

Impact of Digital Health Interventions on Birth Equity: A Review

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Abstract

The rise in smartphone utilization and technology uptake has popularized digital health interventions as a means of supporting healthy pregnancies and optimizing maternal and child health. Digital health interventions include several modalities, such as telemedicine, remote patient monitoring, smartphone applications, web-based interventions, wearables, and health information technology. However, the impact of these interventions on improving maternal and infant health outcomes by race and socioeconomic status to achieve birth equity is unknown. This review summarizes current literature on the impact of digital health interventions on the outcomes of communities of color and lower socioeconomic status in the United States. We demonstrate there is emerging evidence of the impact of digital health interventions on maternal health outcomes, particularly for telemedicine, but evidence specifically focused on assessing outcomes by race and ethnicity and for other modalities, like mHealth apps or wearables, is limited. Digital health interventions may play a part in birth equity initiatives, but should not be considered a standalone solution, and instead should be integrated into other existing efforts to achieve birth equity, like diversifying the clinician workforce, expanding access to high-quality prenatal and postpartum care, or delivering respectful maternity care.

Keywords

- ▶ digital health
- ▶ birth equity
- ▶ pregnancy
- ▶ mHealth
- ▶ telemedicine

Birth equity is the assurance of the conditions of optimal births for all people with a willingness to address racial and social inequalities in a sustained effort.¹ Birth inequity is typically measured as greater adverse maternal and infant health outcomes among vulnerable patient populations, such as increased cesarean section, preeclampsia, gestational diabetes, preterm birth, low birth weight, lower breastfeeding initiation and duration, lower prenatal and postpartum care initiation and adherence, and others. Underserved communities at greatest risk of birth inequity include low-income patients, rural patients, people of color, immigrants, LGBTQ+ patients, patients with disabilities, older patients, patients with limited English proficiency or digital literacy, uninsured or underinsured patients, and other social vulnerabilities.

In the United States, thanks to the advocacy of communities of color pushing to improve local and federal quality

reporting related to maternal morbidity and mortality, birth inequity is better documented than ever before. Despite the United States' enormous healthcare expenditure surpassing that of any other developed nation, the United States reports the highest maternal mortality and morbidity rate compared to other advanced economies.² Four in five maternal deaths are due to preventable conditions, with Black and American Indian/Alaska Native women in the United States two to three times more likely to die from a pregnancy-related cause than white women.^{3,4} These groups are also more likely to experience preterm birth, deliver low birth weight infants, and less likely to receive adequate prenatal care than other racial or ethnic groups.^{5,6} Notably, these disparities persist across socioeconomic levels; a Black woman with a college degree or higher educational attainment is almost twice as likely to die from a pregnancy-related complication than a white woman with less than a high school diploma.⁷

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The birth inequities observed in the United States are indications of persistent social and economic inequities rooted in racism and discrimination. The increasing industrialization of medical care, shrinking obstetric provider workforce, exacerbation of maternity care deserts, and other forces threaten to widen existing disparities.

Despite these headwinds, efforts exist to close these gaps and achieve birth equity. Payers, governments, providers, and patients all have a vested financial and ethical interest in interventions to bolster birth equity. Creating a society in which pregnant patients of all races, socioeconomic statuses, geographies, and nationalities can experience empowered and safe births requires a multidisciplinary, intersectional collaboration of public and private stakeholders. Existing efforts include addressing provider implicit bias, expanding the provision of respectful maternity care (RMC), and increasing accountability for providers and systems via quality measures to improve access to high-quality preventative, prenatal, and postpartum care.⁸

One of the technology sector's endeavors to achieve birth equity is via digital health interventions. Digital health is a broad arm of the technology sector that includes modalities such as telehealth and telemedicine, mobile health (mHealth) and smartphone applications (apps), health information technology (IT), and wearable devices.⁹ Digital health tools may be used for a range of uses from patient education to supporting clinical decision-making, diagnosis, and treatment.

Given the average age of first birth for women in the United States is 27.4 years old, pregnant women represent a generation of patients fluent in using technology in their everyday lives and eager to apply technology to their healthcare management.¹⁰ Pregnancy is often a time of rapid personal, familial, and medical transition for women and their families, and the increased contact with the healthcare system and potentially increased motivation to improve health during this period can provide a window of opportunity for health interventions for women. Pregnancy can be a critical inflection point in a woman's lifelong health course, and can set a precedent for lifelong health. For example, half of pregnant patients diagnosed with gestational diabetes go on to develop type 2 diabetes later in life, and patients with preeclampsia and other hypertensive disorders of pregnancy are twice as likely to develop heart disease and stroke.^{11,12} Preventing these conditions during pregnancy could have a positive generational impact on health, especially given these conditions are leading factors in deaths among women of color.¹³

Digital health has been hailed as an opportunity to collect novel and more detailed patient data, transgress geographical hurdles to connect providers with more patients, and reinforce positive health behaviors outside of traditional provider interactions. Though the idolization of technology as a means to improving health remains fervent, the measured impact of technology on achieving health equity for all patients, particularly improving the proportion of the most vulnerable mothers and babies surviving and thriving, is mixed. This review aims to assess the impact of digital health

solutions on maternal and infant outcomes, specifically disparities between racial and ethnic groups, in the United States. In this review, we use "pregnant women" and "pregnant people" interchangeably to represent the patient population able to achieve pregnancy, recognizing that not all pregnant people may identify as women.

Digital Health Modalities and Impact on Birth Equity

This review explores the following digital health modalities and their impact on birth equity: telehealth and telemedicine, remote patient monitoring (RPM), mobile health (mHealth) and smartphone applications, and wearable technology. ► **Table 1** summarizes the digital health modalities discussed in this review and their advantages and disadvantages in influencing birth equity.

Telehealth and Telemedicine

Telehealth encompasses using digital technology to deliver healthcare services remotely. Telemedicine is a subset of telehealth encompassing remote patient-provider interactions via audio, video, or message to provide treatment and diagnostic services, such as patient education, prescription management, or delivering medical advice, and is typically deployed via computer, tablet, smartphone, or other Internet-accessible devices.¹⁴ Telemedicine has emerged as a means to provide care to patients outside of the traditional clinical or hospital setting. It has drastically grown in popularity since the COVID-19 pandemic, which halted traditional in-person care and forced patients and providers to adapt to virtual care. Since 2020, telehealth regulations have rapidly expanded to support telemedicine as a viable medical model, such as increasing reimbursement equity to in-person reimbursement, expanding interstate licensure and provision of care, and training medical professionals to provide virtual services. However, the future of sustainable telemedicine remains unclear. Pandemic-era flexibilities extended under the Consolidated Appropriations Acts of 2023 are slated to expire at the end of 2024, prompting Congress to secure long-term protections for telehealth.^{15,16} Major threats to ensuring telemedicine remains viable include setting reimbursement rates, ensuring sufficient patient choice, and clarifying licensing to better distinguish telemedicine from in-person care.

Despite legislative limbo, telemedicine has emerged as a promising means to achieve birth equity given it has the unique potential to overcome logistical and economic barriers of distance and time to provide more convenience to patients and providers alike. Additional trends such as the increasing ubiquity of technology, provider shortages, and improving patient satisfaction and access to care have led to a surge in the popularity of telemedicine as a means to provide medical care.¹⁷ Research has shown that telemedicine can be equivalent to in person for certain acute and chronic conditions, but may not be generalizable across all clinical condition areas.

Table 1 Summary of digital health modalities and their influence on impacting birth equity

Digital health modality	Overview	Advantages for influencing birth equity	Disadvantages for influencing birth equity
Telehealth and telemedicine	Uses digital technology to deliver healthcare services remotely; an emerging application of telemedicine in obstetrics is offering a hybrid prenatal care regimen replacing some in-person visits with virtual visits throughout pregnancy and postpartum	Endorsed by entities such as the American College of Obstetricians and Gynecologists; hybrid prenatal care regimen demonstrate similar outcomes compared to traditional in-person care, and some improved outcomes among Black-identifying patients; virtual visits could overcome transportation or financial barriers for some patients, especially those in maternity care deserts; opportunity to expand culturally competent care by connecting providers with patients in other geographic regions	Availability is subject to changing regulations regarding reimbursement and quality; requires reliable access to the Internet and privacy; not clinically indicated for all prenatal visits or risk levels; may not be preferred by all patients, such as nulliparous patients; may be more difficult to foster provider-patient relationship virtually; results of hybrid models by race or ethnicity still emerging
Remote patient monitoring	A form of telehealth that allows providers to monitor and manage their patients' chronic conditions virtually via health-monitoring tools such as blood pressure cuffs, glucose monitors, scales, pulse oximeters, or other tools	An attractive option for patients with transportation or financial barriers; efficacious way to monitor chronic conditions such as hypertension in pregnant and postpartum populations	Patients may encounter logistical or financial challenges with acquiring and using health-monitoring tools; unfamiliarity with using tools accurately
Mobile health (mHealth)	Smartphone applications designed for users to track their pregnancy's progress and other health-related information; may provide gestational-age-appropriate education about fetal development and staying healthy during and after pregnancy	Easy to download and use, given the growing ubiquity of smartphones across socioeconomic levels; can promote prenatal, postpartum, and infant health literacy	Published efficacy on improving maternal or fetal outcomes is unknown; often unsupervised by clinicians; content validity can vary; users have concerns regarding individual data security; intersectionality can be limited (e.g., may not support multiple languages or address cultural competency)
Wearable technology	Devices such as smartwatches, rings, bands, or other technology worn on the body are designed to collect continuous biometric data such as heart rate, respiration, or sleep, and provide feedback to the user	Growing interest and uptake in wearables among the general population; may be useful for encouraging adherence to healthy lifestyle behaviors, like physical activity and sleep; could be useful in detecting concerning conditions such as cardiovascular disease in pregnant or postpartum individuals	The cost of wearables remains a prohibitive factor for many potential users; the utility of collected data without provider supervision or interpretation may be mixed; little evidence exists on the impact on maternal or infant health outcomes

Telemedicine for Traditional Prenatal and Postpartum Care

Telemedicine offers a range of services for pregnant patients, from traditional prenatal care to RPM, and may also offer accompanying features like self-health tracking, educational content, and messaging platforms with providers. Telemedicine may be integrated within a patient's existing healthcare system or may exist as a standalone offering where providers may or may not accept insurance. These standalone platforms may go beyond provider-patient interactions and extend different types of care, such as lactation consultant support, doula support, and other specialties.

A major advantage of telemedicine is overcoming the logistical and economic barriers of traveling to be assessed in person. Initiating prenatal care early in pregnancy is

related to improved neonatal outcomes. The recommended prenatal visit schedule can be cumbersome for patients, ranging from 12 to 14 provider interactions throughout a full-term pregnancy.¹⁸ The first prenatal visit to establish care is typically the longest at up to 45 minutes, but remaining visits may average only 10 to 15 minutes each. Taking into account transportation time, time off work to travel and attend appointments, and potential office waiting times, the opportunity cost of these subsequent short visits becomes increasingly expensive and especially burdensome for patients with transportation or financial insecurities. The logistical challenges of attending numerous prenatal visits in person is a well-known barrier to receiving adequate prenatal care.^{19,20} Research suggests that patients with financial or transportation insecurity, of Black race, of Hispanic ethnicity,

of lower socioeconomic status, and with existing children are less likely to attend prenatal visits than other pregnant patients.^{21,22}

Telemedicine could be a powerful complement to in-person prenatal care, and though it is not a replacement for in-person care, it affords the ability for some patients to receive their care in a more convenient mode and may be a means to increase provider contact with patients, especially those with social determinants of health increasing susceptibility to missed appointments. This case may be particularly useful for addressing gaps in access to prenatal care, given the dramatic increase in maternity care deserts in the United States (a county with zero hospitals or birth centers offering obstetric care, zero obstetricians, or certified nurse midwives per 10,000 births).²³ Over one-third of counties in the United States are considered a maternity care desert, a 5% increase from 2020. Telemedicine can offer increased convenience for patients who experience transportation or financial vulnerabilities, especially for lower socioeconomic patients for whom the opportunity cost of traveling to and attending prenatal appointments is too expensive.

Though managing a pregnancy completely virtually may not be clinically recommended or preferred by patients, replacing some later gestational in-person prenatal visits with a virtual option has been recently suggested by the American College of Obstetricians and Gynecologists (ACOG). In 2021, in collaboration with the University of Michigan, ACOG released a new modified recommended prenatal care regimen, which represents the largest change to prenatal care regimens since 1930, though these recommendations are not yet considered official ACOG clinical guidance.^{24,25} It offers two tracks personalized to average-risk patients with or without preexisting conditions or complications, substituting some in-person visits with telemedicine visits, all supplemented by remote health monitoring. In-person visits are reserved for diagnostic testing, fetal monitoring, and physical examinations, while telemedicine encounters focus on patient counseling, evidence reinforcement, and educating patients on how to use tools like blood pressure (BP) monitors or glucose monitors to monitor physiological changes. This new model better personalizes care plans for each patient and their unique circumstances, rather than applying a one-size-fits-all prenatal care model. Telemedicine is not currently recommended for patients of all risk levels and is likely most appropriate for low-risk pregnancies. However, given the majority of pregnancies are low-risk, offering a hybrid model could reduce patient burden and still result in high patient satisfaction.²⁶

Past studies have suggested that a hybrid model of alternating in-person and virtual prenatal care may strike a sweet spot for low-risk patients and their providers to achieve clinical safety and even reduce medical spending.²⁷ According to one financial model, if 25% of eligible pregnant patients in the United States modified their prenatal schedule from 12 to 9 in-person touchpoints and supplemented the remaining visits virtually, this could avoid an estimated \$188 million annually in medical spending.²⁸ Existing hybrid models like OB Nest from the Mayo Clinic, which replaced some

in-person visits with virtual visits and supplemented patient care with virtual nursing-connected care support, have demonstrated that hybrid participants reported higher patient satisfaction, lower pregnancy-related stress, and achieved similar maternal and health outcomes compared to participants receiving traditional prenatal care.²⁹ However, the results regarding cost savings for OB Nest are mixed; though transportation costs, overhead costs, and in-person provider time with either physicians or midwives decreased, increased telemedicine nursing support for the OB Nest group resulted in significantly greater labor costs compared to the control arm.³⁰ OB Nest participants averaged 54 fewer minutes of in-person prenatal provider time compared to traditional care, but averaged 174 more minutes of nurse-connected care contact per pregnancy, resulting in significantly higher nursing labor costs and an overall increase of \$120 in personnel cost for OB Nest prenatal care in comparison to traditional care.³⁰ Hybrid models like OB Nest could continue to be refined and personalized based on a practice's labor workforce and priorities to balance increased labor costs with improved patient experience and similar outcomes. Hybrid prenatal care models may also be personalized according to patient preferences. Past examples of hybrid routine prenatal care models suggest that multiparous patients are seven times more likely to opt into virtual visits than their nulliparous counterparts, proposing that hybrid models could be offered to parents who have past lived experience in birth, reserving more face-to-face provider contact for newly expectant patients.^{31,32}

Telemedicine's impact on reducing barriers to receiving prenatal care to achieve birth equity is emerging, though more research is needed to assess the impact of telemedicine on birth outcomes across races, ethnicities, abilities, socioeconomic statuses, and other variables. Participants in the aforementioned OB Nest randomized controlled trial were disproportionately white (>91% in both arms), and though maternal outcomes were not significantly different between groups, results were not stratified by race or ethnicity, so the impact of this model on reducing birth disparities is unknown. Some retrospective research during the COVID-19 pandemic demonstrated that when telehealth was implemented for postpartum visits, disparities in postpartum visit attendance rates and postpartum depression screening rates between Black and non-Black patients disappeared.³³ Telehealth is also useful for extending proven interventions for achieving birth equity, such as the existing benefit of doula support in reducing preterm birth and low birth weight among Black pregnant women.^{34,35} A recent study on virtual doula support via a digital health platform demonstrated lower odds of Cesarean section and improved birth experience outcomes, particularly for Black-identifying users.³⁶ This emerging research presents a promising intervention for pregnant women of color, especially those with financial or transportation barriers to in-person care, and layering on racial or cultural concordance between doulas and patients could magnify the benefit to women and infants. However, more research specifically exploring how communities at greatest risk of birth inequity use and benefit from

telemedicine—and whether telemedicine may unintentionally harm these communities—is vital before expanding these efforts.

Despite scant research on telemedicine's influence on delivery and maternal health outcomes by race, ethnicity, or socioeconomic status, telemedicine could be used to overcome known barriers for these groups to access prenatal and postpartum care. Telemedicine could increase the expansion of racially and culturally concordant care for patients; it is well-known that providers of the same race, ethnicity, and/or language improve patient satisfaction and health outcomes, such as reducing neonatal mortality among Black infants.^{37,38} Providers licensed across multiple states could expand their patient base and provide virtual culturally competent care to patients outside of their immediate geographies. The impact of virtual culturally concordant care is not well-explored, particularly among pregnant and postpartum patients, though some studies have suggested that racially concordant care could increase patient-reported satisfaction with telehealth visits.³⁹

Additionally, providing hybrid prenatal and postpartum care could alleviate pressure on an increasingly resource-scarce healthcare system, especially in rural areas where maternity care deserts grow year over year.⁴⁰ Obstetrician shortages in states with high concentrations of maternity care deserts are increasing at an alarming rate post-*Dobbs v. Jackson Women's Health Organization*; a recent study found that there was a 5% drop in overall obstetrics and gynecology resident applicants in the application cycles following the Supreme Court's decision, with the largest drop (11%) in applicants in states with complete abortion bans.⁴¹

Despite its promising advantages, telemedicine for achieving birth equity does present some challenges. A basic barrier is access to a reliable Internet connection. Though disparities in broadband access have decreased in recent decades, as of 2023, 87% of U.S. adults with a household income of \$30,000 or greater reported being able to access the Internet, suggesting that some patients are still unable to achieve a reliable Internet connection.⁴² Other barriers such as technology literacy, privacy concerns, and securing a quiet and private place to meet with providers make virtual prenatal and postpartum care difficult.³² There are mixed results on whether telemedicine may impede patient-centered communication and shared decision-making, which are critical levers to supporting birth equity. Literature suggests that patients felt in-person visits were better for establishing rapport, trust, and open communication compared to telehealth visits.⁴³ Strong patient-provider relationships are important for effective shared decision-making, so ensuring in-person visits are dedicated to fostering these relationships is critical. Training providers on telehealth communication skills could increase shared decision-making between patients and providers via telehealth modalities.

Remote Patient Monitoring and Wearables

RPM, also called telemonitoring, is a form of telehealth that allows providers to monitor and manage their patients' chronic conditions virtually.⁴⁴ Symptoms and conditions

like high BP, diabetes, weight management, asthma, and others can be tracked via familiar devices such as scales, BP cuffs, pulse oximeters, and others. Providers can monitor these data and receive alerts if readings are outside of set thresholds, allowing for timely intervention. Similar to the benefits of telemedicine, RPM is an attractive option for patients with transportation or financial barriers.

RPM for obstetric conditions has become a common companion service to prenatal and postpartum telemedicine regimes and is a component of the Michigan Plan for Appropriate Tailored Healthcare in Pregnancy Prenatal Care (MiPATH) recommendations. According to the MiPATH model, RPM is recommended for capturing BP, fetal heart tones, weight, and fundal height throughout pregnancy.²⁴ These data points are critical for monitoring the development of conditions like gestational hypertension, sudden weight changes, uterine activity, gestational diabetes, and more.

The evidence of the impact of telemonitoring on maternal and infant health outcomes is limited given this relatively new area of clinical care, and mixed depending on the conditions and symptoms monitored. For example, a recent meta-analysis among patients with gestational diabetes monitoring their blood glucose levels remotely found no significant differences in glycemic control or maternal and infant outcomes.⁴⁵ Conversely, there is greater evidence that remote BP monitoring is clinically impactful; several studies have affirmed that BP readings can be successfully and accurately collected at home outside of the clinic setting.⁴⁶ ACOG recommends at-home BP monitoring as an important component of comprehensive obstetric care. Remote BP monitoring is generally considered acceptable and appealing to pregnant and postpartum patients, and has been shown to reduce short-term hypertension-related morbidity and even mortality, though more research is needed to understand longitudinal impacts on maternal health.^{47,48} Monitoring BP remotely could be particularly powerful in the postpartum period, given the majority of maternal deaths occur within the first year postpartum, and Black women are more likely to die due to cardiac and circulatory conditions compared to other races and ethnicities.³ Up to half of all postpartum individuals do not receive any health care, with significant disparities by race, geography, immigration status, and socioeconomic status, and postpartum healthcare remains elusive for the majority of pregnant patients.⁴⁹ As the majority of postpartum women are largely unmonitored throughout the first year following delivery, remote monitoring could offer a means of timely identification of concerning conditions earlier, and increase the proportion of women receiving life-saving interventions. Additionally, remote monitoring has been suggested as a solution for white coat hypertension (WCH). WCH is a hypertensive disorder that affects up to 30% of all pregnant patients, particularly patients of color, and refers to elevated clinic BP but normal BP measured at home or work.⁵⁰ A recent meta-analysis reported that WCH increases the risk of preeclampsia and small-for-gestational-age, and preterm delivery among pregnant women, though these results were not stratified by race, ethnicity, or socioeconomic status.⁵¹ Remote BP monitoring

can be used to detect WCH and assess baseline BP levels in pregnant and postpartum patients.

Given hypertensive disorders of pregnancy disproportionately impact women of color, RPM could be a powerful lever in improving birth equity and postpartum outcomes by race and ethnicity.^{52,53} A recent study of postpartum women with hypertension disorder of pregnancy found that the follow-up visit completion rate was significantly higher among patients who used telemedicine, with a pronounced difference among Black patients.⁵⁴ Similarly, a randomized control trial among postpartum patients at elevated cardiovascular risk using remote monitoring via a wearable activity tracker recorded significantly increased physical activity throughout 12 weeks postpartum.⁵⁵ Some recent research efforts have focused specifically on Black postpartum women, who are at increased risk of postpartum hypertension, and have found that RPM with home-based BP monitoring machines and text-message reminders were more likely to record BP, yet outcomes were not different between the groups.⁵⁶ Participants in the OB Nest program found self-monitoring afforded an increased level of control, confidence, and reassurance during pregnancy.⁵⁷ This may be particularly powerful for women of color who historically feel dismissed at provider visits or may experience white coat syndrome to increase self-efficacy and confidence throughout their prenatal care journey. However, a recent review determined there is insufficient evidence to conclude that postpartum remote BP monitoring influences severe maternal morbidity or mortality or reduces racial disparities in clinical outcomes.⁵⁸

Barriers to RPM include logistical or financial access to health monitoring tools, unfamiliarity with using tools accurately, difficulty reporting these measurements back to the provider, and low engagement with data collection platforms.^{46,59} These could be mitigated via expanding durable medical equipment benefits among payers, training providers on educating patients to accurately capture readings with health-monitoring tools, and designing patient-centered channels for patients to simplify reporting readings back to providers.

Mobile Health (mHealth) and Smartphone Applications

More than 95% of reproductive-age women and 88% of pregnant women in the United States have smartphones, and 80% of people with a household income under \$30,000 own a smartphone.^{60,61} With technology becoming increasingly universal across socioeconomic levels and geographies, mobile health, or mHealth, interventions for supporting pregnancy have grown exponentially in recent years, and with it the potential to influence birth equity.⁶² There are hundreds of smartphone apps related to tracking one's pregnancy in the Apple iTunes store and Google Play store, and the number of these apps is rapidly increasing. Pregnancy-tracking apps typically offer prenatal or postpartum educational content, symptom and gestational age tracking, fetal kick counters, appointment reminders, or health monitoring features. They may also offer other engaging features

like community boards where users can interact with one another, or communication channels with healthcare providers. Most apps are available to users at no additional cost, though may offer third-party advertising or a subscription model for more "premium" content or features.

Major life events like pregnancy or the birth of a child tend to be catalysts for app downloads; past research indicates people experiencing these and other life events download 2.5 times more apps than those without any significant life changes.⁶³ Exploration suggests up to 50% of pregnant women use pregnancy-tracking apps, and download an average of three during the prenatal period.⁶⁴ Qualitative research suggests that pregnant patients may have a high appetite for web-based pregnancy applications, especially if they are personalized, permit health monitoring, and integrate into their daily routine and pregnancy care.⁶⁵ Patients pregnant for the first time, or those caring for their first child, are more likely to use digital health apps than their multiparous counterparts to track their pregnancy or postpartum period.^{66,67} Nulliparous patients and new parents have a steeper learning curve than existing parents to understand what is happening to their bodies and how to prepare for life with an infant, resulting in a strong desire for evidence-based information and support. Some patients use digital apps as a daily companion in-between provider visits, but similar to Internet searches, the overwhelming amount of information and confusion in knowing which sources to trust are identified as challenges for information-seeking pregnant women.^{68,69} Though using smartphone applications to track pregnancy is common, concerns such as content quality and individual data security remain important considerations for selecting and using a mHealth application for pregnancy. Some evidence suggests that women feel less comfortable tracking their reproductive health information digitally following the *Dobbs v. Jackson Women's Health Organization* Supreme Court ruling in 2022.⁷⁰

Unlike digital health modalities like telemedicine or RPM, the majority of pregnancy-tracking apps are developed and managed by private technology companies, as opposed to other mHealth interventions that may be designed by a health system or medical team as part of a research study; so, evidence on any impact these apps have on maternal or infant health for their users may never be externally reported. It is important to note that few pregnancy-tracking apps claim to actually improve maternal health or clinical outcomes in any way, and state that their purpose is educational in nature. Additionally, regulation on content review and development for these apps does not exist; in fact, there is little regulation by the Food and Drug Administration for any health app unless it intends to diagnose or treat a condition, or integrates with a medical device.⁷¹ Many of these apps have not been evaluated for content accuracy prior to going to market, which may make it difficult for users to ascertain the reliability of the information presented to them.^{65,72,73}

Differences in utilization of pregnancy-tracking apps by race and ethnicity are not well-known, though some evidence suggests that women of color and lower income are

less likely to use digital health modalities like accessing their virtual medical chart or using tracking apps.^{74,75} The digitalization of healthcare has created a divide known as digital inequity, where patients with limited time, resources, and competing priorities have fewer opportunities to adopt and utilize digital health interventions.⁷⁶ The current research and regulatory landscape offers little data or guidance to inform users about the efficacy of using apps to support maternal and infant health, especially outcomes among low-income mothers, mothers of color, and non-English-speaking mothers.⁷³

Tracking patient-reported outcomes using smartphone applications has been successful in igniting positive behavioral change in pregnant patients in areas such as smoking cessation and prenatal nutrition.⁷⁷ Other studies have demonstrated improved knowledge in general prenatal health knowledge, some health behaviors like clinic attendance rate, and positive health beliefs, but did not assess differences in birth outcomes.^{73,78} Pregnancy-tracking apps may still be helpful in offering educational resources to empower users to make informed decisions and better understand their prenatal and fetal development. However, offering educational content is only as powerful as the quality of the content; a recent review of the most popular commercial pregnancy-tracking apps affirmed that clinical content quality is incongruent across apps, and few contained evidence-based behavioral change techniques to promote healthy prenatal and postpartum behaviors.⁷⁹

Unfortunately, few apps are intentionally designed with culturally diverse or non-English-speaking women in mind.⁷⁴ However, research has shown that developing apps with cultural competence in mind can result in high uptake and impressive health outcome results.⁸⁰ In recent years, several pregnancy-tracking apps and digital health platforms have been launched specifically for women of color with the specific intention to improve outcomes for mothers and babies of color and support birth equity. An example is Irth, a free app that allows women of color to report reviews of maternity care providers and birthing hospitals.⁸¹ It aims to provide transparency on perceived experiences of racism and bias, enabling patients to understand prior patients' experiences regarding discrimination so they can select a provider they feel comfortable with. Though there are efforts by entities like the National Committee for Quality Assurance and RH Impact to create validated quality measures to measure RMC and promote birth equity, none are widely implemented or recognized to date.⁸ Given the lack of rigorous quality measures in place to measure RMC at the provider or health system levels, this app is a community-sourced collection of patient reviews of reproductive healthcare providers by women of color, for women of color. It is available in both English and Spanish, and has forged collaborations with hospitals and health systems to encourage recent postpartum patients to submit reviews of their providers (such as obstetricians and gynecologists, certified nurse midwives, and others) to bolster a dataset to drive transparency and increase accountability for providers to deliver RMC.⁸² However, the proven efficacy of pregnancy

apps on birth equity will remain murky until more research is dedicated to this area.

Wearable Technology

Wearable devices, or wearables, such as smartwatches, rings, or bands, collect continuous biometric data and provide feedback to the user. They may be used in remote-monitoring interventions, but many users track their own health via wearables without a supervising provider. An estimated one in three U.S. adults report using a wearable, and women are more likely to use wearables compared to men.⁸³ One study found that Black and Hispanic individuals were more likely to report wearable use than their white counterparts.⁸⁴ Given an increased focus on disparities in women's health, some studies have demonstrated that wearables can potentially influence maternal and child health outcomes. Research shows adherence to wearables can be high depending on the technology, and accurately measure metrics like BP, physical activity, heart rate, stress, sleep, and others.⁸⁵

Research suggests patients are interested in donning wearables before, during, and after pregnancy to monitor important health indicators, and providers are interested in collaborating with their patients to use these measurements in managing their health.⁸⁶ Many biometrics captured via wearables are important indicators of the onset of adverse conditions, such as cardiovascular disease, the leading cause of death in women, and hypertensive disorders of pregnancy, a leading cause of maternal mortality.^{3,87} Wearables have also risen in popularity in arenas such as fertility awareness for women to track fertility indicators like basal body temperature, heart rate, and sleep. The benefits of wearables on influencing birth equity are similar to that of RPM in that they may be especially supportive to patients in remote areas with limited obstetric care and may increase self-efficacy, yet the data collected by patients may not be useful without provider's interpretation to understand relative risk.

The existing literature on wearables mostly explores the development and validation of wearable devices, with most published within the last 5 years.⁸⁵ A study by the creators of a wrist wearable indicated that there was a notable rise in heart rate variability (HRV) around 7 weeks prior to the onset of labor for term and preterm deliveries, indicating HRV might be an indicator for preterm labor that can be continuously monitored via a wearable.⁸⁸ Another study of a commercial smart ring worn on the finger reported that physiological data captured in the third trimester may improve the prediction of the natural duration of pregnancy relative to the estimated due date.⁸⁹ This could have future implications in understanding the shift between pregnancy to labor using physiological data rather than the estimated due date (EDD). Assessing the progression of labor by physiology rather than EDD could potentially avoid unnecessary labor inductions, which increase the risk of adverse outcomes like cesarean delivery.⁹⁰ Some of the strongest evidence for wearables to date on maternal and fetal health outcomes is how wearables can support healthy lifestyle behaviors such as increasing physical activity during and after pregnancy, but further impact on maternal morbidity is

unknown.⁸⁵ There is little research to date on the impact of these devices on maternal or fetal outcomes, such as delivery mode, preeclampsia, gestational diabetes, or preterm birth, especially by race or ethnicity, to improve birth equity.

Despite studies demonstrating interest in wearables among patients of color and of varying socioeconomic statuses, the sample of participants included in the previous studies is not representative of the individuals at greatest risk of adverse maternal health outcomes, given both samples were overwhelmingly white, had at least an undergraduate degree, and had employer-based health insurance. Though patients of color and lower socioeconomic status express interest in using wearables to track their health, cost remains a persistent barrier to uptake and use.⁹¹ Ranging from \$150 to \$1,000 or more, the expense of direct-to-consumer wearables remains prohibitory for many patients, especially for patients facing financial insecurity.⁹²

There is little published research available to date on the impact of wearables on birth equity. However, there are active investigations exploring this important research phenomenon with a specific interest in understanding the impact on women of color and other underrepresented groups. The Better Understanding the Metamorphosis of Pregnancy (BUMP) study is an ongoing longitudinal feasibility project aimed at gaining a deeper understanding of the pre-pregnancy and pregnancy symptom experience using digital tools. This study aims to recruit women from more diverse and underrepresented backgrounds and are provided with several digital tools, including a smart ring, a smartwatch, and a smart scale, alongside companion smartphone apps, to track multimodal symptoms during the perinatal window to inform individual-level symptom trajectories.⁹³ These and other projects specifically studying diverse populations would shed light on whether there is a significant impact on wearable technology and maternal and infant health outcomes.

Discussion

Digital health interventions represent an exciting frontier, especially in reimagining equitable prenatal and postpartum healthcare in the United States. They have demonstrated budding success in improving some positive health behaviors, maternal health outcomes, and reducing medical spend. However, evidence-based interventions to reduce disparities in outcomes among women and babies of color, lower socioeconomic statuses, and other vulnerabilities to achieve total birth equity are lacking. Digital health interventions are a growing companion to in-person care, but at the moment do not generate sufficient evidence to replace traditional healthcare. Telemedicine has a more robust body of evidence supporting its impact on improving health outcomes compared to other digital health modalities, such as mHealth and wearables.

The current evidence suggests that a multimodal approach to digital health interventions may be most effective in supporting positive maternal and infant health outcomes—such as implementing a remote-monitoring BP regime with text-message reminders, offering an app to pregnant

patients sharing evidence-based prenatal educational content that permits health tracking coupled with wearables, or encouraging postpartum health tracking alongside telemedicine visits.

Regardless of digital health modality, studies specifically reporting outcomes by race, ethnicity, income level, educational level, immigration status, ability status, language, and other social determinants of health are rare. Specific attention should be paid to closing this gap in the literature. Recent federal commitments to funding research focused on women's health, a chronically underfunded and understudied area of research, could be promising catalysts to generate the evidence needed to assess whether digital health is a viable tool for achieving birth equity.

Additionally, given the complexity of birth equity, digital health interventions alone are unlikely to represent a complete solution. Relying on digital health solutions alone to solve the systemic, persistent challenge of whether a Black, indigenous, or other marginalized person in the United States has a safe and empowered delivery, for example, is reductive. Access and uptake to digital health solutions themselves are subject to inequities, and these solutions are often not designed with vulnerable communities in mind. Digital health interventions should not distract from other existing efforts to achieve birth equity, like diversifying the clinician workforce, expanding access to high-quality prenatal and postpartum care, or delivering RMC, and should instead amplify these existing initiatives. Addressing racial and ethnic disparities in birth equity requires a holistic response, of which digital interventions may play a part. What is clear is that interventions which prioritize user design and cultural competence are most successful in these communities and will be a critical component in their expansion to achieve optimal maternal and child health outcomes.

Conflict of Interest

Dr. Malloy is an employee of Ovia Health, a subsidiary of Labcorp.

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