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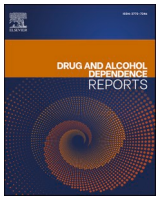

A phase I pilot study of a mobile education tool for supporting pregnant women with opioid use disorder

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HIGHLIGHTS

- Videos covered neonatal abstinence syndrome, stigma, child protective services, postpartum support, and infant care.
- Perinatal women found the tool to be highly acceptable and usable.
- Perinatal women reported greater preparedness, self-advocacy, and confidence navigating the perinatal period.
- Tool holds promise for improved clinical and neonatal outcomes to be evaluated in future trials.

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ABSTRACT

Background: Perinatal opioid use disorder (OUD) and neonatal abstinence syndrome (NAS) require targeted interventions to address gaps in maternal education and support. Maternal involvement in non-pharmacological NAS care is essential for improving neonatal outcomes, yet many mothers lack accessible resources to manage NAS symptoms and to navigate social and healthcare challenges. Mobile health applications offer a promising solution, but few cater specifically to the needs of perinatal women with OUD.
Objective: We assessed the usability, acceptability, and feasibility of a new mobile educational tool for pregnant women with OUD, focusing on the perinatal period and NAS care.
Results: Six perinatal women with OUD (n = 1 pregnant, n = 5 postpartum; mean age 31) found the tool highly acceptable (modified CSQ-8 mean=28.8 out of 32) and usable (modified SUS mean=45.0 out of 50). Most were likely to use the tool during pregnancy and postpartum, citing improved preparedness for advocating for themselves, managing NAS, and navigating CPS. Feedback suggested expanding content on infant withdrawal medications.
Conclusions: This mobile tool shows promise in empowering perinatal women with OUD. Further research is needed to evaluate its impact on clinical and neonatal outcomes.

1. Introduction

Substance use disorders and specifically opioid use disorder (OUD) during pregnancy have remained a significant public health concern, with a notable impact on maternal and neonatal health. The prevalence of perinatal OUD in the United States has increased sharply, with a 131 % rise in opioid use during pregnancy and an 82 % increase in neonatal abstinence syndrome (NAS) between 2010 and 2017 (Haight et al., 2018; Hirai et al., 2021; Martin et al., 2020; Ryan et al., 2023; Short et al., 2018). NAS, which results from in-utero exposure to opioids

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and other substances, manifests as withdrawal symptoms in newborns, including autonomic and neurobehavioral dysfunction, feeding difficulties, and respiratory distress (Jones et al., 2019; Kocherlakota, 2014; McQueen and Murphy-Oikonen, 2016). Federal agencies introduced the term Neonatal Opioid Withdrawal Syndrome (NOWS) to specify opioid-related withdrawal, but given the frequent co-use of substances, NAS remains the more inclusive term (Food and Administration, 2016; Jilani et al., 2022; Jones and Kraft, 2019). The rise of potent synthetic opioids like fentanyl has further exacerbated this crisis, potentially increasing the severity and complexity of NAS cases (Bruzelius and Martins, 2022; Jalal et al., 2018; Wouldes and Lester, 2023).

Depending on symptom severity and other risk factors such as preterm birth, infants with NAS may require prolonged hospital stays and ongoing follow-up care to monitor developmental milestones and provide long-term support for both the infant and their family (Hudak and Tan, 2012; Kocherlakota, 2014; McQueen and Murphy-Oikonen, 2016; Patrick et al., 2016; Van Horn et al., 2020; Velez and Jansson, 2008). Effective NAS management requires a multidisciplinary approach, with nonpharmacologic interventions such as swaddling, skin-to-skin contact, and responsive caregiving serving as first-line treatments, along with pharmacological therapies such as morphine, methadone, or clonidine when necessary (Patrick et al., 2016; Wachman et al., 2018). The "Eat, Sleep, and Console" (ESC) model which prioritizes parental involvement and minimizes pharmacologic interventions, has become the gold standard of care (Devlin et al., 2024; Grossman et al., 2018; Young et al., 2023). However, the success of these approaches relies on engaging and supporting mothers, who are often the most effective caregivers for infants with NAS (Grossman et al., 2017; Jones and Fielder, 2015; McQueen and Murphy-Oikonen, 2016; Patrick et al., 2016; Hudak and Tan, 2012; Kocherlakota, 2014; MacMillan et al., 2018; Velez and Jansson, 2008). Engaging mothers in the postpartum period is critical to reducing infant hospital readmissions and overall length of stay, as well as encouraging breastfeeding, decreasing the need for pharmacologic interventions, and supporting maternal-child bonding (Grossman et al., 2018; Suchman et al., 2004; Velez and Jansson, 2008). However, challenges such as poverty, stigma, lack of access to treatment, housing insecurity, and involvement with child protective services (CPS) can disrupt maternal-infant bonding and hinder effective NAS management. Marginalized populations, in particular, face additional barriers, including exposure to violence and criminal justice involvement, further restricting access to perinatal care and negatively impacting maternal and infant outcomes (Ashford et al., 2018; Faherty et al., 2018; Holbrook and Kaltenbach, 2012; Jones and Fielder, 2015; Leiner et al., 2021; Marcelin et al., 2019; Salazar et al., 2023; Stone, 2015; Van Boekel et al., 2013; Bailey et al., 2017; Prather et al., 2018; Schiff et al., 2022; Sohn, 2017).

While medications for opioid use disorder (MOUD) remain a cornerstone of perinatal OUD treatment, comprehensive care also requires education and support services tailored to the needs of mothers and their infants. Mobile health applications have emerged as promising tools for enhancing adherence to opioid treatment and providing accessible, stigma-free education on sensitive health topics to individuals with opioid-related disorders (Bricker and McAfee, 2021; Jordan et al., 2023; Richterman et al., 2023; Sop et al., 2022; Vilardaga et al., 2020). Many studies emphasize the growing interest and potential of digital health interventions, particularly mobile applications, in addressing substance use disorders and related health challenges (Hai et al., 2019; Kazemi et al., 2017; Raynor et al., 2023; Silang et al., 2021).

Mobile health applications have strengths that can make them a particularly useful option for certain topics and populations. For example, mobile health applications offer increased convenience, privacy, and portability over other intervention methods (Willoughby, 2017). Additionally, technology-based tools are often seen as appealing and offer benefits such as interactivity (Willoughby, 2021), which has been found beneficial for mobile intervention engagement (Wei et al., 2020). Pregnant and postpartum individuals with OUD may particularly benefit from a mobile-based intervention due to these features. The information provided can be accessed at their convenience, at a time and location they deem appropriate, and offers privacy for learning about a topic that is highly sensitive and stigmatized.

Although digital interventions for substance use disorders exist, most focus on treatment adherence rather than education, lack interactivity, and do not specifically address the unique challenges of pregnant and postpartum women with OUD. Some prior research has shown feasibility and efficacy of prenatal education initiatives targeting pregnant mothers with OUD in areas such as breastfeeding, parenting skills and infant care (Brocato et al., 2022; Giles et al., 2016), but there appears to be a lack of standardized or readily available mobile educational resources that incorporate comprehensive information and skills based on our current perinatal and neonatal care knowledge (Raynor et al., 2023). For example, a recent scoping review of digital health interventions designed for pregnant and early parenting women with substance use disorders found that while many digital health interventions exist, most focus on pregnancy rather than postpartum care, lack family or community involvement, include text-based, not intuitive designs, and have limited research on long-term efficacy, highlighting the need for more tailored and comprehensive approaches to support sustained recovery and empowerment (Raynor et al., 2023).

A notable recent technology-based educational intervention for perinatal women with OUD is Project BETTER (Martin et al., 2022). This program evaluated the feasibility and acceptability of a web-based educational tool that covers topics such as NOWS, postpartum maternal health, and interactions with child welfare services. The modules, delivered through an animated narrator, incorporate non-stigmatizing language, motivational interviewing techniques, and professionally produced videos featuring patient testimonies and trauma-informed healthcare providers. While Project BETTER shares similarities with our tool and represents an important advancement in perinatal OUD education, our tool differs in key ways. It offers expanded modules, including hands-on skills for caring for a newborn with NAS, and specific resources during the perinatal period (e.g. housing, treatment, food, legal aid), as well as it is designed for use both within and beyond clinical settings, ensuring broad applicability and accessibility for women with OUD.

1.1. *Development of NAS caregiving educational tool*

Building on our previous work developing an NAS educational tool for Neonatal Intensive Care Unit (NICU) healthcare providers, we created a mobile educational tool designed specifically for pregnant and postpartum women with OUD. Unlike general prenatal apps, this tool provides targeted, evidence-based content addressing evidence-based NAS care, maternal health, postpartum resources, navigating stigma in interactions with healthcare providers, and CPS involvement. It incorporates a person-centered approach based on qualitative insights from both perinatal patients and healthcare providers. Additionally, it delivers content through engaging, video-based modules rather than static text, making it more accessible for individuals with varying literacy levels and learning preferences (Burduli et al., 2019).

To develop a relevant educational tool for pregnant women with OUD, we initiated a multi-stage study (Burduli et al., 2021). Formative research that involves understanding the needs and perspectives of the target audience is an important step in the health communication planning process (Noar, 2006; Willoughby and Noar, 2022). In the first stage, we conducted semi-structured interviews with 10 perinatal women with OUD and 10 healthcare providers experienced in NAS and perinatal OUD. The findings highlighted several challenges. Perinatal women with OUD reported a lack of clarity regarding how to access treatment and resources. They expressed a desire for less judgment and more transparency, support, education, and preparation from their healthcare providers when navigating the health, social, and legal systems during pregnancy and postpartum. Detailed results of our

interviews are published elsewhere (Burduli et al., 2022). The interviews offered valuable insight into the needs of pregnant women navigating OUD, pregnancy, and parenting while preparing to care for infants with NAS. This feedback formed the basis for adapting our existing tool to meet the specific needs of this vulnerable population. Detailed findings of the semi-structured interviews have been previously published (Burduli et al., 2022). We incorporated this input from the semi-structured interviews together with content from a previously developed NAS Primer and Reference tool (Burduli et al., 2019), an interactive mobile resource for NICU healthcare providers which features evidence-based modules on various NAS topics. In total, seven educational modules were developed for perinatal women with OUD. The content development process involved multiple iterations over a one-year period, with input from several authors and refinement by a health communications researcher (Author JW) to ensure intuitive, person-first, and de-stigmatizing language at an 8th-grade reading level.

1.2. Study objective

In this study, our specific objective was to assess the usability, acceptability, and feasibility of a mobile educational tool designed to support pregnant and postpartum women with OUD in navigating pregnancy, postpartum care, and infant care related to NAS in a pilot study.

2. Methods

2.1. Description of NAS caregiving educational tool

We created seven educational modules, covering several topics designed to prepare and empower perinatal women with OUD to navigate pregnancy, postpartum, NAS care, and the challenging healthcare and legal systems. A key objective was to minimize the overall tool's duration to less than an hour to reduce the time strain while ensuring no individual video exceeded 15 minutes, making the content more manageable and accessible for viewers. These modules address key informational gaps identified in the interviews from stage one (Burduli et al., 2022), and range in length from 3:52–12:37 minutes. The total duration of the intervention for all modules was approximately 50 minutes. Each video has a section titled "Key points to remember" which outlines the highlights of that specific video. All videos include subtitles. See Table 1 for detailed overview of each video and see Fig. 1 for static examples of the videos.

Table 1
NAS caregiving educational tool overview.

Module Title	Description	Key Features	Duration in Minutes
1. Introduction	Introduces the viewer to the educational content and animated characters. A pregnant patient shares her substance use story and reasons for the visit.	Character introduction, context setting	04:23
2. Preparing for Baby and Delivery	The provider defines NAS and explains assessment and treatment. Offers an overview of pregnancy, delivery, and immediate postpartum. Patient discusses concerns.	NAS overview, patient-provider dialogue	06:11
3. Hospital Experience	Covers expectations during delivery, self-advocacy, stigma navigation, pain management, and breastfeeding considerations.	Stigma awareness, self-advocacy tips	03:52
4. NAS Assessment	Describes newborn assessment methods (ESC, Finnegan Scoring System) and pharmacological treatment options.	Assessment tools, treatment explanation	07:44
5. Newborn Care	Explains non-pharmacological NAS care (e.g., low-stimulating environment, feeding), safe newborn care practices, and introduces a pediatric nurse character demonstrating skills.	Caregiving skills, safe sleep, newborn care education	12:37
6. Postpartum Maternal Care	Provides postpartum care information, emphasizes MOUD treatment, medical follow-up, naloxone, mental health, and access to community/legal resources.	MOUD benefits, community resources, naloxone info	05:37
7. Child Protective Services (CPS)	Introduces a social worker who educates on CPS rights/responsibilities, plans of safe care, legal rights, and advocacy strategies to help keep newborns with parents.	Legal rights, CPS education, advocacy tips	07:09

Note. NAS=Neonatal Abstinence Syndrome. MOUD= Medication for opioid use disorder. CPS= Child protective services. ESC = Eat, Sleep, Console.

2.2. Acceptability, usability, and feasibility

2.2.1. Data collection and outcomes

Perinatal women receiving MOUD from various recovery centers across Washington State contacted our study team through flyer advertisements from March to November 2024. Consented participants viewed the educational videos via a private REDCap survey link with the seven videos embedded in it and then completed a survey assessing several measures.

Acceptability was evaluated with the modified 8-item Client Satisfaction Questionnaire (CSQ-8). The CSQ-8 measures satisfaction with health services using a 4-point Likert-type scale (Attkisson and Greenfield, 2004; Attkisson and Zwick, 1982). The CSQ-8 has been validated and translated to multiple languages (Attkisson and Greenfield, 2004). Possible total scores on the CSQ-8 range from 8 to 32, with higher scores (>23) indicating greater satisfaction with health services. We adapted the language to fit the educational videos used in this study. For example, *"How would you rate the quality of care you received"* was changed to *"How would you rate the quality of the educational videos you viewed."* Acceptability was additionally assessed via an open-ended question for feedback (in response to the prompt *"Do you have any suggestions to improve any of the educational videos? Please be as detailed as possible and include any suggestions for adding, removing, or clarifying information")* to capture participants' perceptions and suggestions for improvement.

Usability was assessed using a modified 10-item Systems Usability Scale (SUS), in which participants are asked to answer questions about a mobile app or website using a 5-point Likert scale ranging from strongly disagree to strongly agree, with higher scores indicating more favorable ratings. The SUS is currently the industry standard for evaluation of a wide variety of products and services such as software, mobile devices, websites, and applications (Bangor et al., 2009; www.usability.gov, 2019). The SUS has been shown to successfully differentiate between usable and unusable systems, as well as it can be used in small samples with reliable results (Bangor et al., 2009; www.usability.gov, 2019). The SUS questions were adapted to reflect the educational videos instead of an app or website. For example, the item *"I think that I would like to use this app/website frequently"* was changed to *"I think that I would like to use these educational videos frequently."*

Feasibility was assessed through questions about the ability to incorporate the NAS caregiving tool into daily activities (e.g., *"To what*

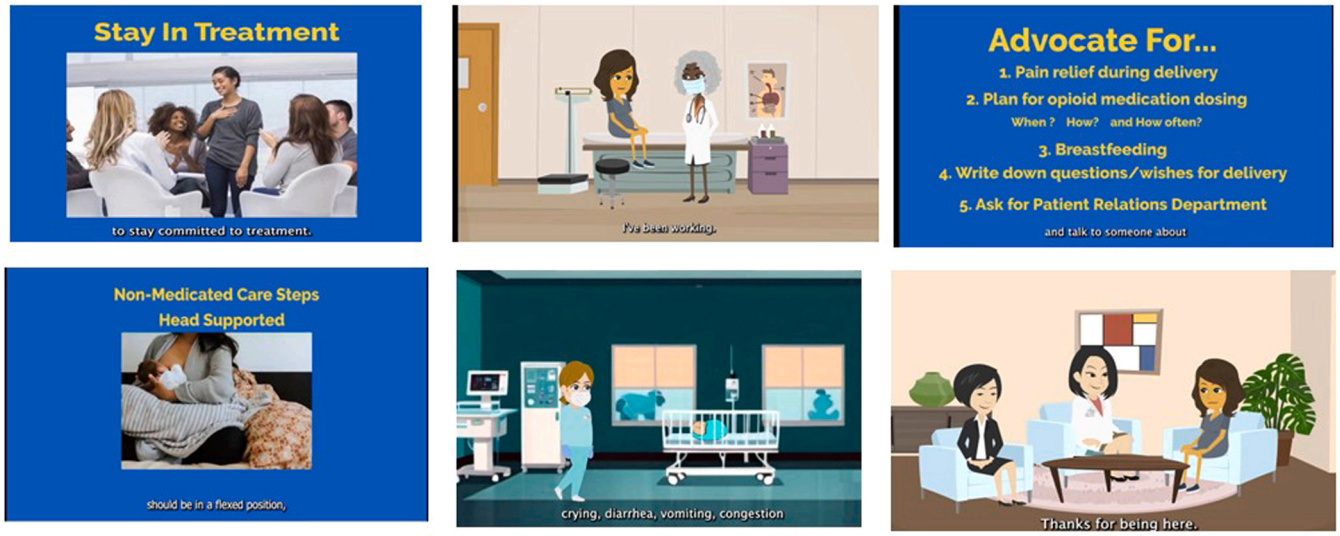

Fig. 1. Example from the different educational videos.

extent do you expect to be able to incorporate the NAS caregiving tool in your daily activities during pregnancy and postpartum?") and tracking module usage. Participants received a $25 Amazon e-gift card for their time. Detailed survey responses are given in Table 2.

Table 2
Participant characteristics and acceptability, usability, feasibility response frequencies.

DEMOGRAPHIC QUESTIONS	Mean (SD)	N (out of 6)
Age	31.0 (3.35)	
Perinatal status		
Pregnant		1
Postpartum		5
MOUD		
Methadone		4
Buprenorphine		1
Buprenorphine + Naloxone		1
ACCEPTABILITY, USABILITY, FEASIBILITY QUESTIONS		
Modified CSQ—8 Total Score (out of 32)	28.8 (2.32)	
Modified SUS Total Score (out of 50)	45.0 (4.86)	
How likely are you to use the information you learned from the educational videos in your daily activities during pregnancy?		
Very Likely		4
Somewhat Likely		2
How likely are you to use the information you learned from the educational videos in your daily activities during postpartum?		
Very Likely		5
Somewhat Likely		1
Did the information from the educational videos help you feel better prepared for (please select all that apply)		**Endorsement Frequency**
Taking care of a newborn		1
Taking care of a newborn experiencing opioid withdrawal symptoms		4
Navigating pregnancy and birth		1
Finding available resources (treatment/ housing/food)		3
The hospital experience		2
The postpartum period		4
Advocating for myself		4

Note. MOUD=Medication for opioid use disorder. M= Mean. SD=Standard deviation. CSQ-8 = Client Satisfaction Questionnaire. SUS= Systems Usability Scale.

2.2.2. Inclusion criteria

Participants had to be pregnant or postpartum individuals (within 12 months postpartum) (1) who were currently receiving MOUD, (2) aged > 18 years, and (3) who were able to speak and understand English.

2.2.3. Data analysis

Descriptive analyses were conducted using percentages, means, and standard deviations (SDs) to describe the feasibility and acceptability of the adapted mobile educational tool for pregnant women receiving MOUD. All descriptive analyses were conducted using SPSS version 29. This developmental stage did not require inferential tests due to the small sample size, and the qualitative work was the primary driver of the modifications to be made and eventually to be tested in a randomized trial in a future study.

The university's Institutional Review Board deemed this study exempt from review.

3. Results

3.1. Acceptability, usability, and feasibility

3.1.1. Participant characteristics

A total of six participants contacted the study team after encountering the study flyer and all six were screened eligible to participate in the study. All six watched the videos and completed the feedback questionnaire. The average reported age of participants was 31 years, (standard deviation [SD]=3.35; range 28–37 years). Five of the participants were postpartum (within 12 months of giving birth) and one participant was (6 months) pregnant. Four of the participants reported receiving methadone as their MOUD, one reported receiving Suboxone as their MOUD and one was receiving Buprenorphine as their MOUD.

3.1.2. Acceptability, usability, and feasibility

Modified CSQ-8 total scores for the six participants ranged from 26 to 32, mean= 28.83 (SD=2.32). Modified SUS total scores ranged from 38 to 50, mean= 45.0 (SD=4.86). To the question "*How likely are you to use the information you learned from the educational videos in your daily activities during pregnancy?"* n = 4 participants answered "very likely" and n = 2 participants answered "somewhat likely". Similarly, to the question "*How likely are you to use the information you learned from the educational videos in your daily activities during postpartum?"* n = 5 participants answered "very likely" and n = 1 participant answered "somewhat likely". Three participants noted watching four of the videos

(*Hospital Experience, Neonatal Abstinence Syndrome Assessment and Treatment, Postpartum Newborn Care,* and *Child Protective Services*) more than once. For the question *"Did the information from the educational videos help you feel better prepared for (please select all that apply)"*, the most common reasons endorsed (by at least 4 out of the 6 participants), were: "*Advocating for myself*", *"Taking care of a newborn experiencing opioid withdrawal symptoms", "Finding available resources", and "The postpartum period"*.

Open ended feedback included several positive comments about the content of the educational videos. For example, one participant noted *"This video made me feel very confident in dealing with situations that I may be faced with at the hospital and with CPS."*, and another wrote *"Thank you for better preparing me for my delivery and taking the time to make this educational video. I am happy there are people out there who care about women like me in my circumstance."* One participant recommended adding more detailed information about the utility of opioid medications for infant withdrawal symptoms *"I would give more information on what the morphine and clonidine does for the babies."*

4. Discussion

This pilot study highlights the potential of a mobile educational tool to address gaps in the support and education of perinatal women with OUD. Participants reported high levels of usability and acceptability for the educational tool, as evidenced by high ratings on the modified SUS and CSQ-8 scores. Open-ended feedback emphasized the tool's practicality and its potential to empower mothers with knowledge and confidence in caring for their infants experiencing NAS. Specific benefits identified included improved preparedness for hospital experiences, enhanced abilities to advocate for themselves, a focus on postpartum health and resources, and greater confidence in managing NAS symptoms in their newborns. These findings align with previous research suggesting that mobile health interventions can improve patient engagement and self-efficacy in managing health conditions (Bricker and McAfee, 2021; Brocato et al., 2022; Giles et al., 2016; Richterman et al., 2023).

This study builds on prior research emphasizing the importance of digital health interventions in addressing substance use disorders. Previous studies have demonstrated the feasibility and acceptability of mobile applications for supporting behavioral health and promoting adherence to treatment in individuals with substance use disorders (Giles et al., 2016; Richterman et al., 2023; Vilardaga et al., 2020). However, few interventions have specifically targeted the perinatal period or focused on empowering mothers to care for infants with NAS. The findings of this study align with prior work showing that targeted educational interventions can improve maternal confidence and reduce stigma in healthcare settings (Brocato et al., 2022; Corrigan et al., 2017; Jordan et al., 2023; Livingston et al., 2012; Martin et al., 2022; Merritt et al., 2022). While several mobile tools focus on general substance use disorder treatment adherence (Hai et al., 2019; Kazemi et al., 2017; Marsch et al., 2020), or broader prenatal education that does not specifically address the unique challenges of perinatal women with OUD and NAS care (Campbell et al., 2014), our mobile educational tool is uniquely designed to fill this gap. Unlike general prenatal apps, our tool specifically addresses the medical, social, and legal challenges faced by pregnant women with OUD, including NAS care, stigma, and CPS involvement. It was adapted from a previously validated NAS educational tool for NICU healthcare providers (Burduli et al., 2019), ensuring evidence-based content tailored for a patient-facing audience. Additionally, our tool takes a person-centered, stigma-reducing approach, incorporating qualitative insights from perinatal patients and healthcare providers to ensure accessibility, empowerment, and nonjudgmental, person-first language. Finally, rather than relying on text-heavy formats, our tool delivers educational content through concise, engaging videos featuring diverse, relatable characters, making it more accessible to individuals with varying literacy levels and learning preferences.

A recent digital intervention that also aims to support perinatal individuals with OUD is Project BETTER (Martin et al., 2022), which is a web-based educational platform covering similar topics such as NOWS, maternal health in the postpartum period, and interactions with child welfare systems. The program's content is presented through animated narration and includes motivational interviewing strategies, person-first language, and video segments featuring real patient stories and trauma-informed clinicians (Martin et al., 2022). While this intervention represents a meaningful advancement in perinatal OUD education, our tool builds upon a similar foundation and offers more expansive content, including practical training on newborn NAS care and functionality designed for both clinical and nonclinical environments—enhancing reach and relevance for women navigating OUD during the perinatal period. These distinctions highlight the novelty and necessity of our tool in addressing critical gaps in digital health interventions for this population.

This study's strengths include its focus on addressing a well-documented gap in resources for perinatal women with OUD and its use of iterative, patient-centered design principles informed by qualitative feedback from both patients and healthcare providers. By adapting an existing NAS educational tool for healthcare providers, this study capitalized on established content to create tailored modules that address the unique challenges faced by this population. The incorporation of intuititve, person-first language and concise and accessible video modules with diverse characters ensured the tool was approachable and relevant for perinatal women with OUD while also being sensitive and inclusive. The tool is ready to be tested in a future clinical trial.

The potential implications of this work are numerous. By equipping mothers with the knowledge and skills to provide effective non-pharmacologic care for NAS, the educational videos serve as a valuable resource that supports maternal-infant bonding, an outcome increasingly associated with the implementation of the ESC model of care. Furthermore, the tool's emphasis on navigating stigma in healthcare settings and understanding the role of CPS addresses broader psychosocial barriers that often complicate care and recovery for this population.

5. Limitations and future directions

Despite its promising results, this study has several limitations. The small sample size ($n = 6$) limits the generalizability of findings. Passive recruitment methods (e.g., flyers) proved ineffective in engaging individuals with OUDs in this study, contributing to the low recruitment numbers. Furthermore, passive recruitment may have introduced selection bias, as participants were self-selected and motivated to engage with the study. Additionally, the study's focus on women actively engaged in MOUD treatment may not fully capture the experiences and needs of those outside formal treatment programs. Future research should focus on scaling up this intervention and testing it in diverse, larger samples. Longitudinal evaluations are also needed to assess the tool's impact on clinical outcomes, such as maternal treatment adherence, postpartum depression, anxiety, and neonatal health metrics, over time. Expanding the tool's content to address additional topics, such as managing comorbidities, and the impact of fentanyl on care and outcomes, could further enhance its utility. In addition, incorporating feedback from diverse populations, including non-English speakers and individuals not engaged in MOUD, will be essential to ensure the tool's accessibility and relevance across different demographic and socioeconomic groups. Finally, integrating the videos and content into an app may increase its reach and accessibility, especially to perinatal women with OUD who are not currently engaged in treatment services.

6. Conclusions

This study demonstrates the feasibility and promise of a mobile educational tool designed to support perinatal women with OUD. This

tool contributes to addressing existing gaps in the education and empowerment of perinatal women with OUDs, representing a step toward improving outcomes for mothers and infants affected by NAS. With further development and evaluation, mobile health interventions like this may enhance the quality of maternal and neonatal health care while fostering resilience in women facing challenges associated with substance use.

Disclosures

The authors report there are no competing interests to declare.

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CRediT authorship contribution statement

McPherson Sterling M.: Writing – review & editing, Supervision, Resources. **Winquist Anna:** Writing – review & editing, Validation, Formal analysis. **Jones Hendrée E:** Writing – review & editing, Visualization, Validation, Supervision. **Johnson Ron Kim:** Writing – review & editing, Visualization, Software. **Burduli Ekaterina:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Paulsgrove Kaylee:** Writing – review & editing, Writing – original draft, Conceptualization. **Willoughby Jessica Fitts:** Writing – review & editing, Validation.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Ekaterina Burduli reports financial support was provided by National Institutes of Health. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.dadr.2025.100327.

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