantly between arms, participants who engaged more frequently with intervention messaging demonstrated significantly higher knowledge about the risks of ANC non-attendance and the importance of healthy pregnancy behaviors than lower-engagement participants and controls, echoing findings from other bidirectional-messaging interventions targeting adolescents and young women's sexual and reproductive health knowledge in LMIC settings [8].

5. Synthesis of Randomized Controlled Trial Evidence

Table 1 summarizes representative RCTs and pooled meta-analytic findings discussed in this review, organized by intervention modality, target population, and primary adherence-related outcome.

Table 1. Representative mHealth Trials and Pooled Evidence for Antenatal Care Adherence in High-Risk Pregnancy

Study / Program	Setting & Population	mHealth Modality	Primary Adherence Outcome	Key Finding
Teen MomConnect [8,9]	South Africa; pregnant adolescents 13–20 yrs	Tailored 2-way SMS + motivational interviewing session	ANC appointment attendance	No significant difference vs. control; knowledge gains among high responders
SMS reminder pooled evidence [10–14]	Multiple LMICs; general antenatal population	Unidirectional/bidirectional SMS reminders, some with calls	ANC4+, skilled birth attendance, PNC visits	RR 1.34 (ANC4+), RR 1.18 (SBA), RR 1.51 (PNC); pooled OR 1.6–1.9 across reviews
SMARThealth Pregnancy [15,16]	Rural India; high cardiometabolic-risk pregnant/postpartum women	Mobile clinical decision-support app for community health workers	Screening/referral completion; hemoglobin follow-up	High fidelity (100% pre-pandemic); feasible, acceptable; signal of improved anemia detection/management
SPARK / GDM-DH / MY GODDESS [18–20]	Sweden, Nepal, Malaysia; women with gestational diabetes	Self-monitoring & lifestyle apps with feedback engines	Self-monitoring adherence, glycemic control	Protocols/early trials show high feasibility; larger trials ongoing
eMOM [21]	Finland; diet-controlled GDM	App with continuous glucose monitor & activity tracker, no human coaching	Daily self-tracking adherence (>90%)	Lower fasting/postprandial glucose, less weight gain, less macrosomia
Pharmacist-led app for insulin adherence [24]	Women with GDM on multiple daily insulin injections	Smartphone app with pharmacist-led education/reminders	Medication adherence (MARS-5), injection technique	Improved adherence and injection technique vs. usual care
Remote BP monitoring RCTs [25–29]	UK, US, Australia; high risk of / with hypertensive disorders of pregnancy	Bluetooth-enabled home BP devices with remote transmission	BP ascertainment frequency, clinic visit reduction, antihypertensive uptake	Comparable safety to office-based care; fewer visits; reduced racial

				disparity in postpartum follow-up

Several cross-cutting patterns emerge from this synthesis. First, effect sizes for service-utilization outcomes (ANC visit frequency, skilled birth attendance, postnatal care) in LMIC SMS-reminder trials are generally modest-to-moderate (relative risks and odds ratios in the range of approximately 1.2 to 1.9) but consistently favor the intervention arm across multiple independent meta-analyses, even though individual trial heterogeneity is often high [10–14]. Second, trials targeting self-management adherence in high-income or upper-middle-income settings—particularly GDM glucose self-monitoring and hypertensive disorder blood pressure self-monitoring—tend to report very high engagement (often exceeding 90% daily use) when the technology is well-integrated into existing clinical workflows and paired with automated feedback, even in the absence of ongoing human coaching [21,25,26]. Third, interventions targeting the most vulnerable populations, such as pregnant adolescents, appear to face the greatest engagement challenges and the least consistent evidence of improved appointment adherence, suggesting that reminder-based or bidirectional-messaging strategies alone may be insufficient without more intensive behavioral or social support components [8]. Fourth, CHW-facing mobile decision-support tools appear to achieve very high fidelity and retention, likely reflecting the professional (rather than personal-health-behavior) nature of the target behavior, though rigorous clinical outcome data from adequately powered trials remain limited [15,16].

6. Outcome Domains Assessed Across Trials

6.1 Health Service Utilization Outcomes

The most frequently reported outcome across LMIC-focused trials is attendance at four or more ANC visits (ANC4+), followed by skilled birth attendance and postnatal care visit completion [10–14]. These outcomes are typically extracted from facility records or self-report and are the primary metrics used in the largest pooled meta-analyses of SMS-based reminder interventions.

6.2 Clinical and Biomarker Outcomes

In GDM and hypertensive disorder trials, clinical outcomes take precedence over simple attendance metrics: fasting and postprandial plasma glucose, gestational weight gain, macrosomia, blood pressure control, antihypertensive medication uptake, and composite perinatal outcomes (perinatal death, placental abruption, superimposed preeclampsia with severe features, and indicated preterm birth) are commonly used as primary or secondary endpoints [20,21,25,29]. These biomarker-driven outcomes offer a more direct link between mHealth-supported adherence and downstream maternal-fetal health than service-utilization metrics alone, though they typically require larger sample sizes and longer follow-up to detect meaningful between-arm differences.

6.3 Psychosocial and Knowledge Outcomes

Several trials, particularly those targeting adolescents, also assess psychosocial determinants of adherence behavior—knowledge, attitudes, social support, risk perception, self-efficacy, intention, and action planning—recognizing that these constructs may mediate or precede changes in actual attendance or self-management behavior [8,9]. The Teen MomConnect trial's finding of significant knowledge gains in the absence of significant attendance change illustrates the importance of measuring these intermediate outcomes, both to interpret null primary findings and to inform iterative intervention refinement [8].

6.4 Engagement with the Intervention Itself

Because mHealth interventions can only influence downstream adherence to the extent that participants actually use them, engagement metrics—message response rates, app login frequency, device-sync frequency, and self-monitoring log completeness—are increasingly reported as both feasibility outcomes and moderators of clinical effect [8,18,20,21]. High engagement (e.g., eMOM's >90% daily use) is consistently associated with more favorable downstream outcomes, whereas low engagement (e.g., Teen MomConnect's low two-way messaging response rate) appears to explain several null or attenuated primary findings [8,21].

7. Effect Sizes, Heterogeneity, and Methodological Quality

Pooled effect estimates for SMS-based reminders on ANC and related outcomes are generally in a favorable but modest range and are accompanied by substantial statistical heterogeneity (I^2 values of 78–96% across pooled analyses), reflecting variation in message content, frequency, bidirectionality, population risk profile, baseline ANC coverage, and co-interventions (e.g., accompanying phone calls or home visits) [10]. Risk-of-bias assessment in these reviews, typically conducted using JBI critical appraisal tools or the Cochrane Risk of Bias 2 tool, has generally found low-to-moderate overall study quality, with common concerns including inadequate allocation concealment, lack of blinding (largely unavoidable given the nature of the intervention), and reliance on self-reported or facility-recorded attendance data subject to recall or documentation bias [10,11,30]. In the remote blood pressure monitoring literature, a formal meta-analysis using the ROBINS-I tool for non-randomized studies and RoB2 for randomized studies similarly identified considerable heterogeneity across 18 included studies and emphasized the paucity of adequately powered trials with hard clinical endpoints, as opposed to process measures such as visit frequency [30]. Many of the trials identified in this review—including SPARK, the GDM-DH app trial in Nepal, and the REMOTE CONTROL trial—are ongoing or recently initiated, meaning that the current evidence base for several high-risk pregnancy mHealth modalities is still weighted toward feasibility and pilot-stage findings rather than definitive, adequately powered efficacy trials [18,20,31].

8. Equity Considerations and the Digital Divide

A central and recurring theme across the reviewed literature is the tension between mHealth's promise of extending care to underserved populations and its risk of reproducing or even widening existing health inequities. Empirical reviews of mHealth adoption in LMICs consistently identify a “digital divide” shaped by inequitable device ownership, connectivity, affordability, and digital literacy, which systematically disadvantages rural populations, women, older individuals, and socioeconomically marginalized groups—with the paradoxical consequence that mHealth tools often reach populations already well-connected to health systems while excluding those with the greatest unmet need [50,52]. At the same time, the remote blood pressure monitoring literature offers a striking counter-example of mHealth's equity-enhancing potential: a US-based multisite RCT

found that remote postpartum blood pressure monitoring eliminated a pre-existing racial disparity in blood pressure ascertainment between Black and White patients, a population in which hypertensive disorders of pregnancy and their complications are disproportionately concentrated [26]. This apparent contradiction underscores that equity outcomes in mHealth are not intrinsic to the technology itself but are contingent on deliberate design choices—language and literacy-appropriate content, device provision or subsidy for low-income participants, and workflow integration that removes rather than adds barriers to access [26,50,52].

9. Barriers and Facilitators to Implementation and Scale-Up

9.1 Infrastructure and Connectivity

Reviews of digital health implementation in LMICs consistently identify limited network coverage, unreliable internet connectivity, and unstable electricity supply as critical structural constraints, particularly in rural settings where high-risk pregnancy CHW-facing tools such as SMARThealth Pregnancy are often deployed [50]. These infrastructural gaps can compromise both the reliability of two-way SMS delivery and the feasibility of Bluetooth- or app-based remote monitoring platforms that depend on periodic data synchronization.

9.2 Digital and Health Literacy

Even where connectivity and device access are adequate, low digital literacy and low health literacy can limit the ability of pregnant women—particularly adolescents, first-time smartphone users, and those with limited formal education—to interpret tailored health content, navigate app interfaces, or correctly perform self-monitoring tasks such as home blood pressure measurement [27,50,52]. Co-design approaches involving target users in intervention development have been proposed as a strategy to mitigate this barrier, particularly in culturally and linguistically diverse LMIC settings [52].

9.3 Privacy, Data Security, and Trust

Data privacy and security concerns—particularly salient for sensitive reproductive health information, and acutely so for adolescent populations—represent a further barrier to sustained engagement and trust in mHealth

platforms, with several implementation reviews explicitly identifying data security and privacy governance as unresolved challenges across LMIC digital health deployments [51,53,54].

9.4 Health System Integration and Policy Environment

The WHO's 2019 digital health guideline emphasizes that digital interventions are most effective when embedded within, rather than parallel to, existing health system structures, and cautions against the proliferation of short-lived, poorly evaluated pilot projects that fail to achieve integration with routine service delivery [6,7,40]. Reviews of mHealth sustainability in sub-Saharan Africa and South Asia similarly identify government and institutional support, alignment with national health information systems, and clear policy and financing frameworks as key facilitators of scale-up beyond the pilot stage, while fragmented funding, unclear data-governance policy, and weak inter-agency coordination are recurrent barriers [51,55].

9.5 Sustainability and Financing

A persistent critique across the digital maternal health literature is that many mHealth pilots—including several of the high-risk pregnancy trials reviewed here—have not yet progressed beyond feasibility or exploratory-RCT stages, reflecting broader challenges in securing sustained financing and institutional ownership once initial research grants conclude [18,20,55]. Scoping reviews of mHealth for non-communicable disease management in LMICs note that projects frequently remain “stuck at the pilot stage,” limiting the accumulation of longer-term effectiveness, cost-effectiveness, and implementation data necessary to justify national scale-up [55].

10. Policy Context: WHO Guidance and Global Health Strategy

The WHO's 2019 Guideline: Recommendations on Digital Interventions for Health System Strengthening remains the most authoritative global policy reference for mHealth interventions relevant to antenatal and maternal health, offering nine evidence-based recommendations spanning targeted client communication for behavior change across sexual, reproductive, maternal, newborn, child, and adolescent health; health worker decision support; digital tracking of client health status; and digital provision of training to health workers via mobile devices [6,36]. Notably, the guideline explicitly recognizes SMS-based ANC and immunization reminders

as one of the digital interventions already demonstrating positive effects in some contexts, while emphasizing that recommendations were graded according to the certainty of the evidence, and that implementation should attend to acceptability, feasibility, resource use, and equity [6,7]. This global guidance provides a framework within which the trial-level evidence synthesized in this review—spanning SMS reminders, GDM self-management apps, remote blood pressure monitoring, and CHW decision-support tools—can be situated for policymakers considering national or regional scale-up of mHealth-supported antenatal care for high-risk pregnancy.

11. Methodological Gaps and Limitations in the Current Evidence Base

Several methodological gaps limit the strength of conclusions that can currently be drawn from the high-risk pregnancy mHealth literature. First, definitions of "adherence" vary considerably across trials—some measuring facility-recorded visit counts, others self-reported attendance, others app-log engagement metrics, and others biomarker-based proxies of self-management behavior—limiting comparability and precluding a single quantitative meta-analysis across the full range of high-risk pregnancy mHealth trials [8,10,21]. Second, many of the most clinically detailed trials (in GDM self-management and remote blood pressure monitoring) remain in protocol, pilot, or feasibility stages, with definitive, adequately powered efficacy data on hard maternal and neonatal outcomes still pending [18,20,29,31]. Third, most rigorously conducted SMS-reminder trials originate from LMIC public-health-utilization contexts, whereas most app-based self-management and remote-monitoring trials for GDM and hypertensive disorders originate from high-income or upper-middle-income settings, creating an uneven evidence base in which the highest-risk, lowest-resource populations are studied predominantly with the least technically sophisticated interventions [10,20,25]. Fourth, long-term and postpartum follow-up—particularly regarding sustained blood pressure control, glycemic normalization, and subsequent pregnancy or cardiometabolic outcomes—remains sparse across most trial designs, despite the recognized long-term cardiovascular risk conferred by hypertensive disorders of pregnancy and GDM [15,16,29]. Finally, cost-effectiveness data, essential for government and donor decision-making on scale-up, are reported in only a minority of the trials and reviews identified in this synthesis [51,55].

12. Implications for the Design of Future Randomized Controlled Trials

Building on the gaps identified above, several design recommendations emerge for future mHealth RCTs targeting ANC adherence in high-risk pregnancy. First, trials should adopt standardized, pre-specified adherence definitions—ideally combining an objective service-utilization measure (e.g., number and timing of ANC contacts against the WHO eight-contact schedule) with an intervention-engagement measure (message response rate, app-use frequency, or device-sync frequency)—to permit more direct cross-trial comparison and future meta-analysis [4,8,10]. Second, given the demonstrated engagement challenges among adolescents and other highly vulnerable subgroups, trial designs for these populations should consider more intensive, multi-component strategies (e.g., combining tailored messaging with in-person or community-based motivational support) rather than relying on messaging alone, and should be adequately powered to detect effects within these specific subgroups rather than only in aggregate samples [8,9]. Third, trials of remote physiological monitoring (blood pressure, glucose) should prioritize hard clinical and neonatal outcomes—rather than process outcomes alone—as primary endpoints, and should include sufficiently long postpartum follow-up to capture downstream cardiometabolic risk, consistent with the established links between hypertensive disorders of pregnancy, GDM, and later cardiovascular disease [15,16,29]. Fourth, equity should be built into trial design from the outset, including recruitment strategies that intentionally reach digitally underserved populations, provision of devices or connectivity subsidies where needed, and pre-specified subgroup analyses by race, socioeconomic status, and rurality, following the model demonstrated in the postpartum remote blood pressure monitoring trial that found reduced racial disparity in follow-up [26]. Fifth, future trials should incorporate embedded cost-effectiveness and implementation-science endpoints (fidelity, reach, adoption, and maintenance) to generate the evidence base needed for sustainable financing and health-system integration, addressing the persistent “pilot-stage stagnation” documented in the broader mHealth implementation literature [51,55]. Finally, given the consistent finding that engagement (not mere access) drives outcomes across intervention types, future trials should incorporate iterative, user-centered co-design phases—involving pregnant women, community health workers, and health system stakeholders—prior to full-scale RCT deployment, as modeled in several of the LMIC-based app development protocols reviewed here [18,52].

13. Conclusion

Mobile health interventions represent a promising, increasingly evidence-supported strategy for improving antenatal care adherence among high-risk pregnant women, spanning simple SMS reminders in resource-limited settings to sophisticated app-based self-management platforms and remote physiological monitoring systems for gestational diabetes and hypertensive disorders of pregnancy. Pooled evidence indicates modest but consistent benefits of SMS-based reminders on ANC visit frequency, skilled birth attendance, and postnatal care uptake in LMIC settings, while emerging trial evidence supports high engagement and favorable clinical outcomes for app-based glucose and blood pressure self-monitoring, and demonstrates that remote monitoring can, in some contexts, reduce rather than exacerbate health disparities. At the same time, interventions targeting the most vulnerable subgroups—adolescents in particular—have shown more limited effects on appointment attendance, and much of the evidence base for the most clinically sophisticated interventions remains at the pilot or protocol stage. Realizing the full potential of mHealth to improve outcomes in high-risk pregnancy will require standardized adherence metrics, equity-centered design and evaluation, deeper integration with health system infrastructure and policy consistent with WHO digital health guidance, and a sustained pipeline of adequately powered trials measuring hard clinical, neonatal, and long-term cardiometabolic outcomes rather than process measures alone.

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