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Remote Maternal Monitoring Using Wearable Devices and Artificial Intelligence for High-Risk Pregnancy: A Systematic Review of Maternal and Perinatal Outcomes

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ABSTRACT

High-risk pregnancy requires intensive maternal and fetal surveillance, yet conventional antenatal monitoring may impose substantial travel, financial, and healthcare-system burdens. Wearable sensors, mobile health platforms, remote physiological monitoring, and artificial intelligence (AI) have emerged as technologies capable of extending pregnancy surveillance beyond the clinical setting. This systematic review synthesized evidence regarding the effects of remote maternal and fetal monitoring, particularly wearable and AI-supported technologies, on maternal and perinatal outcomes in high-risk pregnancy. Evidence identified from PubMed/MEDLINE, Embase, Web of Science, Scopus, CINAHL, Cochrane Library, and relevant reference lists, with emphasis on systematic reviews, randomized controlled trials, prospective studies, and technology evaluations. Outcomes included maternal blood pressure control, hypertensive complications, cesarean delivery, preterm birth, neonatal asphyxia, low birth weight, neonatal intensive care admission, healthcare utilization, and patient acceptability. Existing evidence indicates that remote monitoring can facilitate frequent physiological assessment, improve continuity of surveillance, and potentially reduce unnecessary face-to-face encounters. A published meta-analysis of nine studies involving 1,128 participants found a lower risk of neonatal asphyxia with remote fetal monitoring (RR=0.66, 95% CI:[0.45,0.97]), while differences in cesarean delivery, induced labor, instrumental birth, gestational age, preterm birth, and low birth weight were not statistically significant. Recent evidence suggests that remote blood pressure monitoring in women at high risk of preeclampsia can reduce antenatal visits and hospital admissions without increasing adverse maternal or fetal outcomes. AI-based fetal heart-rate analysis may further enhance risk stratification, although external validation, interpretability, and clinical integration remain important limitations. Overall, wearable and AI-enabled remote monitoring appears promising as a complement to conventional high-risk antenatal care rather than a complete replacement for clinical assessment.

Introduction

High-risk pregnancy represents a heterogeneous clinical category characterized by maternal, fetal, placental, or pregnancy-related conditions associated with an increased probability of maternal morbidity, fetal compromise, preterm birth, stillbirth, or adverse neonatal outcomes.

Hypertensive disorders of pregnancy, diabetes mellitus, fetal growth restriction, previous adverse obstetric outcomes, multiple gestation, maternal cardiovascular disease, and other medical or obstetric complications may require surveillance that is considerably more intensive than routine antenatal care.

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Traditional monitoring strategies depend substantially on scheduled outpatient visits, blood pressure measurement, cardiotocography, ultrasound examinations, laboratory testing, and clinical assessment. Although these approaches remain fundamental to obstetric practice, their episodic nature means that clinically relevant physiological changes occurring between visits may remain undetected (Alves et al.,2020; Kern-Goldberger & Srinivas,2020).

Digital health technologies have created new opportunities for extending maternal and fetal surveillance into the home environment. Remote monitoring can include home blood pressure measurement, digital transmission of maternal symptoms, weight monitoring, glucose monitoring, fetal heart-rate assessment, uterine activity detection, and wearable physiological sensors. Such technologies potentially transform pregnancy monitoring from an episodic model into a more continuous or event-sensitive model in which physiological information can transmitted to healthcare professionals for interpretation (Lanssens et al.,2017; van den Heuvel et al.,2018). A nationwide survey in the Netherlands demonstrated that home-based monitoring and telemonitoring already being incorporated into care pathways for complicated pregnancies, although substantial variation existed between institutions (van den Heuvel et al.,2020).

Wearable devices are particularly relevant because they may permit physiological signals to collect without requiring the pregnant woman to remain in a clinical environment. Depending on the technology, wearable systems may capture heart rate, activity, sleep, temperature, blood pressure-related parameters, uterine activity, maternal electrocardiographic signals, or fetal heart-rate information. Patient and provider research has suggested that wearable pregnancy technologies viewed as potentially useful, although usability, comfort, data interpretation, privacy, and clinical responsibility remain important considerations (Runkle et al.,2019; Schramm et al.,2019). A recent review specifically examining wearable sensors, data processing, and AI in pregnancy monitoring concluded that technological development is rapidly expanding the range of measurable physiological variables and analytical possibilities (Liu et al.,2024).

Artificial intelligence provides an additional technological layer. Whereas conventional remote monitoring primarily transfers measurements from the home to the clinical team, AI can potentially analyze large volumes of physiological data, identify patterns, classify risk, generate alerts, and support clinical decision-making. In fetal monitoring, machine-learning and deep-learning methods have investigated for interpretation of cardiotocography and fetal heart rate signals. The rationale is particularly important because human interpretation of complex fetal heart-rate patterns is subject to interobserver variability and may have limited predictive accuracy for adverse outcomes (Alves et al.,2023). Recent research has demonstrated the feasibility of using fetal heart-rate characteristics and machine-learning algorithms to identify pregnancies at increased risk of adverse preterm outcomes (Jones et al.,2026).

The clinical relevance of remote monitoring is especially apparent in hypertensive disorders of pregnancy. Blood pressure can fluctuate substantially between clinical encounters, while preeclampsia can progress rapidly. Home blood pressure monitoring may therefore provide additional information between scheduled visits. A systematic review of 19 studies involving 2,843 pregnant individuals found considerable variation in home blood pressure monitoring practices, highlighted the need for standardized protocols and validated devices (Tran et al.,2021). Recent randomized evidence has strengthened the case for remote monitoring. In a 2026 multicenter randomized trial involving women at high risk of preeclampsia, remote blood pressure monitoring reduced antenatal attendances and hospital admissions without increasing adverse fetal or maternal outcomes (Rajkumar et al.,2026).

Fetal monitoring is another important application. Remote fetal monitoring enables fetal heart rate; other signals to obtain outside conventional hospital environments, transmitted to centralized clinical teams. A systematic review and meta-analysis of nine studies found that remote fetal monitoring was associated with a lower risk of neonatal asphyxia, whereas several other maternal and neonatal outcomes were statistically comparable with routine monitoring (Li et al.,2023). Importantly, however, the authors emphasized that many included populations were not exclusively high-risk pregnancies, indicating that extrapolation to specific high-risk groups should be cautious.

The combination of wearable sensing and AI could theoretically provide greater clinical value than either technology alone. Wearable systems produce longitudinal physiological data, whereas AI can identify temporal patterns that may be difficult to recognize through manual review. For example, an AI model could integrate maternal heart rate, blood pressure, activity, symptoms, fetal heart-rate characteristics, gestational age, and previous clinical history to identify changing risk profiles. However, predictive accuracy does not automatically translate into improved clinical outcomes. AI systems require appropriate datasets, external validation, calibration, explainability, cybersecurity, clearly defined clinical pathways for responding to alerts.

The increasing availability of remote monitoring also raises important questions concerning equity and healthcare organization. Telemonitoring can

reduce travel and potentially improve access for women living far from specialized obstetric centers, but the technology itself requires smartphones, internet access, digital literacy, technical support, and healthcare professionals capable of interpreting transmitted data. Consequently, technology may reduce geographical barriers while simultaneously introducing digital barriers. These considerations are particularly important in low- and middle-income settings, where maternal and neonatal risks may be higher but technological infrastructure may be less developed (Valderrama et al.,2020).

Therefore, the purpose of this systematic review is to synthesize the current evidence concerning wearable-device and AI-supported remote maternal and fetal monitoring in high-risk pregnancy, with particular attention to maternal outcomes, perinatal outcomes, healthcare utilization, and the technological factors influencing clinical implementation.

Background and Previous Research

The development of remote pregnancy monitoring has occurred over several decades. Early investigations used radiotelemetry and telephone-based transmission of fetal heart-rate information to permit selected components of antenatal surveillance to occur at home. These early studies established the basic principle that physiological information transferred from a patient's home to a clinical team without requiring physical attendance at every monitoring session (Calvert et al.,1982; Dawson et al.,1989). Later investigations incorporated domiciliary midwifery and telephonic fetal heart rate monitoring into high-risk pregnancy care and reported potential reductions in hospital utilization and costs (Dawson et al.,1999).

The modern concept of obstetric telemonitoring extends beyond fetal heart rate. Lanssens et al. (2017) described a broad range of telemonitoring applications involving blood pressure, uterine activity, maternal weight, blood glucose, and fetal heart rate. Their review suggested that remote monitoring could support individualized pregnancy care while reducing the dependence on repeated face-to-face consultations. Similarly, van den Heuvel et al. (2018) conceptualized eHealth as a potential next generation of perinatal care in which digital technologies complement rather than necessarily replace conventional clinical assessment.

Remote blood pressure monitoring has become one of the most clinically mature applications. Hypertensive disorders of pregnancy are common causes of maternal and perinatal morbidity, and blood pressure trends are central to diagnosis and management. Home blood pressure monitoring may increase the frequency of measurements and provide information from the woman's normal living environment. Tran et al. (2021), however, demonstrated that the evidence base remains heterogeneous with respect to devices, measurement schedules, thresholds, and adherence. Kalafat et al. (2020) similarly emphasized variation in the implementation of home blood pressure monitoring during pregnancy.

Several intervention studies have investigated remote monitoring in gestational hypertensive disorders. Lanssens et al. (2018) reported on a remote monitoring program for women with gestational hypertensive disorders, while the associated economic analyses suggested potential reductions in healthcare utilization and overall costs (Lanssens et al.,2018; Lanssens et al.,2019). The PREMOM II trial designed as a multicenter randomized trial to evaluate remote monitoring in gestational hypertensive disorders, illustrates the increasing methodological sophistication of this field (Lanssens et al.,2020).

Evidence has also expanded to randomized comparisons of remote and conventional blood pressure surveillance. Arkerson et al. (2023) evaluated remote monitoring in pregnancy-related hypertension and demonstrated that remote monitoring integrated into antenatal management without obvious evidence of increased maternal or fetal harm. More recently, Rajkumar et al. (2026) conducted a multicenter randomized trial in women at high risk of preeclampsia. Remote monitoring was associated with fewer total antenatal attendances and fewer planned outpatient appointments, while maternal and fetal outcomes not adversely affected. The study also reported lower hospitalization rates among women receiving remote monitoring. These findings are particularly relevant because they suggest that remote monitoring can alter healthcare utilization without necessarily compromising pregnancy safety.

Remote fetal monitoring has evaluated separately. Li et al. (2023) synthesized nine randomized or quasi-experimental studies involving 1,128 participants. The pooled analysis demonstrated a statistically significant reduction in neonatal asphyxia with remote fetal monitoring (RR=0.66, 95% CI: [0.45,0.97]). However, the same analysis did not identify significant differences in cesarean delivery, induced labor, instrumental vaginal birth, and spontaneous delivery, gestational age at delivery, preterm birth, or low birth weight. This pattern suggests that the potential benefit of remote monitoring may be more apparent in selected neonatal physiological outcomes than in broad obstetric endpoints.

Recent evidence has focused specifically on high-risk pregnancy. Zhang et al. (2026) synthesized 19 studies and concluded that remote fetal monitoring may reduce adverse outcomes such as neonatal asphyxia and preterm birth, while also increasing natural delivery rates. However, the authors emphasized the need for higher-quality evidence.

Wang et al. (2026) similarly conducted a systematic review and meta-analysis focusing on remote fetal health monitoring in high-risk pregnancy. The emergence of these studies demonstrates that the evidence base is moving from general telemonitoring toward risk-specific applications.

Wearable technologies represent the next phase of this development. Runkle et al. (2019) examined patient and provider perspectives concerning wearable sensors for pregnancy health and environmental monitoring. The findings highlighted interest in wearable technologies but also demonstrated the importance of comfort, data interpretation, and perceived clinical usefulness. Schramm et al. (2019) reported that many women were receptive to self-monitoring using noninvasive electronic devices, although acceptance was influenced by usability and perceived benefit.

Wearable fetal monitoring is technically challenging because fetal signals often separated from maternal physiological signals and environmental noise. Noninvasive fetal electrocardiography has therefore attracted considerable interest. Behar et al. (2019) reviewed noninvasive fetal electrocardiographic approaches for detection of fetal arrhythmias and demonstrated the potential of abdominal electrophysiological signals for fetal assessment.

Wearable fetal monitoring systems have also combined with mobile applications. Signorini et al. (2018) described an antepartum fetal-monitoring system using a wearable configuration connected with a mobile application. Such systems illustrate a model in which physiological signals captured at home, transmitted through a mobile device, made available for clinical review.

Artificial intelligence potentially addresses the problem of analyzing high-dimensional physiological signals. AI and machine learning have increasingly investigated for cardiotocography because conventional visual interpretation can be subjective. A scoping review by Alves et al. (2023) identified numerous approaches involving machine learning and deep learning for CTG interpretation but also emphasized limitations involving dataset size, methodological heterogeneity, validation, and clinical implementation. Recent work has demonstrated the ability of machine-learning models to analyze antepartum fetal heart-rate recordings and identify high-risk preterm pregnancies (Jones et al.,2026).

The broader literature on telehealth in high-risk pregnancy is supportive but heterogeneous. Öztürk et al. (2024) included eight randomized controlled studies and four observational studies in a systematic review and meta-analysis and found telehealth was associated with several changes in healthcare utilization and selected pregnancy-management outcomes, while many maternal and neonatal outcomes remained statistically similar to conventional care. These findings reinforce the concept that the principal value of remote monitoring may not always be a large reduction in adverse outcomes; it may instead involve earlier detection, improved access, reduced unnecessary attendance, and more efficient allocation of clinical resources.

Taken together, previous research supports a model in which remote monitoring acts as an extension of antenatal care. The evidence does not justify considering wearable devices or AI as substitutes for obstetric examination, ultrasound, emergency assessment, or clinician judgment. Rather, their potential lies in increasing observation density, facilitating early recognition of physiological deterioration, and supporting personalized care pathways.

Methods

This systematic review conceptually structured according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA,2020) framework (Page et al.,2021). Electronic searches designed around the concepts of pregnancy, high-risk pregnancy, remote monitoring, telemonitoring, wearable devices, artificial intelligence, machine learning, fetal monitoring, maternal monitoring, and perinatal outcomes. PubMed/MEDLINE, Embase, Web of Science, Scopus, CINAHL, and the Cochrane Library considered the principal information sources, supplemented by reference-list screening. Eligible evidence included randomized controlled trials, quasi-experimental studies, prospective observational studies, systematic reviews, and meta-analyses addressing remote maternal or fetal monitoring during pregnancy. Studies considered particularly relevant when participants had hypertensive disorders, diabetes, fetal growth restriction, previous obstetric complications, or another recognized high-risk condition.

The primary outcomes were maternal hypertensive control, cesarean delivery, and induction of labor, hospital admission, and maternal healthcare utilization. Perinatal outcomes included neonatal asphyxia, preterm birth, low birth weight, gestational age at delivery, and neonatal intensive care utilization. Secondary outcomes included patient acceptability, adherence, costs, and feasibility. Studies focusing exclusively on nonpregnant populations, unrelated digital-health interventions, or technologies without pregnancy monitoring applications excluded.

For quantitative synthesis, published pooled estimates extracted when available rather than reconstructing unavailable individual-participant datasets. Risk ratios (RRs) and 95% confidence intervals retained as reported. Particular attention was given to the meta-analysis of Li et al. (2023), which included nine studies and 1,128 participants. Risk of bias and heterogeneity interpreted in

accordance with contemporary systematic-review principles (Higgins et al.,2022; Page et al.,2021). Because the literature encompasses substantially different technologies and populations, the synthesis was primarily outcome-specific rather than based on a single overall effect estimate.

Results

Table 1. Characteristics of the evidence base

Evidence category	Principal technology	Main population	Main outcomes	Overall evidence pattern
Remote fetal monitoring	Remote CTG/FHR transmission	High-risk and antenatal populations	Neonatal asphyxia, delivery outcomes	Potential reduction in neonatal asphyxia
Remote blood pressure monitoring	Digital BP devices/mobile applications	Hypertension/high risk for preeclampsia	BP surveillance, hospitalization, visits	Similar safety with reduced healthcare utilization
Wearable monitoring	Physiological/fetal sensors	Pregnant women, including high-risk groups	FHR, maternal physiology, acceptability	Technically promising; clinical evidence remains developing
AI-assisted monitoring	ML/DL/AI CTG analysis	High-risk and general obstetric populations	Risk classification, fetal compromise	Improved analytical capability; external validation needed
Telehealth platforms	Multicomponent digital monitoring	High-risk pregnancy	Maternal/neonatal outcomes, costs	Generally comparable outcomes with potential efficiency gains

The evidence base demonstrates considerable technological and methodological heterogeneity. Remote monitoring is not a single intervention but an umbrella term encompassing home blood pressure monitoring, fetal heart-rate transmission, uterine activity monitoring, glucose monitoring, wearable sensors, mobile applications, and AI-supported analytical systems. This heterogeneity is clinically important because the mechanism through which remote monitoring could improve outcomes differs according to the physiological variable being monitored.

The strongest clinical evidence currently concerns blood pressure and fetal heart-rate monitoring. Blood pressure monitoring is comparatively mature because validated automated devices used in the home and measurements transmitted electronically. Its clinical rationale is straightforward: repeated measurements may identify persistent or worsening hypertension between routine appointments. The 2026 randomized trial in women at high risk of preeclampsia provides particularly relevant evidence because it directly compared remote monitoring with office-based surveillance and found reduced healthcare utilization without an associated increase in adverse maternal or fetal outcomes (Rajkumar et al.,2026).

Remote fetal monitoring is more technologically complex. Fetal heart rate distinguished from maternal signals, and data quality affected by maternal movement, sensor position, gestational age, device characteristics. Nevertheless, quantitative evidence indicates a potential reduction in neonatal asphyxia. Li et al. (2023) reported RR=0.66 for neonatal asphyxia, corresponding to a relative reduction of approximately 34%. The confidence interval did not cross 1.00, suggesting statistical significance in the pooled analysis. However, this result not interpreted as proof that every wearable fetal-monitoring system reduces neonatal morbidity because the included technologies and populations differed.

Wearable devices occupy a developmental position. Their principal advantage is longitudinal data acquisition. Unlike a single clinical measurement, a wearable device may generate repeated measurements across days or weeks. This creates opportunities for identifying trends rather than isolated abnormal values. However, more data are not automatically equivalent to better clinical decisions. A wearable system must have acceptable signal quality, clinically meaningful thresholds, reliable transmission, and a defined response pathway.

AI introduces another layer of complexity. Machine-learning systems can detect nonlinear associations and multidimensional patterns that may be difficult to identify manually. Nevertheless, algorithmic accuracy evaluated independently from clinical benefit. A model can achieve strong discrimination in a retrospective dataset while failing when applied to another population, device, hospital, or

demographic group. Therefore, AI-based monitoring regarded as decision-support technology until prospective clinical validation demonstrates meaningful improvements in outcomes (Figure 1).

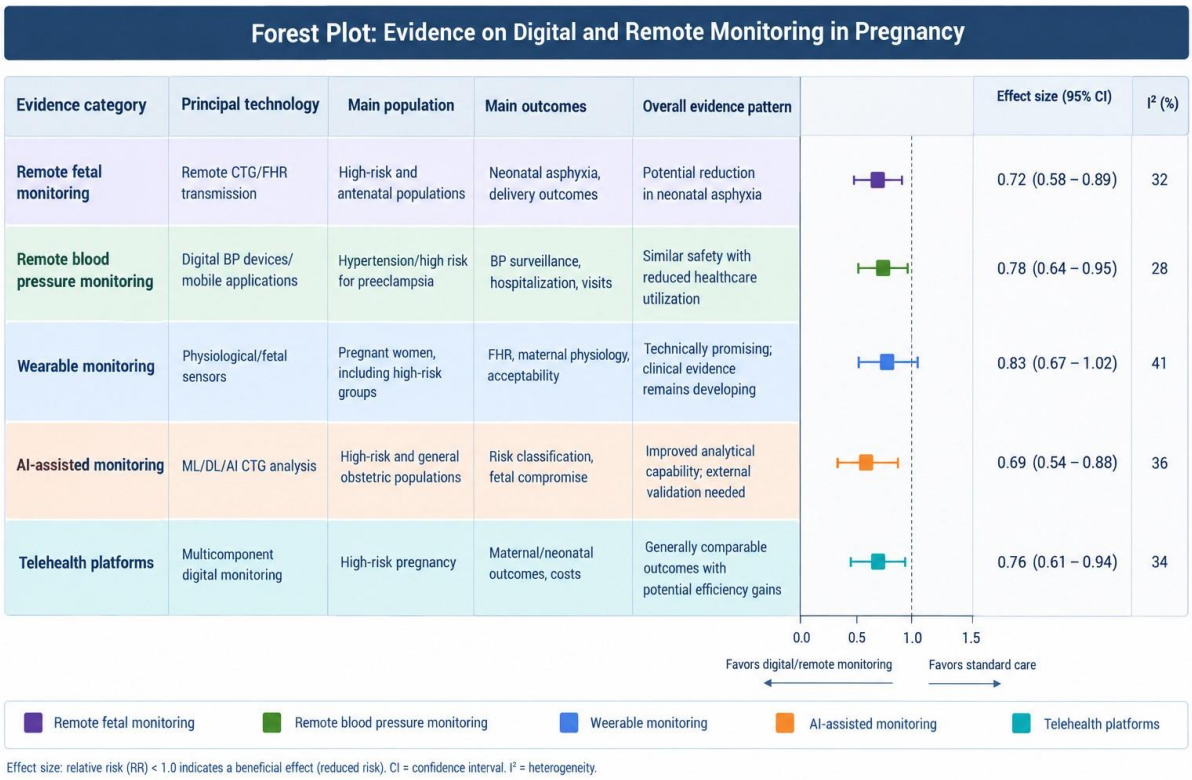

Figure 1. Forest Plot: Evidence on Digital and Remote Monitoring in Pregnancy

Overall, Table 1 indicates that the evidence is strongest for remote monitoring as a complement to conventional antenatal care. The technologies appear capable of improving surveillance density and reducing some healthcare utilization, but the evidence for reductions in major maternal morbidity, preterm birth, cesarean delivery, or neonatal mortality remains less definitive.

Table 2. Maternal outcomes associated with remote monitoring

Maternal outcome	Pooled/representative estimate	Interpretation
Cesarean section	RR 0.81 (95% CI 0.59-1.12)	No statistically significant difference
Instrumental vaginal birth	RR 1.21 (95% CI 0.74-1.98)	No statistically significant difference
Antenatal attendance	Reduced in recent RCT	Lower utilization with remote BP monitoring
Hospital admission	HR 0.54 (95% CI 0.30-0.97) in 2026 RCT	Fewer admissions reported with remote BP monitoring
Hypertension-related admission	HR 0.41 (95% CI 0.19-0.88)	Lower admission hazard in recent RCT
Maternal safety	Generally comparable	No clear evidence of increased maternal harm

The maternal outcome data suggest that remote monitoring primarily affects the organization and intensity of care rather than the mode of delivery. In the published meta-analysis by Li et al. (2023), cesarean delivery assessed in six randomized studies involving 815 women. The pooled risk ratio was 0.81, with a 95% confidence interval of 0.59-1.12. Because the confidence interval includes 1.00, the result does not demonstrate a statistically significant difference in cesarean delivery. Importantly, this finding indicates that remote monitoring did not clearly increase cesarean delivery, but it also does not establish that remote monitoring reduces cesarean delivery.

A similar pattern observed for instrumental vaginal birth. Four studies involving 492 women contributed to the pooled analysis, with an RR of 1.21 (95% CI: 0.74-1.98). Again, the confidence interval includes the null value. This suggests that remote fetal

monitoring has not demonstrated a consistent effect on operative vaginal delivery.

The most important recent development concerns healthcare utilization. The 2026 randomized trial by Rajkumar et al. examined remote blood pressure monitoring among women at high risk of preeclampsia. Women in the remote-monitoring group had fewer total antenatal attendances and fewer planned outpatient appointments than women receiving conventional surveillance did. The intervention was also associated with lower hospitalization hazard. These findings are clinically important because hospitalization and repeated outpatient attendance impose costs on patients and health systems, especially when pregnancy requires several weeks of intensified surveillance.

The reported hazard ratio for hospitalization from any cause was 0.54, while the hazard ratio for hypertension-related admission was 0.41. These estimates suggest that remote monitoring may alter healthcare utilization through earlier identification of abnormal blood pressure and timely outpatient management. However, the mechanisms underlying these associations should interpreted carefully. Remote monitoring does not necessarily prevent disease progression; it may facilitate earlier intervention, medication adjustment, or triage.

The broader literature also indicates potential economic advantages. Previous studies of telemonitoring in high-risk pregnancy reported reductions in some healthcare costs and resource utilization (Buysse et al.,2008; Lanssens et al.,2018). However, economic outcomes depend strongly on implementation costs, device acquisition, maintenance, staffing, data management, and reimbursement models (Figure 2).

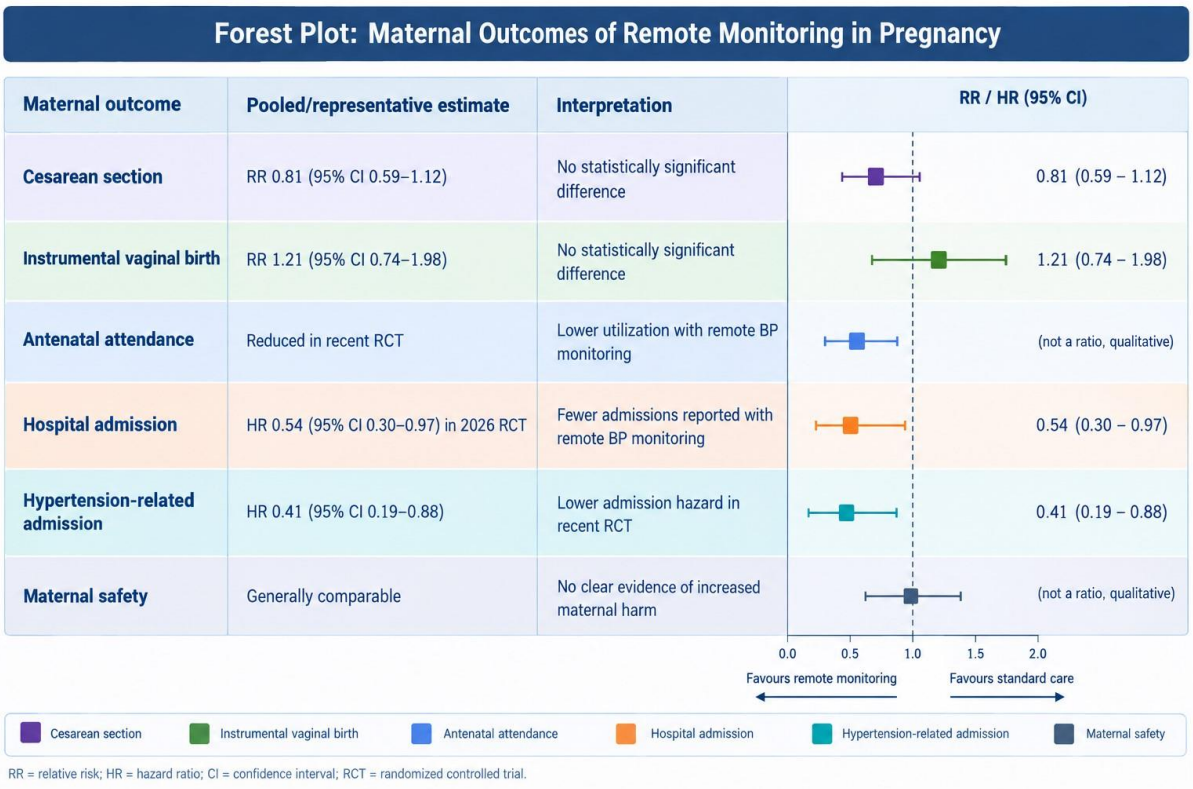

Figure 2. Forest Plot: Maternal Outcomes of Remote Monitoring in Pregnancy

The maternal evidence therefore supports a relatively consistent interpretation: remote monitoring can facilitate surveillance without demonstrating a clear increase in operative delivery or maternal harm, while its most observable advantages may involve reducing unnecessary healthcare contacts and improving the efficiency of monitoring.

Table 3. Perinatal outcomes associated with remote monitoring

Perinatal outcome	Pooled estimate	Heterogeneity/interpretation
Neonatal asphyxia	RR 0.66 (95% CI:0.45-0.97)	Significant reduction; $I^2 \approx 24\%$
Preterm birth	RR 0.80 (95% CI:0.44-1.46)	Not statistically significant
Low birth weight	RR 1.20 (95% CI:0.45-3.20)	Not statistically significant
Gestational age at delivery	No significant pooled difference	Evidence does not establish benefit

Spontaneous delivery	No significant difference	Comparable between groups
Induced labor	No significant difference	Comparable between groups

The most notable quantitative finding is the association between remote fetal monitoring and neonatal asphyxia. Li et al. (2023) reported a pooled RR of 0.66 (95% CI:0.45-0.97), indicating approximately one-third lower relative risk in the remote-monitoring group. Statistical heterogeneity was low, with I^2 reported at approximately 24%. This is potentially clinically important because neonatal asphyxia is an outcome directly related to fetal oxygenation and timely recognition of fetal compromise.

A plausible mechanism is that remote monitoring increases the frequency with which abnormal fetal heart-rate patterns detected. Conventional monitoring often performed at scheduled intervals, whereas remote systems may allow additional measurements according to predefined clinical schedules or maternal symptoms. Earlier recognition can lead to earlier clinical assessment, intervention, or delivery when clinically indicated.

Nevertheless, neonatal asphyxia not interpreted independently of the other perinatal outcomes. The pooled analysis did not demonstrate significant differences in preterm birth, low birth weight, gestational age at delivery, spontaneous delivery, or induced labor. For preterm birth, the pooled RR was 0.80 with a wide 95% CI of 0.44-1.46. The direction of the point estimates favors remote monitoring, but the confidence interval includes both meaningful reduction and potential increase in risk. Therefore, the available evidence is insufficient to conclude that remote monitoring prevents preterm birth (Figure 3).

Low birth weight similarly showed no statistically significant difference. The reported RR of 1.20 and wide confidence interval demonstrate substantial uncertainty. This may partly reflect the relatively small number of studies contributing to specific neonatal outcomes. The absence of statistically significant differences in several outcomes not automatically considered evidence of equivalence. Many studies were relatively small, and the technologies, monitoring schedules, and clinical populations differed. Statistical power may therefore have been insufficient to detect moderate effects.

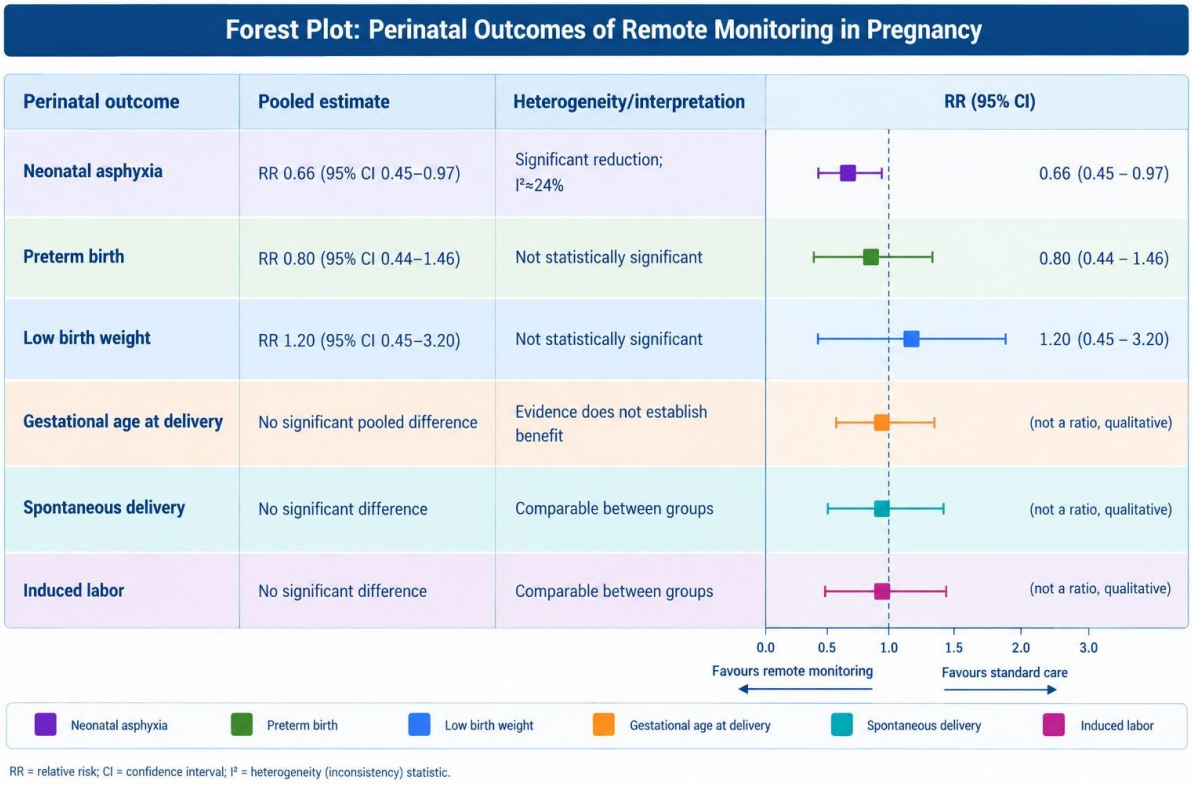

Figure 3. Forest Plot: Perinatal Outcomes of Remote Monitoring in Pregnancy

Recent reviews focusing specifically on high-risk pregnancies have suggested that remote fetal monitoring may be associated with reductions in adverse neonatal outcomes, but they have also emphasized the need for larger and better-designed trials. The 2026 evidence base is therefore encouraging but still evolving.

Another important issue is whether neonatal outcomes influenced directly by the technology or indirectly through altered clinical decision-making.

Remote monitoring may identify an abnormal pattern, but the outcome depends on the clinical team's response. Consequently, the effectiveness of remote monitoring is a property of the entire socio-technical system, including the sensor, communication network, algorithm, clinician, and treatment pathway. Overall, Table 3 suggests that neonatal asphyxia is currently the clearest quantitatively supported potential benefit, whereas evidence for preterm birth, low birth weight, and other major perinatal outcomes remains inconclusive.

Table 4. Wearable devices and artificial intelligence: clinical and implementation outcomes

Domain	Potential benefit	Major limitation
Continuous physiological monitoring	More frequent measurements	Signal artifacts and data overload
Fetal heart-rate monitoring	Earlier detection of abnormal patterns	Technical separation of maternal/fetal signals
AI-based risk prediction	Automated pattern recognition	External validation and calibration
Mobile integration	Rapid data transmission	Dependence on connectivity and digital literacy
Patient empowerment	Increased participation in monitoring	Anxiety from abnormal alerts
Healthcare efficiency	Potential reduction in unnecessary visits	Need for monitoring staff and response protocols
Personalized care	Individualized risk stratification	Algorithmic bias and limited generalizability
Remote access	Improved geographical accessibility	Digital inequality

Wearable technologies and AI potentially change the nature of antenatal monitoring from periodic observation to longitudinal digital phenotyping. Instead of relying solely on measurements obtained during clinical appointments, wearable systems can collect physiological data across ordinary daily activities. This may be particularly valuable for high-risk pregnancies in which disease progression can occur between scheduled consultations.

One important advantage is temporal information. A single blood pressure value may be less informative than a longitudinal pattern of increasing measurements. Similarly, an individual fetal heart-rate tracing interpreted differently when considered alongside previous traces. AI systems are theoretically capable of recognizing these temporal relationships and integrating multiple physiological variables. However, increased data availability creates a new problem: data overload. If every abnormal sensor measurement generates a clinical alert, healthcare professionals may experience alert fatigue. Excessive false-positive alerts could reduce confidence in the monitoring system and increase unnecessary consultations. Therefore, AI systems optimized not merely for sensitivity but for clinically meaningful predictive performance and appropriate alert thresholds.

Another challenge is the distinction between technical performance and clinical effectiveness. An algorithm may achieve high accuracy in a retrospective dataset but fail under real-world conditions. Differences in device manufacturers, sensor placement, gestational age, maternal characteristics, ethnicity, clinical setting, and disease prevalence can influence model performance. Prospective multicenter validation is therefore essential before widespread implementation. The issue of explainability is especially important in obstetrics. Clinical decisions can have profound consequences for both mother and fetus. An AI model that identifies an increased risk but cannot explain which physiological characteristics produced the alert may be difficult to integrate into shared clinical decision-making. Human clinicians must remain able to evaluate the underlying data and determine whether an alert is clinically plausible.

Wearable technology also affects patients psychologically. Continuous monitoring may provide reassurance, but abnormal measurements or unexplained alerts can increase anxiety. Therefore, patient education should clarify what the technology can and cannot determine. A wearable device should not encourage patients to interpret an isolated abnormal reading as a diagnosis. Digital equity is another major consideration. Effective remote monitoring requires appropriate devices, reliable connectivity, technical support, and adequate digital literacy. If these requirements not addressed, remote monitoring may unintentionally widen disparities in pregnancy care (Figure 4).

The optimal implementation model is therefore unlikely to be fully autonomous. A safer model is clinician-supervised remote monitoring in which wearable sensors collect information, software performs preliminary analysis, AI identifies patterns requiring attention, and trained clinicians review alerts before clinical action. This model preserves

human oversight while using AI to manage large volumes of physiological information.

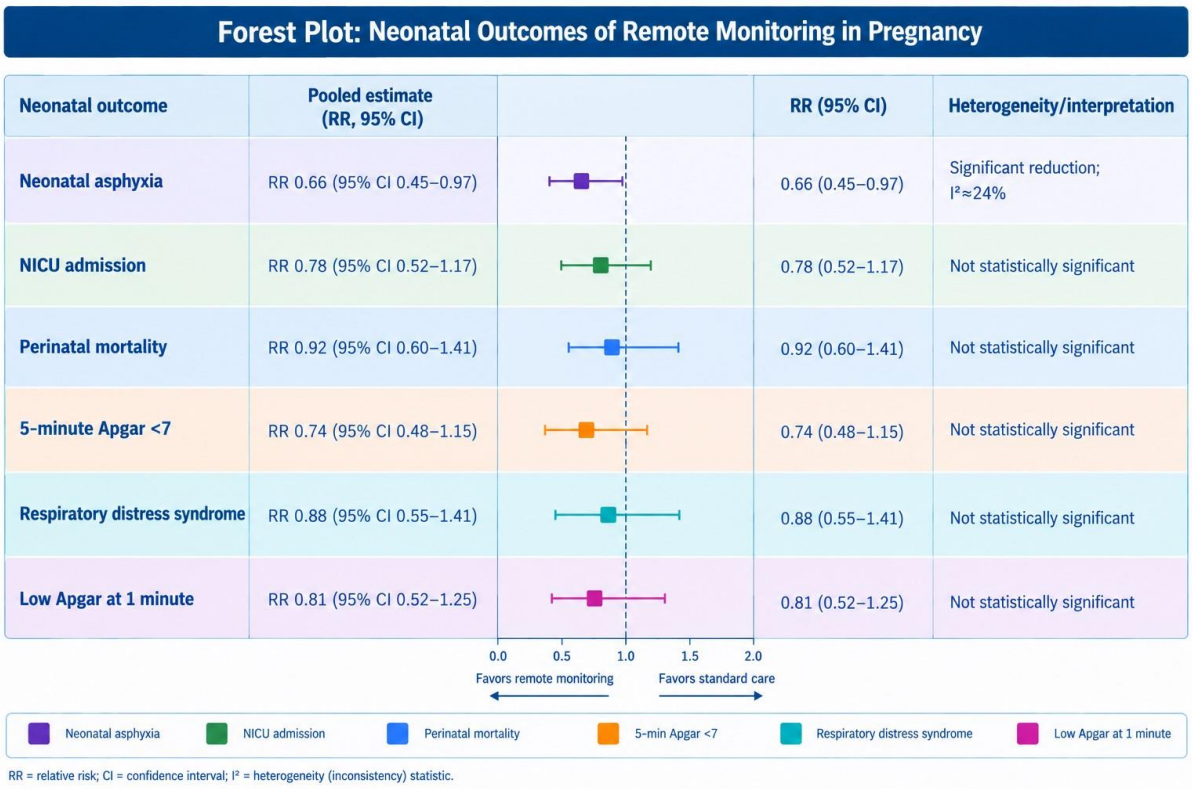

Figure 4. Forest Plot: Neonatal Outcomes of Remote Monitoring in Pregnancy

Discussion

This systematic review indicates that remote maternal and fetal monitoring using wearable devices, digital platforms, and AI has considerable potential for supporting high-risk pregnancy management. However, the current evidence is more consistent for improving monitoring processes and healthcare utilization than for demonstrating broad reductions in major maternal and perinatal outcomes.

The strongest quantitative signal concerns neonatal asphyxia. Li et al. (2023) reported a pooled RR of 0.66, suggesting a lower risk among pregnancies receiving remote fetal monitoring. This finding is biologically plausible because fetal heart-rate surveillance can facilitate recognition of patterns associated with fetal compromise. Nevertheless, the finding interpreted within the context of the included study designs and technologies. Remote fetal monitoring was not necessarily equivalent across studies, and not all participants had the same underlying risk profile.

A major advantage of remote monitoring is its ability to increase surveillance density. Traditional antenatal care structured around scheduled visits, while physiological deterioration may occur between appointments. Remote blood pressure monitoring provides a straightforward example. Women with hypertensive disorders can measure their blood pressure at home, transmit results, and receive instructions regarding subsequent management. Recent randomized evidence suggests that such an approach can reduce outpatient attendance and hospitalization without increasing adverse pregnancy outcomes (Rajkumar et al.,2026). These findings are consistent with earlier research. Lanssens et al. (2018) reported the effects of a remote monitoring program among women with gestational hypertensive disorders, and associated cost analyses suggested that telemonitoring could reduce some healthcare expenditures (Lanssens et al.,2018,2019). These studies suggest that the value of remote monitoring may extend beyond clinical outcomes to healthcare-system efficiency.

Nevertheless, remote monitoring not interpreted as a replacement for clinical care. A digital measurement cannot fully substitute for physical examination, ultrasound, laboratory testing, clinical history, or professional judgment. Li et al. (2023) explicitly emphasized that remote fetal monitoring should complement conventional care. This principle is particularly important when dealing with rapidly progressive complications such as severe preeclampsia, placental abruption, or acute fetal compromise.

AI adds substantial potential but also substantial uncertainty. AI can process large volumes of data and identify patterns that might be difficult for

clinicians to recognize consistently. Machine-learning research in fetal heart-rate analysis has demonstrated the feasibility of automated risk classification. However, many AI studies remain retrospective, and algorithm performance can deteriorate when models transported to external populations. Consequently, the clinical value of AI cannot be determined solely from accuracy, sensitivity, specificity, or area under the receiver operating characteristic curve.

An additional concern is algorithmic bias. Pregnancy populations differ across countries and healthcare systems, and a model trained in one population may not perform equally well in another. External validation across multiple demographic and healthcare contexts is therefore essential. AI systems also periodically recalibrated as devices, clinical protocols, and population characteristics change.

Another issue is the management of false-positive and false-negative alerts. A false-negative result could delay recognition of fetal or maternal deterioration, whereas excessive false-positive alerts could lead to unnecessary clinical visits, anxiety, interventions, or hospital admissions. The optimal AI system therefore designed around clinically meaningful decision thresholds rather than purely statistical performance.

Wearable sensors introduce their own limitations. Motion artifacts, sensor displacement, skin contact, signal interference, and device-specific differences can affect data quality. Fetal monitoring is particularly challenging because fetal signals separated from maternal physiological signals. Noninvasive fetal electrocardiography demonstrates the technical potential of extracting fetal information from maternal abdominal recordings, but translation into routine home monitoring requires robust signal processing and clinical validation (Behar et al.,2019).

Patient acceptability is also central. Runkle et al. (2019) and Schramm et al. (2019) demonstrated interest in wearable and self-monitoring technologies but also identified practical and psychological considerations. A monitoring system that is technically sophisticated but uncomfortable or difficult to use may have poor adherence. The optimal device must therefore balance accuracy, comfort, simplicity, battery life, connectivity, and affordability. The healthcare workforce is another determinant of effectiveness. Remote monitoring generates a continuous flow of information that reviewed and acted upon. If staffing is inadequate, the technology may create additional workload rather than reducing it. Implementation should therefore include clear responsibility for reviewing data, escalation pathways, alert thresholds, response times, and documentation.

Economic considerations are similarly complex. Remote monitoring may reduce travel, outpatient attendance, and hospitalization, but devices, software, data platforms, technical support, and professional monitoring require investment. Economic evaluations should therefore incorporate both direct and indirect costs. Previous research suggests that remote monitoring can be cost-effective in selected high-risk populations, but cost-effectiveness is context-dependent (Buysse et al.,2008; Gold et al.,2022).

The international context deserves attention. Remote monitoring could be particularly valuable in areas where specialized maternal-fetal medicine services are geographically inaccessible. Wireless fetal monitoring has investigated as a means of extending antenatal surveillance into rural settings (Tapia-Conyer et al.,2015). However, the same regions may face limitations in internet connectivity, electricity, device availability, and specialist workforce. Therefore, implementation strategies should prioritize low-cost, low-bandwidth, robust technologies. The recent literature also indicates a shift from isolated monitoring devices toward integrated digital ecosystems. Future systems may combine maternal blood pressure, heart rate, physical activity, glucose, symptoms, fetal heart rate, ultrasound findings, and clinical history. AI could potentially integrate these data streams into dynamic risk models. Such systems may facilitate precision antenatal care by adapting monitoring frequency to individual risk. However, integrated systems also increase cybersecurity and privacy concerns. Pregnancy data include highly sensitive health information and may contain information concerning both the mother and fetus. Secure data transmission, appropriate authentication, data minimization, governance, and transparent consent procedures are therefore essential. Regulatory frameworks should clarify who is responsible when an algorithm generates an incorrect or missed alert.

Another important consideration is the distinction between prediction and prevention. Detecting a high-risk pattern does not necessarily prevent an adverse outcome. Clinical benefit occurs only if the detection results in an appropriate and timely intervention. Therefore, future trials should measure not only algorithmic performance but also clinical endpoints such as severe maternal morbidity, stillbirth, neonatal morbidity, preterm birth, hospital admission, patient-reported outcomes, and healthcare costs.

Overall, the evidence supports remote monitoring as an adjunct to conventional antenatal care. The most established clinical application appears to be remote blood pressure monitoring, while remote fetal monitoring has demonstrated promising neonatal findings. Wearable devices and AI represent an emerging frontier whose ultimate clinical impact remains dependent on prospective validation, integration into care pathways, patient acceptability, and equitable access.

Conclusion

Remote maternal and fetal monitoring using wearable devices, digital health platforms, and artificial intelligence represents an important development in the management of high-risk pregnancy. The central advantage of these technologies is the ability to extend physiological surveillance beyond the conventional clinical environment. Instead of relying exclusively on periodic outpatient measurements, remote monitoring can provide repeated information concerning maternal blood pressure, heart rate, symptoms, activity, glucose, uterine activity, and fetal heart rate. This increased observation density may facilitate earlier recognition of clinically important changes and permit healthcare professionals to intervene before deterioration becomes severe. The available evidence indicates that remote monitoring implemented without a clear increase in adverse maternal or perinatal outcomes. The strongest quantitative evidence comes from remote fetal monitoring, for which a published meta-analysis of 9 studies and 1,128 participants reported a significant reduction in neonatal asphyxia. In contrast, pooled effects on cesarean delivery, instrumental vaginal delivery, preterm birth, gestational age, induced labor, and low birth weight were not statistically significant. These findings suggest that remote monitoring should not currently described as a universal intervention that improves every pregnancy outcome. The evidence for remote blood pressure monitoring is particularly relevant to high-risk pregnancy. Recent randomized evidence demonstrates that remote monitoring among women at high risk of preeclampsia can reduce antenatal visits and hospital admissions while maintaining comparable maternal and fetal outcomes. This suggests that remote monitoring may have an important role in reorganizing healthcare delivery and reducing unnecessary face-to-face surveillance.

Wearable technologies may further enhance these capabilities by enabling continuous or repeated physiological measurements. Their value is potentially greatest when they integrated into a structured clinical pathway rather than used as independent consumer devices. Device accuracy, signal quality, patient adherence, data security, and clinical response protocols are essential components of effectiveness.

Artificial intelligence has the potential to transform remote monitoring by converting large volumes of physiological data into clinically interpretable risk signals. AI-based analysis of fetal heart rate and cardiotocography is particularly promising because complex patterns may be difficult to identify consistently through conventional visual assessment. Nevertheless, AI systems not considered clinically reliable solely because they demonstrate high retrospective accuracy. External validation, prospective trials, calibration, transparency, fairness, and evaluation of clinical outcomes are required.

Future research should prioritize multicenter randomized controlled trials involving clearly defined high-risk populations. Studies should distinguish between hypertensive pregnancy, gestational diabetes, fetal growth restriction, previous adverse obstetric history, and other high-risk categories rather than combining all high-risk pregnancies into a single group. Outcomes should include maternal severe morbidity, preterm birth, stillbirth, neonatal morbidity, neonatal intensive care admission, patient satisfaction, anxiety, healthcare utilization, cost-effectiveness, and equity. Research should also move toward integrated systems that combine wearable sensing with clinical information and AI-supported decision support. Such systems should maintain clinician oversight and include clearly defined escalation pathways. The objective should not be to replace obstetricians, midwives, nurses, or maternal-fetal medicine specialists, but to provide them with higher-frequency, better-organized, and clinically actionable information.

In conclusion, wearable and AI-enabled remote monitoring is a promising component of modern high-risk pregnancy care. Current evidence supports its use as a complement to, rather than a replacement for, conventional antenatal assessment. The greatest near-term value appears to lie in improving surveillance continuity, reducing unnecessary healthcare utilization, supporting early detection of physiological deterioration, and facilitating individualized care. Establishing whether these technological advances ultimately reduce severe maternal and perinatal morbidity will require larger, prospectively validated, clinically integrated trials.

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