Technology-Based Approaches for Supporting Perinatal Mental Health

Andrew M. Novick[1] · Melissa Kwitowski[1] · Jack Dempsey[2] · Danielle L. Cooke[1] · Allison G. Dempsey[1]

Abstract

Purpose of Review This review explores advances in the utilization of technology to address perinatal mood and anxiety disorders (PMADs). Specifically, we sought to assess the range of technologies available, their application to PMADs, and evidence supporting use.

Recent Findings We identified a variety of technologies with promising capacity for direct intervention, prevention, and augmentation of clinical care for PMADs. These included wearable technology, electronic consultation, virtual and augmented reality, internet-based cognitive behavioral therapy, and predictive analytics using machine learning. Available evidence for these technologies in PMADs was almost uniformly positive. However, evidence for use in PMADs was limited compared to that in general mental health populations.

Summary Proper attention to PMADs has been severely limited by issues of accessibility, affordability, and patient acceptance. Increased use of technology has the potential to address all three of these barriers by facilitating modes of communication, data collection, and patient experience.

Keywords Digital mental health · Perinatal mental health · Mobile health · Behavioral health technology · Wearable technology

Introduction

Postpartum mood and anxiety disorders (PMADS) remain a major public health concern, with the six-year costs of untreated PMADS estimated at 4.2 billion per birth year cohort and approximately $32,000 per mother-parent dyad due to lost productivity costs, increased maternal health and obstetric-specific expenditures, and child expenditures related to preterm birth, developmental and behavioral challenges, and child injury [1]. Beyond the fiscal burden, maternal suicide is a leading cause of maternal mortality with rates of suicide peaking in the postpartum period [2–4]. Although the American College of Obstetricians and Gynecologists (ACOG) recommends ongoing care and regular screenings for PMADs to address these concerns [4, 5], access to care remains limited, with 27% and 19% of metropolitan counties lacking a psychiatrist or a psychologist, respectively [6••]. This lack is more pronounced in rural areas, increasing to 65% and 47% of non-metropolitan counties lacking a psychiatrist or psychologist, respectively [6••]. Beyond issues with access, other challenges in perinatal mental health include lack of training and experience in screening and diagnosis for obstetric providers, insufficient screening tools, lack of awareness or resources for referrals, limited inclusion of partner's mental health, ethnic and socio-economic differences in identification, and lack of specialized community providers [7].

Technology-based approaches to perinatal mental health care may help address many of these concerns. Recent ACOG guidelines have highlighted the use of technology and mobile app-based tools in optimizing postpartum care within and outside of the clinic [5]. The flexibility inherent in digital platform modalities represent opportunities for prevention, early symptom detection, and facilitation of various treatment options [8]. Many web applications, including those for mental health screening and treatment,

✉ Allison G. Dempsey
Allison.dempsey@cuanschutz.edu

1 Department of Psychiatry, University of Colorado School of Medicine, 1890 N Revere Ct, MS F546, Aurora, CO 80045, USA

2 Department of Pediatrics, University of Colorado School of Medicine, Aurora, CO, USA

provide psychoeducation and have a focus on prevention or exacerbation of various illnesses [9••]. Another key advantage of digital methods for use in mental health is the ability to provide users with screening, psychoeducation, and possible treatment depending on need and symptom severity [8]. Given the known prevalence of PMADs, additional screening during the prenatal period is an enhanced window of time to engage in early detection and intervention of psychological distress [10]. Furthermore, the ability to provide transdiagnostic psychoeducation to users regardless of symptom presentation serves to normalize common peripartum experiences that may otherwise leave parents feeling isolated or misunderstood [11]. Below, we discuss multiple technology-based approaches to aspects of perinatal mental health care that can be incorporated into stepped care models, ranging from prevention to intervention. The various approaches include (a) provision of preventive care through psychoeducation, peer support, and self-monitoring of mental wellness and mental health symptoms; (b) monitoring of biometric data associated with mental health and wellness; (c) direct service delivery of interventions to patients; and (d) indirect intervention delivery to promote access to specialized medical care.

Mobile Health (mHealth)

Mobile health (mHealth) technologies allow for widespread access to tools that support efforts to prevent development of PMADS and promote awareness of symptoms and quicker access to services when they are needed. mHealth technologies use portable electronic devices to support public health and health care delivery through text messages, blogs/forums, social media, and digital apps [12]. Although mobile devices can also be used for telemedicine and receiving internet-based therapy (to be discussed in a future section), we do not include them under the conceptualization of mHealth in this manuscript. Instead, we here are referring to technologies that rely on use of apps and interactions typically conducted using a phone or mobile device.

Many expectant parents routinely use app-based tools as a way of accessing relevant health information during pregnancy [13, 14]. Indeed, use of digital platforms appears an almost ubiquitous part of the current pregnancy experience [15]. This represents a drastic shift from just several years ago and presents opportunities for implementation of novel approaches to supplement traditional health care [16]. In the perinatal period, mHealth may be used to provide social connection through web-based social forums or clinician-hosted virtual support groups, mobile phone apps for screening for self-screening for symptoms and to provide psychoeducation about symptoms and how to obtain support, or interactive platforms to briefly share information about coping, symptoms, and behaviors with providers [17••].

Research on utilization of mHealth-based care approaches have demonstrated improved outcomes during both pregnancy and in the postpartum period, though not specific to perinatal mental health [18]. For example, some mHealth interventions (sometimes referred to as antenatal care apps) seek to introduce lifestyle interventions to manage chronic health conditions such as overweight/obesity, hypertension, diabetes, and asthma during pregnancy [19–21]. Other platforms aim to improve preparedness for pre-term birth, labor/delivery, NICU transition to home, infant care, or parental attachment [22, 23]. Moreover, these internet-based tools represent an opportunity to connect frequently with patients and provide supplemental information and support between and alongside perinatal provider visits [15]. Thus, a primary advantage of mHealth technologies as an adjunct to the traditional, in-person medical office visit is the broader reach across patient populations and the opportunities for enhanced contact to enhance care in pregnancy [24]. That is, use of mHealth technologies allows for more frequent opportunities to provide psychoeducation that may serve to address some barriers to positive birth and postpartum outcomes [18].

The use of mHealth-based approaches to perinatal mental health care is more limited. Emerging evidence has provided preliminary support for the efficacy of mHealth interventions in both preventing PMADs and relieving mild symptoms [17••]. Specifically, mHealth technologies that provide platforms for peer interaction and support and psychoeducation have been shown to be both acceptable and effective in improving mood symptoms in women during the perinatal period [25–29]. These studies have been largely limited to mothers without prior mental health histories, those with only mild to moderate depressive symptoms, those with healthy infants, and in a single language, limiting the generalizability of this research. Further still, many currently available mobile peripartum apps suffer a number of significant limitations, including lack of accessibility, limited usability, lack of inclusivity of women of color, and inadequate evidence-based maternal health information, all of which may contribute to suboptimal use and engagement [12, 30, 31].

Overall, mHealth approaches to perinatal mental health care allow patients to access and review information about PMADs and may serve to decrease stigma and improve likelihood that patients will seek out treatment [32]. They may also be appropriate, from a public-health perspective, for providing sub-clinical interventions (e.g., peer support interventions) that are helpful for addressing mild symptoms of PMADs. However, many patients require more individualized care approaches that are more appropriate for other technology-based approaches to mental health care

delivery that involve both symptom monitoring and direct intervention.

Wearable Technology

Wearable technology, as it relates to medicine, consists of devices that patients use outside the medical clinic to collect clinically relevant data that can then be transmitted remotely to the clinician and/or reviewed during appointments. Not only can such technology potentially help avoid the need for in-office appointments via remote communication of data, it can help in the detection and progress-monitoring of mental health and wellness during the perinatal period through ongoing collection of data that are proxy indicators for declining mental health (e.g., reduced movement/activity, social engagement, and sleep).

Use of wearable technology also has the potential to remedy some of the major limitations inherent in detection of traditional diagnosis, monitoring and treatment of perinatal mental health disorders. Specifically, the mental health clinician usually has very few objective measures at their disposal for diagnosis and management, relying on subjective reports that are vulnerable to bias and inaccuracy as the patient attempts to describe their symptoms over the past weeks and months. Wearable technology can provide information about a patient's behavior and biological function outside of their appointments, and thus allow the clinician access to data that can assist in diagnosis, treatment monitoring, and prevention [33, 34].

Unlike highly specialized remote monitoring technology such as that used in OB/GYN for cardiotocography, the wearables studied in mental health tend to be common, commercially available devices that many individuals already use. These include an individual's smart phone (which has the capacity to monitor physical activity, Global Positioning System (GPS) location, and timing, duration, and type of use of various features such as time spent on phone calls or social media apps). Commercially available fitness watches utilize actigraphy to provide data on physical activity and sleep quality and can often measure heart rate and heart rate variability. Similar to mHealth interventions, there has been little research devoted specifically to the use of wearables with PMADs. However, there is now an extensive literature describing the utility of wearables in psychiatric disorders outside the perinatal period which in turn suggest its potential for application to PMADs.

Several meta-analyses and systematic reviews on the use of wearable technology in psychiatric disorders have been published in just the past 3 years [35–37]. Most of these reviews tend to focus on actigraphy which provides an indication of sleep and physical activity. Actigraphy has a high-degree of relevant face-value for psychiatric disorders and is also easy to measure and interpret using currently available technology. These reviews have concluded that, across studies, actigraphy is able to capture significant differences in physical activity and sleep parameters in individuals with psychiatric disorders compared to healthy controls, and these measures change with successful treatment [35–37]. As such actigraphy data collected by smart phones and watches appears to be a viable source of objective data to assist in clinical diagnosis, monitoring of treatment response, and early detection of exacerbations.

Two studies have reported on the application of wearable technology in perinatal depression. In one study, 36 pregnant women with elevated depression scores used an app on their smart phone to monitor both daily physical activity (steps walked) as well as daily travel radius (via GPS) for 8 weeks [38]. More severe depressive symptoms were associated with a contracted travel radius; specifically, a prior day's report of more severe symptoms corresponded with decrease travel radius the subsequent day. Additionally, while women with mild symptoms demonstrated increased physical activity over the 8-week period, women with more severe symptoms demonstrated the opposite. This study emphasizes the importance of travel radius in addition to physical activity as a relevant measurement for postpartum depression, and also suggests that decreased physical activity over a period of time could be a signal for more severe perinatal depressive symptoms.

In another study of postpartum mothers with preterm infants, wrist actigraphy demonstrated that higher levels of daytime activity correlated with decreased symptoms of postpartum depression, suggesting not only the importance of physical activity on its own, but also circadian activity rhythms, which are frequently disrupted in PMADs [39].

Based on the general psychiatric literature as well as the few studies in perinatal populations, wearable technology, particularly actigraphy, represents an exciting, widely available tool to enhance mental health care in PMADs. However, several limitations do exist. Like any clinical measurement, data from wearables is not necessarily always sensitive and specific to mental health disorders, and thus should never be a replacement for skilled evaluation. Furthermore, many of the studies on wearable technology use apps and algorithms were specifically designed by/for the research team and are not easily available to the average clinician and patient [40, 41]. And while most smart phones and watches come with apps that collect and analyze actigraphy data, it may be cumbersome and require technological know-how with regards how to best share the data between patient and clinician and allow for meaningful integration within an EMR. Thus, in addition to enhancing capacity for clinical integration of data from wearables, future studies on wearable technology in

PMADs might focus on common apps and devices that could be utilized "out of the box" among patients and clinicians.

Internet-Based Cognitive Behavioral Therapy (I-CBT)

As summarized thus far, common technology to which most patients have access (phones, activity monitors) can allow for improved access to preventive services and remote monitoring of symptoms for both detection and progress-monitoring of PMADS. Technology can also be used to facilitate delivery of treatments for those requiring additional, individual services. A significant barrier to timely and comprehensive care is patient accessibility to services [9••]. In the vast majority of healthcare systems worldwide, there is a dearth of resources and mental health clinicians to meet the needs of expectant and postpartum mothers [8, 9••, 16]. Utilization of internet-delivered interventions in comparison to traditional face-to-face modalities, represent opportunities to (a) expand access and maintain engagement in mental health services; (b) reduce costs to patients and medical systems; and (c) and enhance privacy [9••, 10, 11].

Internet-based cognitive behavioral therapy (I-CBT) treatments for PMADS, which patients may access in their homes through mobile devices or computers, allow clinicians to provide evidence-based interventions for PMADs without relying on a solely face-to-face traditional therapy session. I-CBT interventions typically involve a hybrid approach to care, combining delivery of clinical content via an asynchronous web-based platform with intermittent synchronous clinical or coaching sessions that can be delivered via telephone, videoconferencing platforms, or in-person.

Prior studies of the general population have found I-CBT interventions have similar acceptability and clinical efficacy in the reduction of mood and anxiety symptoms as more traditional face-to-face treatments [42••]. In one small (N=43) randomized control trial of a 6-session I-CBT intervention with women in the postpartum period with diagnosed depression, delivery of an internet-based intervention, supported with low-intensity coaching via telephone, showed that after 12 weeks 79% of the 21 women who received the treatment no longer met diagnostic criteria for depression whereas only 18% of the 22 women who received treatment as usual demonstrated a remission in symptoms. Furthermore, 86% of the women in treatment condition completed all session, and reported satisfaction with the program [43]. Similarly, in a systematic review of 8 studies involving investigation of I-CBT interventions for women with PMADS, Lau and colleagues concluded that therapist-supported I-CBT improves stress, anxiety, and depressive symptoms among women receiving I-CBT interventions in comparison to those in the control group.

Virtual and Augmented Reality

Virtual reality exposure therapy or VRET has over 20 years of research demonstrating that it is at least as effective as standard evidence-based therapy in the treatment of fears/phobias [44]. Research on its applications has almost exclusively focused on specific (e.g., arachnophobia, social anxiety) rather than generalized fears; therefore, application of VRET to the treatment of PMADs would largely relate to reduction of specific symptoms which may arise rather than the overall management of the disorder. To provide a concrete example, VRET would not be applicable in reducing a new mother's overall level of anxiety in the postpartum period; however, VRET would be useful if this anxiety manifested as a fear of having a car accident with the baby which was preventing highway driving.

Despite this limitation, when VRET can be used, the advantages are substantial. Specifically, traditional exposure therapy can have substantial time, cost, and risk associated with it (e.g., driving on a busy highway with the patient), and has a 25% rejection rate when introduced as a treatment option [45]. In contrast, VRET has a rejection rate of only 3% and in comparing preference for the two treatment options, 70% of participants expressed a preference for VRET over ET [45]. Although the current price point of many VR systems and corresponding lack of widespread adoption emerge as barriers, a final advantage of VRET over traditional exposure therapy is the ease with which the former could deployed through telehealth.

VRET in Preoperative Anxiety Surrounding Cesarean-section

Approximately 32% of all deliveries in the US are via Cesarean-section c-section [46]. Women undergoing this procedure are at increased likelihood of developing PMADs [47], and evidence exists suggesting that preoperative anxiety may be the mechanism underlying this relationship. Specifically, an inverse relationship between preoperative anxiety and both procedural satisfaction and quality of recovery has been found across a variety of surgical procedures including c-Sect. [48]. Thus, an intervention aimed at reducing preoperative anxiety may reduce the likelihood of developing PMADs following the procedure.

The research base regarding the impact of VRET on preoperative anxiety-related to c-section is too limited at present for any conclusions to be drawn, but some of the early findings are suggestive. Studies using VRET to treat preoperative anxiety related to other surgical procedures have found that both preoperative anxiety and post-operative satisfaction were improved [49, 50]. When VRET was applied to preoperative anxiety surrounding the c-section procedure in a randomized controlled trial, however, the results were inconclusive. Specifically, results trended towards significance ($p=0.08$) with the

authors noting that the analysis was underpowered [51•]. Notably, the timing and level of immersion (e.g., cellphone slotted into headset vs dedicated VR hardware such as the Oculus Rift) differed between this study and some of the other studies showing positive results of VRET on preoperative anxiety (e.g., 49). Thus, at this time, further research is required on this topic, but there is promise that use of VRET to treat preoperative anxiety surrounding c-section may be able to reduce the odds of post-surgical development of PMADs.

eConsultation

One way of improving access to mental health specialists, particularly prescribers, is the eConsult. Distinct from telepsychiatry/tele-mental health where the mental health practitioner directly sees the patient via videoconferencing, eConsultation describes asynchronous secure electronic communication between the patient's current provider and a specialist. This allows for rapid access to specialist expertise, avoiding the often-long wait times of direct referral as well as the difficulties of coordinating phone time between two busy practitioners. Furthermore, eConsultation has many of the advantages of an integrative health model, allowing care to be delivered within the patient's current setting, and thus reducing the potential stigma and non-adherence that can occur with the need for outside visits to a specialist [52]. While there is limited published literature specific to eConsult in perinatal mental health, its adoption in many systems to improve access to specialists (including psychiatrists) has been recently documented and reviewed [53•]. The overarching conclusion of this literature is that eConsultation is associated with improved access to specialist care and is perceived positively by both patients and providers [53•, 54, 55].

Several recent papers have focused specifically on the utilization of psychiatric eConsultation, which can shed light about its potential benefits and limitations for PMADs. eConsultation to psychiatric specialists has been found to be utilized at a lower rate compared to other specialists, suggesting underutilization [53•, 56]. According to feedback from primary care practitioners (PCPs), this decreased utilization might be due to the fact that psychiatric issues are perceived as being more "nuanced" with lack of associated lab values, imaging or objective measurements that can facilitate consultation in the absence of face-to-face evaluation [56]. But even if psychiatry eConsults do end up resulting in more conversions to face-to-face referrals than other specialties, they still might help save limited mental health resources. For example, in one study, PCPs reported that following 30% of their eConsultations to psychiatry, they no longer felt the need to refer the patient [57]. The idea that psychiatric eConsultation provides greater empowerment to handle mental health complaints is supported by surveys demonstrating their ability to improve perceived support for diagnosing and managing problems as well as accessing resources [58].

In a narrative synthesis of PCP experiences with psychiatric eConsultation, the authors gave the specific example of a PCP who wrote about its good utility for assistance with drug management in pregnancy [55]. This points to both the need and appropriateness of eConsultation for PMADs in which the consulting practitioner requires expertise on psychotropic safety in pregnancy and breastfeeding but otherwise feels comfortable with management. Unlike issues of diagnostic complexity which are more likely to require a face-to-face evaluation, questions on the use of psychotropics in pregnancy and breastfeeding are particularly amenable to being addressed through eConsultation. While specific capacity for perinatal psychiatric eConsultation does likely exist at many institutions (including the institution of the present authors), we were only able to find one published description of such [59]. Here the Department of Mental Health in Los Angeles County launched a Reproductive Psychiatry eConsultation Pilot Project in which 59 psychiatrists received specific training in reproductive psychiatry and psychopharmacology. Because the program was separate from the EMR, many individuals found using the platform cumbersome and time consuming. They also noted the lack of incentive to spend the extra time required to engage with the platform. Though it should be noted that under new Center for Medicaid and Medicare Services billing guidelines, time taken to communicate using eConsultation would likely count towards to total billable time of the encounter, so long as it was done on the same day [60].

Currently, there is little published literature about the use of eConsultation that is specific to perinatal mental health. However, literature on the use of eConsultation to psychiatric specialists in general suggests that it has significant potential to improve management of PMADs, and some of the main consultation questions that come up with PMADs (use of drugs in pregnancy and breastfeeding) might be a particularly good fit for the eConsultation model.

Predictive Analytics

One unique approach to the identification of women at risk for postpartum mood disruption is machine learning. Machine learning (ML) leverages large data systems to identify variables to predict risk for disease in order to facilitate early identification and intervention. Research into ML methods for PMADs is still in its infancy, but current research is promising. ML utilizing health care records can predict postpartum depression as well as need for postpartum psychiatric admission with impressive psychometric accuracy [61–63, 64•, 65–67]. Similar predictive capacity with ML for postpartum depression has been demonstrated when utilizing data from

social media posting in mothers [68] and fathers [69]. While studies still differ on variables of importance (ranging from well-established risk factors such as prior mental health history and obstetric history to laboratory results) and appropriate algorithms, this remains a promising potential avenue for identification and treatment.

Conclusions

The World Health Organization recently recognized the potential of technology-based interventions in reducing health disparities, and encouraged the prioritization of the development, evaluation, implementation of technology-based approaches to perinatal mental health care promote equitable, accessible, and affordable evidence-based care [70]. The use of technology in addressing mental health has the exciting potential for creative and novel solutions to traditional limitations, including improving access to care, identification, early intervention, and treatment (for a summary, see Table 1).

Research into the integration of technology in mental health care is still limited. Studies suffer from limited replicability and methodological concerns (non-generalizable clinical populations utilized, small sample sizes, relatively few RCTs, lack of diversity, etc.), but emerging research is promising and exciting. The COVID-19 pandemic facilitated an explosion in the integration of technology services in healthcare although it is unclear how these services will persist beyond the current crisis [71]. Areas of integration can be categorized broadly into three categories: interventions, augmentation of care, and preventative care.

Interventions are perhaps the most well researched and evaluated. The use of eConsultations, mHealth programs/apps, and I-CBT have largely demonstrated efficacy in facilitating or administering mental health care. Patients have described finding these interventions acceptable and preliminary research has demonstrated their efficacy. Mobile and internet facilitated health care has the potential to improve access to specialized care, particularly for those who are not in counties with mental health care providers [6••]. While still woefully under researched, virtual reality technology may demonstrate promise in reducing anxiety in specific situations, such as anxiety surrounding delivery and childbirth.

In terms of augmentation to care, wearable technology may provide valuable information for providers in terms of areas for intervention, such as physical activity, heart rate variability, and sleep. Not only can this provide important biological information about a patient's wellness, but it also has the potential for use in biofeedback interventions that have been demonstrated to be successful interventions to reduce mental health symptoms in the perinatal period [72–74]. While this technology may have applications for

preventative care as well, it is unclear how to most effectively leverage the information provided by devices in a cost-effective manner. Further research is needed to integrate data from wearable technology into preventative care.

More promising than wearables for preventative care is ML and mHealth apps for at risk mothers. Access to psychoeducation and short-term interventions via mobile apps may help low or moderate risk mothers with subsyndromal PMAD symptoms from progressing further [17••], although the research on high-risk mothers is still unclear. Predictive analytic approaches, such as ML, are providing robust prediction of postpartum depression with similar sensitivity and specificity to the commonly utilized Edinburg Postnatal Depression Scale. Still, this is an emerging area that still establishing feasibility of concept—to date, no research study has utilized these predictive approaches to establish a preventive intervention.

Unfortunately, the current status of technology research in PMADS does not lend itself to easily implementable evidence-based recommendations for the average mental health clinician. Nonetheless, given the ubiquity of smartphones as "wearable devices," clinicians might consider asking patients to report actigraphy data (steps, sleep) captured by their smartphone to supplement clinical evaluation. While evidence is lacking to recommend specific smartphone apps for PMADS, patients may occasionally report using such apps with success, and clinicians should take this as an opportunity to familiarize themselves with currently available options. Finally, I-CBT tools (either services or smartphone apps) represent options for individuals for whom access to therapy is limited. However, many of the derivations of I-CBT mentioned in research studies are not necessarily available to the public at this time, preventing more evidence-based adoption.

When clinicians select to adopt technology-based approached to perinatal mental health care, they are recommended to take the following into consideration:

- How will this technology meaningfully improve access to and/or quality of care for this patient population? For whom will this technology not improve access and/or what populations may continue to experience disparities in care?
- How is the security of the patient data maintained? If using 3rd party applications, are the patient data sold or shared?
- How will the clinician(s) incorporate the data into their clinical workflows? Will the data be integrated into the electronic health record system?
- What equipment and other resources (e.g., adequate internet bandwidth) are required for this adopted technology to be used as intended?
- How will the clinicians handle information about potential psychiatric crises that are communicated by patients

Table 1 Summary of technological approaches to mental health care

Technology	Description	Strengths of the technology	Limitations/considerations	Potential applications for perinatal practice
mHealth	Use of portable electronic devices to support public health and health care delivery	- Nearly ubiquitous - Frequent communication - Rapid connection - Bridge support and psychoeducation	- Should supplement, rather than replace care - May increase disparities without adequate supports for diverse parents - Many commercially available applications are of poor quality - Academically developed applications are not widely available - Safety considerations for those with severe mental health concerns	- Asynchronous screening of mental health symptoms - Tracking mood/thought logs or other information for session activities - Providing just-in-time psychoeducation content
Wearable technology	Wearable devices that collect and transmit clinically relevant data	- Detection and progress monitoring of mental health symptoms - Continuous, objective data - Commercial availability	- Provides information on associated symptoms, not diagnoses - Devices may be inaccessible for low-income patients unless provided by the clinic - Commercial devices may make data challenging to compare across devices - Proprietary software with unknown analytic algorithms - May be difficult to integrate into the electronic health record system	- Monitoring sleep, movement, and heart rate variability - Providing real time feedback to patients with prompts to promote sleep hygiene, movement, and/or relaxation strategies
Internet CBT	Use of internet and technology to access and/or facilitate treatment	- Improved accessibility, particularly for rural patients - Reduced overhead - Enhanced privacy - Similar efficacy to traditional CBT	- Reimbursement concerns - Quality/strength of internet connection – may increase disparities for families without internet access unless hotspots are provided - Safety considerations for those with severe mental health concerns	- Deliver psychoeducational content to patients with mild symptoms and/or while waiting for service initiation
Virtual and augmented reality	Use of virtual or augmented reality exposure therapy facilitate extinction for specific situations and fears	- Similar success rates as traditional exposure therapy - Good acceptability - Reduction in risk/liability associated with traditional exposure therapy - Allows for explorations of situations that are too dangerous or unethical for traditional exposure therapy	- Adjunct to traditional therapy - Must be guided by providers - High up-front cost - May not be applicable for those with visual disabilities	- Preparation for procedures during the perinatal period - Exposure treatment for trauma symptoms related to birthing complications

outside of face-to-face sessions? What legal and risk management precautions need to be taken?

In summary, although behavioral technology for supporting perinatal mental health is a rapidly growing and exciting field, large-scale studies designed for translation into the clinical realm are still needed. Greater research into technology for mental health conditions outside of postpartum depression is needed as well. Technology in perinatal mental health has the potential to improve the lives of infants, mothers, partners, and families through improving accessibility to specialized care, enhancing preventative care, and facilitating clinician-patient communication. Given the public health burden PMADs represent, with potential injury to both mother and child, continued research into this area is imperative.

Declarations

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. Luca DL, Margiotta C, Staatz C, Garlow E, Christensen A, Zivin K. Financial toll of untreated perinatal mood and anxiety disorders among 2017 births in the United States. Am J Public Health. 2020;110(6):888–96.
2. Kassebaum NJ, Bertozzi-Villa A, Coggeshall MS, Shackelford KA, Steiner C, Heuton KR, et al. Global, regional, and national levels and causes of maternal mortality during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. The Lancet. 2014;384(9947):980–1004.
3. Mangla K, Hoffman MC, Trumpff C, O'Grady S, Monk C. Maternal self-harm deaths: an unrecognized and preventable outcome. Am J Obstet Gynecol. 2019;221(4):295–303.
4. Earls MF, Yogman MW, Mattson G, Rafferty J. Incorporating recognition and management of perinatal depression into pediatric practice. Pediatrics. 2019;143(1): e20183259.
5. Presidential task force on redefining the postpartum visit committee on obstetric practice. ACOG Committee Opinion No. 736: Optimizing Postpartum Care. Obstetrics & Gynecology. 2018;131(5):e140-e50.
6.•• Andrilla CHA, Patterson DG, Garberson LA, Coulthard C, Larson EH. Geographic variation in the supply of selected behavioral health providers. American journal of preventive medicine. 2018;54(6):S199-S207. **The findings of this article regarding the dearth of mental health providers in many regions help frame the rationale for increasing the ability**

Table 1 (continued)

Technology	Description	Strengths of the technology	Limitations/considerations	Potential applications for perinatal practice
eConsultation	Asynchronous secure electronic communication between the patient's current provider and a specialist	- Allows the patient to continue care with established/trusted provider - Avoidance of waitlists and delays in treatment - Improved access to specialty care - Reduction in stigma and non-adherence - Utilization increases provider comfort and empowers providers to address mental health	- Requires high degree of provider comfort, which may result in underutilization - Institutional/liability concerns - Challenges in reimbursement for time spent in or providing consultations	- Obstetricians/advanced practice providers/midwives, family medicine physicians, and primary care providers can consult with reproductive psychiatrist to initiate or change psychotropic medications for a patient presenting with mental health symptoms
Predictive analytics	Use of predictive analytic approaches to automate large data systems to identify patients at risk for mental health complications	- High psychometric accuracy - Allows for full utilization of the electronic medical records - May identify novel predictors not previously considered	- Limited research - Need for identification of appropriate algorithms - Provider bias and disparities must be considered carefully to avoid encoding bias into the algorithm	- Medical practices and hospital systems may develop and/or adopt algorithms for predicting patients at risk for mental health and/or substance use disorders in the perinatal period

to provide mental health therapy remotely through mobile health applications.

7. Howard LM, Khalifeh H. Perinatal mental health: a review of progress and challenges. World Psychiatry. 2020;19(3):313–27.

8. Müller M, Matthies LM, Goetz M, Abele H, Brucker SY, Bauer A, et al. Effectiveness and cost-effectiveness of an electronic mindfulness-based intervention (eMBI) on maternal mental health during pregnancy: the mindmom study protocol for a randomized controlled clinical trial. Trials. 2020;21(1):933.

9.●● Hussain-Shamsy N, Shah A, Vigod SN, Zaheer J, Seto E. Mobile health for perinatal depression and anxiety: scoping review. J Med Internet Res. 2020;22(4):e17011. **This review explores the scope of mobile health interventions for these conditions and frames the work in the context of the need to expand treatment access for women with these conditions.**

10. Nishi D, Imamura K, Watanabe K, Obikane E, Sasaki N, Yasuma N, et al. Internet-based cognitive–behavioural therapy for prevention of depression during pregnancy and in the post partum (iPDP): a protocol for a large-scale randomised controlled trial. BMJ Open. 2020;10(5): e036482.

11. Loughnan SA, Newby JM, Haskelberg H, Mahoney A, Kladnitski N, Smith J, et al. Internet-based cognitive behavioural therapy (I-CBT) for perinatal anxiety and depression versus treatment as usual: study protocol for two randomised controlled trials. Trials. 2018;19(1):56.

12. Dol J, Richardson B, Murphy GT, Aston M, McMillan D, Campbell-Yeo M. Impact of mobile health interventions during the perinatal period on maternal psychosocial outcomes: a systematic review. JBI Evidence Synthesis. 2020;18(1):30–55.

13. Dalton JA, Rodger D, Wilmore M, Humphreys S, Skuse A, Roberts CT, et al. The Health-e Babies App for antenatal education: feasibility for socially disadvantaged women. PLoS ONE. 2018;13(5): e0194337.

14. Lau Y, Htun TP, Wong SN, Tam WSW, Klainin-Yobas P. Therapist-supported internet-based cognitive behavior therapy for stress, anxiety, and depressive symptoms among postpartum women: a systematic review and meta-analysis. J Med Internet Res. 2017;19(4): e138.

15. Mackintosh N, Agarwal S, Adcock K, Armstrong N, Briley A, Patterson M, et al. Online resources and apps to aid self-diagnosis and help seeking in the perinatal period: a descriptive survey of women's experiences. Midwifery. 2020;90: 102803.

16. Firth J, Torous J, Nicholas J, Carney R, Pratap A, Rosenbaum S, et al. The efficacy of smartphone-based mental health interventions for depressive symptoms: a meta-analysis of randomized controlled trials. World Psychiatry. 2017;16(3):287–98.

17.●● Zhou C, Hu H, Wang C, Zhu Z, Feng G, Xue J, et al. The effectiveness of mHealth interventions on postpartum depression: a systematic review and meta-analysis. Journal of telemedicine and telecare. 2020:1357633X20917816. **This comprehensive review provides preliminary support for the efficacy of mHealth interventions in both preventing PMADs and relieving mild symptoms of them**

18. Lee Y, Cho S. Technology-supported interventions for pregnant women: a systematic review. CIN: Computers, Informatics, Nursing. 2019;37(10):501–12.

19. Dol J, Richardson B, Murphy GT, Aston M, McMillan D, Campbell-Yeo M. Impact of mobile health interventions during the perinatal period on maternal psychosocial outcomes: a systematic review. JBI Evid Synth. 2020;18(1):30–55.

20. Mo Y, Gong W, Wang J, Sheng X, Xu DR. The association between the use of antenatal care smartphone apps in pregnant women and antenatal depression: cross-sectional study. JMIR Mhealth Uhealth. 2018;6(11): e11508.

21. Kernot J, Lewis L, Olds T, Maher C. Effectiveness of a facebook-delivered physical activity intervention for postpartum women: a randomized controlled trial. J Phys Act Health. 2019;16(2):125–33.

22. Richardson B, Dol J, Rutledge K, Monaghan J, Orovec A, Howie K, et al. Evaluation of mobile apps targeted to parents of infants in the neonatal intensive care unit: systematic app review. JMIR Mhealth Uhealth. 2019;7(4): e11620.

23. Rau NM, Hasan K, Ahamed SI, Asan O, Flynn KE, Basir MA. Designing a tablet-based prematurity education app for parents hospitalized for preterm birth. Int J Med Inform. 2020;141: 104200.

24. Fonseca A, Alves S, Monteiro F, Gorayeb R, Canavarro MC. Be a mom, a web-based intervention to prevent postpartum depression: results from a pilot randomized controlled trial. Behav Ther. 2020;51(4):616–33.

25. Shorey S, Chee CYI, Ng ED, Lau Y, Dennis CL, Chan YH. Evaluation of a technology-based peer-support intervention program for preventing postnatal depression (part 1): randomized controlled trial. J Med Internet Res. 2019;21(8): e12410.

26. Shorey S, Ng YP, Danbjørg DB, Dennis CL, Morelius E. Effectiveness of the 'Home-but not Alone' mobile health application educational programme on parental outcomes: a randomized controlled trial, study protocol. J Adv Nurs. 2017;73(1):253–64.

27. Baumel A, Tinkelman A, Mathur N, Kane JM. Digital peer-support platform (7Cups) as an adjunct treatment for women with postpartum depression: feasibility, acceptability, and preliminary efficacy study. JMIR Mhealth Uhealth. 2018;6(2): e38.

28. Fealy S, Chan S, Wynne O, Dowse E, Ebert L, Ho R, et al. The Support for New Mums Project: a protocol for a pilot randomized controlled trial designed to test a postnatal psychoeducation smartphone application. J Adv Nurs. 2019;75(6):1347–59.

29. Sawyer A, Kaim A, Le HN, McDonald D, Mittinty M, Lynch J, et al. The effectiveness of an app-based nurse-moderated program for new mothers with depression and parenting problems (eMums Plus): pragmatic randomized controlled trial. J Med Internet Res. 2019;21(6): e13689.

30. Tucker L, Villagomez AC, Krishnamurti T. Comprehensively addressing postpartum maternal health: a content and image review of commercially available mobile health apps. BMC Pregnancy Childbirth. 2021;21(1):1–11.

31. Hussain-Shamsy N, Shah A, Vigod SN, Zaheer J, Seto E. Mobile health for perinatal depression and anxiety: scoping review. J Med Internet Res. 2020;22(4): e17011.

32. Zhang R, Nicholas J, Knapp AA, Graham AK, Gray E, Kwasny MJ, et al. Clinically meaningful use of mental health apps and its effects on depression: mixed methods study. J Med Internet Res. 2019;21(12): e15644.

33. Insel TR. Digital phenotyping: technology for a new science of behavior. JAMA. 2017;318(13):1215.

34. Onnela J-P, Rauch SL. Harnessing smartphone-based digital phenotyping to enhance behavioral and mental health. Neuropsychopharmacology. 2016;41(7):1691–6.

35. Tazawa Y, Wada M, Mitsukura Y, Takamiya A, Kitazawa M, Yoshimura M, et al. Actigraphy for evaluation of mood disorders: a systematic review and meta-analysis. J Affect Disord. 2019;253:257–69.

36. De Crescenzo F, Economou A, Sharpley AL, Gormez A, Quested DJ. Actigraphic features of bipolar disorder: a systematic review and meta-analysis. Sleep Med Rev. 2017;33:58–69.

37. Reinertsen E, Clifford GD. A review of physiological and behavioral monitoring with digital sensors for neuropsychiatric illnesses. Physiol Meas. 2018;39(5):05TR1.

38. Faherty LJ, Hantsoo L, Appleby D, Sammel MD, Bennett IM, Wiebe DJ. Movement patterns in women at risk for perinatal depression: use of a mood-monitoring mobile application in pregnancy. J Am Med Inform Assoc. 2017;24(4):746–53.

39. Obeysekare JL, Cohen ZL, Coles ME, Pearlstein TB, Monzon C, Flynn EE, et al. Delayed sleep timing and circadian rhythms

in pregnancy and transdiagnostic symptoms associated with postpartum depression. Transl Psychiatry. 2020;10.

40. Carr O, Saunders KEA, Tsanas A, Bilderbeck AC, Palmius N, Geddes JR, et al. Variability in phase and amplitude of diurnal rhythms is related to variation of mood in bipolar and borderline personality disorder. Sci Rep. 2018;8.

41. Tazawa Y, Liang K-C, Yoshimura M, Kitazawa M, Kaise Y, Takamiya A, et al. Evaluating depression with multimodal wristband-type waearable device: screening and assessing patient severity utilizing machine-learning. Heliyon. 2020;6(2).

42.•• Loughnan SA, Joubert AE, Grierson A, Andrews G, Newby JM. Internet-delivered psychological interventions for clinical anxiety and depression in perinatal women: a systematic review and meta-analysis. Archives of women's mental health. 2019;22(6):737–50. **Results revealed I-CBT interventions have similar acceptability and clinical efficacy in the reduction of mood and anxiety symptoms as more traditional face-to-face treatments.**

43. Milgrom J, Danaher BG, Gemmill AW, Holt C, Holt CJ, Seeley JR, et al. Internet cognitive behavioral therapy for women with postnatal depression: a randomized controlled trial of Mum-MoodBooster. J Med Internet Res. 2016;18(3): e4993.

44. Powers MB, Emmelkamp PM. Virtual reality exposure therapy for anxiety disorders: a meta-analysis. J Anxiety Disord. 2008;22(3):561–9.

45. Garcia-Palacios A, Botella C, Hoffman H, Fabregat S. Comparing acceptance and refusal rates of virtual reality exposure vs. in vivo exposure by patients with specific phobias. Cyberpsychol Behav. 2007;10(5):722–4.

46. Martin JA, Hamilton BE, Osterman MJK, Driscoll AK. Births: final data for 2018. Natl Vital Stat Rep. 2019;68(13):1–47.

47. Räisänen S, Lehto SM, Nielsen HS, Gissler M, Kramer MR, Heinonen S. Fear of childbirth predicts postpartum depression: a population-based analysis of 511 422 singleton births in Finland. BMJ Open. 2013;3(11): e004047.

48. Hobson JA, Slade P, Wrench IJ, Power L. Preoperative anxiety and postoperative satisfaction in women undergoing elective caesarean section. Int J Obstet Anesth. 2006;15(1):18–23.

49. Bekelis K, Calnan D, Simmons N, MacKenzie TA, Kakoulides G. Effect of an immersive preoperative virtual reality experience on patient reported outcomes: a randomized controlled trial. Ann Surg. 2017;265(6):1068–73.

50. Koo C-H, Park J-W, Ryu J-H, Han S-H. The effect of virtual reality on preoperative anxiety: a meta-analysis of randomized controlled trials. J Clin Med. 2020;9(10):3151.

51. •Noben L, Goossens SMTA, Truijens SEM, Van Berckel MMG, Perquin CW, Slooter GD, et al. A virtual reality video to improve information provision and reduce anxiety before cesarean delivery: randomized controlled trial. JMIR Mental Health. 2019;6(12):e15872. **This is one of the only published applications of virtual reality exposure therapy to perinatal mental health issues. Results trended towards significance in this RCT, with the authors noting that the study was underpowered.**

52. Lowenstein M, Bamgbose O, Gleason N, Feldman MD. Psychiatric consultation at your fingertips: descriptive analysis of electronic consultation from primary care to psychiatry. J Med Internet Res. 2017;19(8): e279.

53.• Liddy C, Moroz I, Mihan A, Nawar N, Keely E. A systematic review of asynchronous, provider-to-provider, electronic consultation services to improve access to specialty care available worldwide. Telemedicine and e-Health. 2018;25(3):184–98. **The overarching conclusion of this literature is that eConsultation is associated with improved access to specialist care and is perceived positively, but there was limited literature with**

regards to perinatal mental health for the review to draw upon.

54. Liddy C, Drosinis P, Keely E. Electronic consultation systems: worldwide prevalence and their impact on patient care—a systematic review. Fam Pract. 2016;33(3):274–85.

55. Vimalananda VG, Gupte G, Seraj SM, Orlander J, Berlowitz D, Fincke BG, et al. Electronic consultations (e-consults) to improve access to specialty care: a systematic review and narrative synthesis. J Telemed Telecare. 2015;21(6):323–30.

56. Hensel JM, Yang R, Rai M, Taylor VH. Optimizing electronic consultation between primary care providers and psychiatrists: mixed-methods study. J Med Internet Res. 2018;20(4): e124.

57. Archibald D, Stratton J, Liddy C, Grant RE, Green D, Keely EJ. Evaluation of an electronic consultation service in psychiatry for primary care providers. BMC Psychiatry. 2018;18(1):1–7.

58. Golberstein E, Kolvenbach S, Carruthers H, Druss B, Goering P. Effects of electronic psychiatric consultations on primary care provider perceptions of mental health care: survey results from a randomized evaluation. Healthcare. 2018;6(1):17–22.

59. Dossett EC, Benitez C, Garcia N. Perinatal mental health in community psychiatry: a reproductive psychiatry eConsult pilot project. PS. 2019;70(11):1075–6.

60. Centers for Medicare and Medicaid Services. 2020. https://www.cms.gov/medicaremedicare-fee-service-paymentphysicianfeeschedpfs-federal-regulation-notices/cms-1734-f

61. Amit G, Girshovitz I, Marcus K, Zhang Y, Pathak J, Bar V, et al. Estimation of postpartum depression risk from electronic health records using machine learning. BMC Pregnancy Childbirth. 2021;21(1):630.

62. Andersson S, Bathula DR, Iliadis SI, Walter M, Skalkidou A. Predicting women with depressive symptoms postpartum with machine learning methods. Sci Rep. 2021;11(1):7877.

63. Betts KS, Kisely S, Alati R. Predicting postpartum psychiatric admission using a machine learning approach. J Psychiatr Res. 2020;130:35–40.

64.• Hochman E, Feldman B, Weizman A, Krivoy A, Gur S, Barzilay E, et al. Development and validation of a machine learning-based postpartum depression prediction model: a nationwide cohort study. Depr Anxi. 2021;38(4):400–11. **This is a particularly strong study due to its large sample size and while expected variables such as history of depression were identified as a strong predictor of new-onset postpartum depression, so were unexpected variables such as different patterns of blood tests.**

65. Shin D, Lee KJ, Adeluwa T, Hur J. machine learning-based predictive modeling of postpartum depression. J Clin Med. 2020;9(9).

66. Wang S, Pathak J, Zhang Y. Using electronic health records and machine learning to predict postpartum depression. Stud Health Technol Inform. 2019;264:888–92.

67. Zhang W, Liu H, Silenzio VMB, Qiu P, Gong W. Machine learning models for the prediction of postpartum depression: application and comparison based on a cohort study. JMIR Med Inform. 2020;8(4): e15516.

68. Fatima I, Abbasi BU, Khan S, Al-Saeed M, Ahmad HF, Mumtaz R. Prediction of postpartum depression using machine learning techniques from social media text. Exp Syst. 2019;36.

69. Shatte ABR, Hutchinson DM, Fuller-Tyszkiewicz M, Teague SJ. Social media markers to identify fathers at risk of postpartum depression: a machine learning approach. Cyberpsychol Behav Soc Netw. 2020;23(9):611–8.

70. Organization WH. WHO guideline: recommendations on digital interventions for health system strengthening: World Health Organization. 2019.

71. Haque SN. Telehealth Beyond COVID-19. Psychiatr Serv. 2021;72(1):100–3.

72. Kudo N, Shinohara H, Kodama H. Heart rate variability biofeedback intervention for reduction of psychological stress during the early postpartum period. Appl Psychophysiol Biofeedback. 2014;39(3–4):203–11.

73. Beckham AJ, Greene TB, Meltzer-Brody S. A pilot study of heart rate variability biofeedback therapy in the treatment of perinatal depression on a specialized perinatal psychiatry inpatient unit. Arch Womens Ment Health. 2013;16(1):59–65.

74. Herbell K, Zauszniewski JA. Reducing psychological stress in peripartum women with heart rate variability biofeedback: a systematic review. J Holist Nurs. 2019;37(3):273–85.