Mobile applications to support parents in the transition from neonatal intensive care unit to home: a narrative review

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Background and Objective: Among the unique challenges for parents in the transition of infant care from neonatal intensive care unit (NICU) to home are the medical complexity of their babies and the psychological burden of caring for this special patient population. Despite the increased use and accessibility of smartphones, mobile applications (apps) intended for use by families during this transition remain underdeveloped and understudied. Apps to support parents of infants in the NICU represent an accessible potential solution to mitigate existing disparities in follow up. Through this Narrative Review, we intend to describe the characteristics of and development process for apps intended to address the challenges parents with NICU babies may face, and to provide recommendations for further development of apps for this purpose.

Methods: We conducted a review of articles published between November 2012 to November 2022. This search spanned three major databases, PubMed, Embase, and CINAHL, using a controlled vocabulary and keywords for mobile apps and the NICU. These three databases generated 473 articles for review. Utilizing the online primary screening and data extraction tool Covidence, we ultimately included eight articles in this narrative review.

Key Content and Findings: There are few existing mobile apps intended to ease the transition home for parents of babies in the NICU. There are even fewer apps that have been critically evaluated using acceptable methods and produced with contribution from healthcare practitioners. Among the existing articles on app solutions to benefit education and socioemotional support for parents, many emphasized the importance of including key stakeholders during the app development process and highlighted both qualitative and quantitative measures for assessing relative success of these apps in a clinical setting.

Conclusions: Although the experiences of parents with infants admitted to the NICU have been well-studied, there remain relatively few existing apps to provide educational and socioemotional support to this population. Future studies should focus on an iterative process of app development whereby both parents and providers are closely involved, in combination with critical appraisal of the app to assess for appropriate support and education of caregivers.

Keywords: Neonatal intensive care unit (NICU); mobile applications; parents; support

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Introduction

Background

For parents of babies in the neonatal intensive care unit (NICU), the frequently complex medical needs of their newborns create challenges in the transition home upon hospital discharge. These unique difficulties include mitigation of emotional distress and preparedness to care for a medically complex newborn. Existing research demonstrates that a smooth transition home depends upon successful communication with health providers and provision of adequate and appropriate education during hospitalization (1,2). Caregivers require increased educational and socioemotional support to be successful in this critical transition of their baby's care to outpatient follow up (3). Additional barriers and difficulties in this process often arise for families with low socioeconomic backgrounds, those with less healthcare literacy, and for parents who do not speak English or are non-native English speakers (4,5).

Mobile health (mHealth) solutions, including mobile apps, represent an important opportunity not only to improve educational and socioemotional support resources for parents of babies in the NICU, but also to address the existing disparities in care, follow up, and readmissions for NICU graduates. Even with established disparities in healthcare due to the digital divide (6-8), smartphones are an exception and are widely available and used by many patients and their families regardless of socioeconomic status (SES) (9). In addition to the accessibility of mobile devices as a source of education and emotional support, parents of NICU babies have cited online resources and mobile apps as their desired source of assistance and reference during the transition to home (10-12).

Rationale and knowledge gap

Despite a large variety of mobile apps intended for use in clinical settings, there is relatively little existing research on the full spectrum of apps intended for use by parents of infants admitted to the NICU. Mobile apps could be an important source of support for parents in understanding the unique medical needs of their babies and in providing socioemotional resources during a particularly stressful moment in their child's care. Furthermore, many mobile apps for new parents do not provide information about babies who were admitted to a NICU, which may include preterm infants and medically complex neonates, and

many of these apps have not been developed or vetted by healthcare professionals (13). In general, given the diverse medical and pathophysiologic reasons for NICU admission following delivery, we have avoided use of the terms "premature", "preterm", or "medically complex" in favor of terms like "babies admitted to the NICU", "NICU babies", or "NICU graduates". This choice of language is also reflected in how we opted to conduct our narrative review, which included key words generalizable to NICU babies in general rather than a specific diagnosis or reason for admission.

Objective

Through the following narrative review, we intend to provide a structured assessment of the existing mobile apps intended for use by parents of preterm and medically complex newborns as their babies complete the transition from NICU to home. Through this review, the following questions were addressed: what mobile apps currently exist for parents of NICU babies, what information do these mobile apps provide, and what research and app development would further benefit this vulnerable patient population and their caregivers? We present this article in accordance with the Narrative Review reporting checklist (available at https://mhealth.amegroups.com/article/view/10.21037/mhealth-23-10/rc).

Methods

We conducted a literature review to identify existing mobile apps intended for parents of NICU babies. On November 17, 2022, we performed a comprehensive search of multiple databases including PubMed (National Library of Medicine), Embase (Elsevier), and CINAHL Complete (EBSCO) using a combination of controlled vocabulary and keywords for the NICU and mobile apps (*Table 1*). The initial search did not discriminate between apps intended for use by parents and caregivers versus those for other uses in the NICU to capture the full scope of apps currently utilized in association with NICUs worldwide (*Table 3*).

The initial search resulted in 473 total studies, which were all imported into the online review software Covidence (14). Covidence is a web-based collaboration software platform that streamlines the production of systematic and other literature reviews. Covidence identified and removed 176 duplicates for a total of 297 studies for further screening (*Figure 1*). Initial screening by review of titles and abstracts

Table 1 The search strategy summary

Items	Specification
Date of search	11/17/2022
Databases and other sources searched	PubMed, Embase, CINAHL
Search terms used	Mobile Applications OR Smartphone
	mobile AND (app OR apps OR application)
	Smart phone(s)
	iPhone(s)
	Intensive Care Units, Neonatal OR Neonatology OR neonatal intensive care unit OR NICU OR neonatolog*
Timeframe	November 2012 to November 2022
Inclusion and exclusion criteria	See *Table 2*
Selection process	Authors LK and IS performed comprehensive database searches together on 11/17/2022. All authors agreed upon inclusion and exclusion criteria. Author IS conducted the Narrative Review through Covidence

Table 2 Study inclusion and exclusion criteria

Category	Inclusion	Exclusion	Rationale
Intended mobile app beneficiaries	Neonates, premature infants, and/or medically complex infants requiring NICU admission	Healthy newborns born full term; late preterm newborns not requiring NICU admission; fetal/prenatal health; pregnant patients	Focus on newborns; include medical complexity, prematurity
Intended mobile app users	Parents, caregivers	Health care providers (e.g., physicians, trainees, nurses)	Focus on parents and caregivers and the critical transition period from NICU to home
Concept	Mobile phone/cellular device/ smartphone applications	Websites; artificial intelligence; telehealth/telemedicine	Specific interest in novel mobile applications accessible to parents, caregivers
Context	Use of mobile applications to support parental education in the NICU	Studies without use of mobile applications; labor and delivery units, PICU, other pediatric care facilities	NICU stay and transition period to home are particularly vulnerable, challenging for new parents
Language	English	All other languages	Language capacities of the team

NICU, neonatal intensive care unit; PICU, pediatric intensive care unit.

excluded an additional 240 studies based on the following criteria: wrong population (e.g., pregnant patients, infants not requiring NICU admission), wrong context (e.g., labor/delivery units, pediatric intensive care units (PICUs), neonatal resuscitation prior to NICU admission), or wrong concept (e.g., focus on smartphones in general, websites, or messaging platforms/chatbots rather than novel mobile apps, or generic mobile apps not intended for this specific purpose) (*Table 2*).

Of the 57 full-text studies assessed for eligibility, an additional 43 were excluded for the following reasons. Twenty-nine studies were identified as referring to mobile apps intended for various clinical uses in the NICU, for example, retinopathy of prematurity (ROP) screening. Eight studies were identified as intended for educational purposes in the NICU to support either nurses or physician trainees. Lastly, six studies utilized a mobile app for parents or nurses in the NICU to document their reflections as part

Table 3 Detailed search strategy by database

Database	Search strategy
PubMed	("Mobile Applications"[Mesh] OR "Smartphone"[Mesh] OR (mobile AND (app OR apps OR application)) OR smartphone OR smartphone OR "smart phone" OR "smart phones" OR iphone OR iphones) AND ("Intensive Care Units, Neonatal" [Mesh] OR "Neonatology" [Mesh] OR neonatal intensive care unit OR NICU OR neonatolog*)
Database vendor: U.S. National Library of Medicine	
Database coverage: 1946–present	
Date last searched: November 17, 2022	
Limits: ("2012/11/17"[Date - Entry]: "2022/11/17"[Date - Entry])	
Embase	('mobile application'/exp OR 'smartphone'/exp OR (mobile AND (app OR apps OR application)) OR smartphone OR smartphone OR "smart phone" OR "smart phones" OR iphone OR iphones) AND ('neonatal intensive care unit'/exp OR 'neonatology'/exp OR neonatal intensive care unit OR NICU OR neonatolog*)
Database vendor: Elsevier	
Database coverage: 1947–present	
Date last searched: November 17, 2022	
Limits: [17-11-2012]/sd	
CINAHL Complete	(MH "Mobile Applications" OR MH "Smartphone" OR (mobile AND (app OR apps OR application)) OR smartphone OR smartphone OR "smart phone" OR "smart phones" OR iphone OR iphones) AND (MH "Intensive Care Units, Neonatal" OR MH "Neonatal Intensive Care Nursing" OR MH "Neonatology" OR neonatal intensive care unit OR NICU OR neonatolog*)
Database vendor: EBSCO	
Database coverage: 1937–present	
Date last searched: November 17, 2022	
Limits: published date: 2012-11-17 to 2022-11-17	

of a qualitative research project.

The remaining fourteen studies were critically evaluated by the research team for quality assessment and final inclusion in this narrative review. Of those fourteen studies, we ultimately excluded six additional studies for the following reasons: one article that reviewed some internet resources (15), two news articles that described some general features of new mobile apps but did not detail their development or evaluation (16,17), one article that described a mobile app intended as an educational resource about premature birth for parents in the prenatal period (18), one reference that was only an abstract (19), and one systematic review of virtual solutions for parents in the NICU that did not describe any mobile apps (20). At completion of review, eight relevant articles were included (*Table 4*).

Narrative review

For this narrative review, we grouped the included articles by stage of mobile app development. The general themes are as follows: App Development, App Testing and Evaluation, and Alternative App Evaluation. We organized the results in this way to highlight some potential answers to our research question about what kind of research and app development would further benefit this vulnerable patient population and their caregivers. We also aimed to emphasize the information each mobile app provides along with any unique or noteworthy features (*Table 5*).

App development

One of the key thematic elements in four of the eight studies in this narrative review is the app development process. These articles outlined and described a unique approach to this process in detail. For example, Lakshmanan *et al.* is a qualitative prospective study in which study participants were interviewed in focus groups about desired components of a mobile app for parental support during transition from NICU to home (21). A unique feature of this study was the inclusion of both parents (eleven participants total) and providers (eleven participants total) with the aim of gaining insights from both relevant stakeholders. Many of the overall domains that were identified in this study as important app features for both parents and providers are aligned with existing literature describing the unique challenges that parents face during the transition from NICU to home. These include
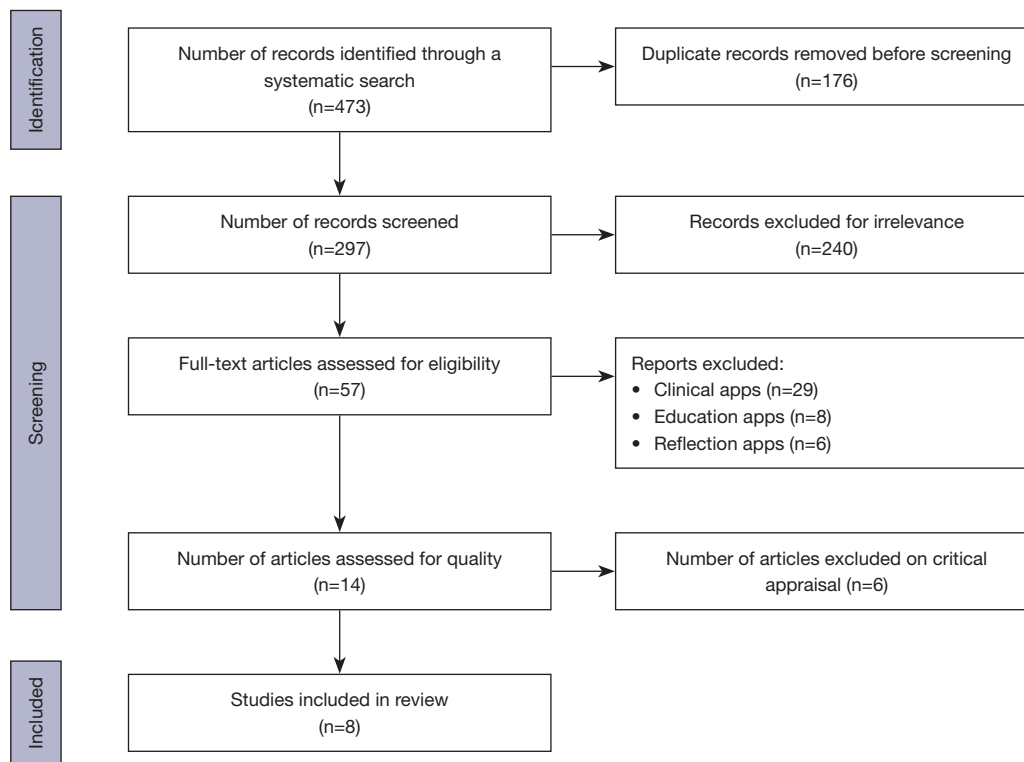
Figure 1 Flowchart of the study selection and inclusion process.

provision of path planning and information, mitigating barriers to care after discharge, and strengthening parenting role and confidence. The authors identified their study population, patients from a safety-net center, as a limitation of this study. Yet given the potential for mobile apps to serve as solutions to the current disparities that exist in NICU patient follow up and information access, the inclusion of study participants who come from diverse and historically underserved backgrounds would benefit future studies aimed at addressing health inequity in this clinical setting.

The study by Phagdol *et al.* describes a conceptual framework for development of a mobile app to support parents with preterm infant home care (22). The researchers focused on the use of a mobile app to reduce healthcare access gaps and improve health outcomes in their study population in India. The authors followed an existing conceptual framework for app development outlined by Mburu, Franz, and Springer in their study entitled "A conceptual framework for designing mHealth solutions for developing countries" (23). Phagdol *et al.*'s focus on low- and middle-income countries (LMICs) also emphasizes the important role that mobile apps may play to remotely monitor the growth and development of premature infants.

This concept may be especially useful in low-resource and rural settings where access to in-person follow up after hospital discharge may be a significant barrier for parents. The authors ensured their app was most appropriate for the intended patient population. They therefore included considerations like android phones being more commonly used than IOS iPhones, and they appreciated that diverse demographics necessitated availability of the app interface in multiple languages. Much like the previously described study by Lakshmanan *et al.*, Phagdol *et al.* emphasize the critical importance of stakeholder incorporation both during early stages of app development and during the iterative process of making changes based on user feedback. The app was therefore designed around a theoretical model which ensures the best fit of content and information for the exact specifications of its intended users.

Jani *et al.* also recognize the potential use of mobile apps to "mitigate social disadvantage", which they identify as a tool to remotely monitor infant health, provide social support for new parents, and to prevent recurrence of preterm births (24). Much like the app development processes highlighted by Lakshmanan *et al.* and Phagdol *et al.*, this article by Jani *et al.* emphasizes the importance

Table 4 Data extraction with study details

Study	Title	Aim of study	Study design	Participants	Data analysis	Results
Banerjee et al. (2020), UK, PMID: 31227521	Improving infant outcomes through implementation of a family integrated care bundle including a parent supporting mobile application	To improve infant health outcomes and parent experiences through a model IFDC* program that included development of a free mobile app to provide educational and reflective opportunities for parents	Quality improvement project	Families of 37 infants requiring a NICU stay and admitted between April 2017–May 2018 GA at birth <34 weeks, LOS at least 14 days, Discharged home	Retrospective control in pre-post intervention analysis Data analyzed using SPSS Statistics V.20.0 to compare variables including NICU LOS between IFDC and control groups	Infants in the IFDC group had shorter median LOS in the NICU and reached both enteral and full-suck feeds earlier than retrospective matched controls Secondary outcomes such as mortality, intraventricular hemorrhage, and necrotizing enterocolitis were not significantly different between the two groups
Garfield et al. (2016), USA; PMID: 27990350	Supporting parents of premature infants transitioning from the NICU to home: A pilot randomized control trial of a smartphone application	To determine whether parents of VLBW infants in the NICU transitioning home with the "NICU-2-Home" app had greater parenting self-efficacy, were better prepared for discharge, and had shorter LOS than control parents	Randomized control trial	90 parents of VLBW infants Parents were at least 18 years old and English-speaking	Linear mixed-effects model was used to examine the change in mean PSOC scores over three time points	Parents who used the app had improved parenting self-efficacy and discharge preparedness Both variables were also influenced by app usage (e.g., increased app usage contributed to higher PSOC scores)
Garfield et al. (2022), USA; PMID: 35033562	A Mobile Health Intervention to Support Parenting Self-Efficacy in the Neonatal Intensive Care Unit from Admission to Home	To test whether parents of premature infants <37 weeks of gestation provided the "NICU-2-Home" app had greater parenting self-efficacy compared with controls	Quasi-experimental, nonrandomized, time-lagged study	298 English-speaking parents of preterm infants (<37 weeks) admitted to a large, urban Midwestern NICU who have an Android or Apple smartphone	Evaluation of the PSOC across the study period	PSOC scores of intervention parents who received the NICU-2-Home app were consistently higher across the study period compared with those in the control group. Parents who used the app more frequently had significantly higher PSOC scores than the control group
Jani et al. (2021), USA; PMID: 33888330	PretermConnect: Leveraging mobile technology to mitigate social disadvantage in the NICU and beyond	To describe the participant-centered design approach of PretermConnect and to present preliminary findings from focus groups and co-designs	Human-centered iterative design methodology with co-design sessions	37 English-speaking mothers with a history of preterm birth <1 year, who have a mobile smartphone	Qualitative analysis consisting of reviewing session audio recordings and transcripts to identify common themes in patient needs and app design	Development of the PretermConnect app to address the social, emotional, and health educational needs of women at risk for preterm birth based on feedback provided through co-design sessions
Lakshmanan et al. (2022), USA; PMID: 35204980	Designing a Mobile Health Solution to Facilitate the Transition from NICU to Home: A Qualitative Study	To elucidate caregiver and provider perspectives on the design of a mobile health application for facilitating the transition from the NICU to home To identify general recommendations and specific priorities of caregivers and providers in terms of the content, design, information, and support that an app might provide	Qualitative research	11 caregivers of infants with complex chronic disease and 11 providers (neonatologists, pediatricians)	Inductive thematic analysis approach, an iterative process of coding to identify the patterns among concepts	Caregiver and provider priorities for designing a mobile health solution during the transition from the NICU to home included the following domains: implementation ideas around user interface and timing, providing path planning and information, increasing support, improving engagement with providers and services, mitigating barriers to care after discharge, and strengthening parenting role and confidence
Phagdol et al. (2022), India; PMID: 34889469	Designing a mobile health intervention for preterm home care: Application of conceptual framework	To describe the process of designing a sustainable mobile app for delivering preterm home care to babies discharged from the NICU and remote monitoring of their growth and development	Application of conceptual framework for designing mHealth app for preterm home care Designed and developed as part of an ongoing randomized controlled trial	Not specified	Not specified	Multifunctional app that is potentially beneficial to preterm infants graduating from NICU, mothers/parents of these preterm infants, and the health care professionals who cared for the infants in NICU
Richardson et al. (2019), Canada; PMID: 30985282	Evaluation of Mobile Apps Targeted to Parents of Infants in the Neonatal Intensive Care Unit: Systematic App Review	To identify and evaluate apps targeting parents of infants in the NICU for quality of information, usability, and credibility	Systematic review (of Apple and Google app stores)	English apps targeting NICU parents that cost less than $20	3 tools were used for evaluation: MARS to measure quality; PEMAT-AV to measure the app's content usability; and Trust it or Trash It to measure credibility	Using MARS, 7 apps (7/18, 39%) received a good score on overall quality (i.e., 4.0 out of 5.0), with none receiving an excellent score 8 apps (8/18, 44%) received a PEMAT-AV score between 51% and 75% on the understandability subscale, and 8 apps (8/18, 44%) scored between 76% and100% on the actionability subscale Trust It or Trash It deemed 13 apps (13/18, 72%) as trash for reasons including no identification of sources or lack of current information, with only 5 (5/18, 28%) deemed trustworthy
Spargo et al. (2018), New Zealand; PMID: 29417669	'Babble': A smartphone app for parents who have a baby in the neonatal unit	To develop a smartphone app 'Babble' with the needs of parents in a NICU in New Zealand in mind	Semi-structured interviews, app development	7 sets of parents of babies in the NICU plus a project group of neonatal nurses, lactation consultant, pediatrician, parents, software developer, designer, photographer, and project manager	Not specified/applicable	Generic neonatal topics on 'Babble' are feeding, routine checks and tests, equipment, gestational expectations, advice for dads, expected problems and common neonatal diseases, how to keep babies safe and medications More local topics are information regarding our NICU environment, staff, and practices, preparing for going home and how to find help once discharged from the NICU

IFDC, integrated family delivered care; NICU, neonatal intensive care unit; LOS, length of stay; GA, gestational age; VLBW, very low birth weight; PSOC, parenting sense of competence; MARS, mobile application rating scale; PEMAT-AV, patient education materials assessment tool for audiovisual materials.

Table 5 Information mobile applications provide and their noteworthy features

Mobile app title or description	Study	Information provided or suggested/noteworthy features
Untitled IFDC mobile application	Banerjee *et al.* (2020)	Intention to provide reliable and detailed educational information
Mobile app part of a family integrated care bundle		Diary for parents to record their neonatal journey
		Developmental timeline to support parents in forming appropriate expectations of their infant
NICU-2-Home	Garfield *et al.* (2016), (2022)	Passport-to-Home:
		• Place for parents to track baby's medical information, feeding, baby items, and home set up
		• Tracking completion of different items, including CPR training, with a virtual stamp
		Education Center:
		• Curated, multi-media educational information pertaining to infant and self-care
		• Topics include preemie infant brain development, diapering, and feeding tips
		Baby Connect©:
		• Daily tracking tool for parents to record their infant's activities
		MoodTracker:
		• Place for parents to record their mood scores and observe their partners' mood changes over time in either list or graph format
		Resource Center:
		• Additional information including tips for using the app, health website links, list of common questions related to NICU infants
		Notes:
		• Place for parents to track items, questions, or concerns they may have about their infant
PretermConnect	Jani *et al.* (2021)	Community forum:
		• Digital bulletin board for participants to exchange messages
		MyHealth feature:
		• Information about mother, baby, and elements of the birth experience; use of trackers to monitor health-promoting behaviors
		Birth Stories:
		• Preterm delivery experience from mothers' perspectives
		Baby University à Library:
		• Health educational library
		Push notifications:
		• Positivity, self-care, and encouragement daily notifications for mothers
Theoretical application not yet developed	Lakshmanan *et al.* (2022)	Path Planning:

Table 5 (*continued*)

Table 5 (*continued*)

Mobile app title or description	Study	Information provided or suggested/noteworthy features
Suggested app content based upon provider and parent priorities		• Clear discharge summaries • Connection to patient navigators Information: • Access to and use of medications, durable medical equipment • Information and referral updates for Early Intervention services Support: • Connection to community-based services • Access to mental health services
Untitled mHealth application	Phagdol *et al.* (2022)	Integration of remote monitoring of infant growth and development for early detection of growth impairment and developmental delay
App designed and developed as part of an ongoing randomized controlled trial		Health information that is updated, validated, and complete, covering all the aspects of preterm home care with relevant images and instructional videos
Multiple mobile apps highlighted through this systematic app review	Richardson *et al.* (2019)	Most frequently addressed topics of the apps evaluated were breastfeeding or feeding, growth and development, and illness or health issues
Babble	Spargo *et al.* (2018)	Generic neonatal topics: • Feeding • Routine checks and tests • Equipment • Gestational expectations • Advice for dads • Expected problems and common neonatal diseases • How to keep babies safe • Medications Local topics: • Information about NICU environment • Staff and practices • Preparing to go home • How to find help once discharged from the NICU Key milestones record: • Journal entries • Photo album • Content shareable with family and friends via email, social media Patient stories

IFDC, integrated family delivered care; NICU, neonatal intensive care unit.

of involving key stakeholders in the early stages of mobile app development. This study design utilizes focus groups and "co-design sessions", wherein mothers with a history of preterm birth answered pre-determined interview questions to assess a prototype of the mobile app, called "PretermConnect", for content, design, and overall aesthetics. Unlike the study population of Lakshmanan *et al.*, which was more homogenous, especially in terms of SES, the study design implemented by Jani *et al.* involved piloting their app in three distinct clinical settings with the intent to "obtain input from socially, economically, and culturally diverse individuals". While their broader and more varied population of NICU parents shared many of the same desires for a mobile app to support them in the transition to home, unique socio-cultural differences in desired app design and interface also emerged with a more diverse population of parents providing their input. These differences included opinions about desired background color of the app and language used to identify different app sections and resources. For example, one section of the app containing articles and videos for health information and education that was originally titled "BabyUniversity" was renamed "Library" following feedback from some participants who found this language more accessible.

The article by Spargo *et al.* highlights a specific mobile app, outlines its development process, and reports on some of the updates that have been undertaken since its introduction to the clinical setting (25). The authors describe using semi-structured interviews with parents to develop their app "Babble" through an iterative process, much like that described by Jani *et al.*, whereby changes were made following weekly meetings of a project group. These focus groups involved neonatal nurses, physicians, lactation specialists, and a project manager. This research team focused on producing an app that provides "a portable, fast, accessible education tool" for parents as they transition to caring for their baby at home. The mobile app this team developed also provides a balance of generic information regarding appropriate care for premature, medically complex newborns in addition to some "local" topics that prepare parents for the care their babies will receive at a specific neonatal unit (NNU) in New Zealand. Another key feature of the "Babble" app is the key milestone records section where parents can create journal entries and save photos, both of which can be shared via email or social media. Focus groups of parent participants who reviewed the "Babble" app commented that they particularly appreciated an integrated feature whereby they could share information with family and friends.

App testing and evaluation

Following app development, another important consideration is appropriate and comprehensive app testing and evaluation. Three of the articles in this narrative review considered how existing, previously developed mobile apps can be critically evaluated for measurable benefits to parents and infants.

Banerjee *et al.* analyzed several infant outcomes, including length of stay (LOS) in the NICU, to evaluate an Integrated Family Delivered Care (IFDC) program for parents of NICU babies (26). This program in the United Kingdom was based on other randomized controlled trials in Canada and Australia, which had demonstrated significant benefit from similar Family Integrated Care (FIC) programs. These studies had identified improvements across multiple outcomes including increased infant weight gain and decreased parental anxiety. The IFDC program evaluated by Banerjee *et al.* included the development and dissemination of a mobile app with the intention of providing reliable educational materials and a journal for parents to document their baby's neonatal journey. The authors recognize that by not evaluating this mobile app separately from the rest of the IFDC program package "benefits of the App as a separate entity cannot be discerned". Other components of the IFDC included a training program for parents facilitated by bedside nurses and one-to-one support from IFDC coordinators. Despite this study limitation, the research presented by Banerjee *et al.* is an example of the potential for very specific, quantitative measures, including LOS and ability to achieve full-suck feeds, to be assessed as part of the testing and evaluation of a mobile app for parents of NICU babies. Much like the highlighted journal entries feature of the "Babble" app developed by Spargo *et al.*, Banerjee *et al.* also reported the importance of providing an integrated space for parents to record their own thoughts and experiences in a mobile app.

In the 2016 study by Garfield *et al.*, the authors utilized a standardized measure of parenting self-efficacy called the Parenting Sense of Competence Scale (PSOC) (27). Much like Banerjee *et al.*, the authors also utilized LOS as a measure for their app "NICU-2-Home" and its relative success. Not only were the authors able to demonstrate improvement across these measures because of their mobile app, but they also saw a dose-dependent relationship

between app usage and these outcomes. For example, when participants in the intervention group were stratified by mean app usage, those with "above average" app usage had significantly increased improvement of their PSOC scores compared to those participants with "lower-than-average" app usage. The content of the app may have also guided some of the measures used by these authors to evaluate the relative success of their app. For example, one unique feature of the NICU-2-Home app is the "MoodTracker", which allows parents and caregivers to monitor their own psychologic and emotional status. The use of the NICU-2-Home app also benefited users in terms of NICU LOS, which could perhaps be in part attributed to app contents like the "Passport-to-Home" section, which aims to provide a virtual to-do list to remind parents about certain milestones like CPR classes home set up prior to being ready for discharge from the NICU. The "above average" app users achieved LOS for their babies that was, on average, less than half that of their counterparts who used the app an average amount. One potential limitation of this study, as highlighted by the authors, was the relative homogeneity of the study population in terms of educational background and SES. Over 80% of their participants carry private medical insurance, and over 50% of participants held at least a college degree.

For the 2022 study by Garfield *et al.*, the NICU-2-Home app was utilized in a larger study population to again test for improvement in PSOC scores with app usage (28). Compared to the 2016 study by Garfield *et al.*, this 2022 study ultimately evaluated the app with an intervention cohort of 146 parents of premature infants <37 weeks' gestation and compared their results to 110 matched controls. Much like the original evaluation of this mobile app from 2016, this more recent study demonstrated similar success in terms of increased PSOC scores amongst app users and a dose-dependent relationship between app usage and scores. Once again, more time spent on the app equated to increased PSOC scores over time versus with average and below average app usage in the intervention group. One of the key limitations of this study is the homogeneity of the study population which again included predominantly "married, educated, and nonminority" parents. The authors suggest that further work focusing on addressing the needs of a more diverse patient population may be necessary to reproduce these results in different settings. Some of the unique features of the NICU-2-Home app do mirror the perspectives and priorities of the study population from Lakshmanan *et al.*, which was significantly more

ethnically and socioeconomically diverse. For example, parents involved in both studies desired and benefitted from path planning related to discharge preparation. This overlap suggests that many of many thematic elements of a successful app for parents of NICU babies are universal, whereas some of the more specific aspects of the information provided and its format may warrant more attention to the unique needs and desires of the target population.

Alternative app evaluation

Amongst the studies included in this narrative review, we also highlight one systematic app review that investigated existing mobile apps to support parents with babies in the NICU during the transition to home after hospital discharge. The review by Richardson *et al.* took a unique approach in directly searching the Apple App Store and Google Play for English-language apps targeting parents with babies in the NICU (29). They used multiple measures to assess quality (Mobile Application Rating Scale: MARS), content usability (Patient Education Materials Assessment Tool for Audiovisual Materials: PEMAT-AV), and credibility (Trust it or Trash It). The authors concluded that of the eighteen unique apps targeting NICU parents, less than half could be considered acceptable educational material. They therefore determined that apps available to parents of NICU babies at the time of publication were lacking both "in terms of quality and credibility". Overall, this study suggests that despite a seemingly significant number of smartphone apps available for free or for purchase for parents with babies in the NICU, relatively few of them have been developed and adequately vetted by trained medical professionals.

Excluded articles

During the narrative review process, six articles were ultimately excluded and "moved back" because they did not represent original research or data-driven descriptions of mobile apps for parents with NICU babies. Two such articles highlighted mobile apps not otherwise mentioned through this narrative review, although they are still pertinent examples of other mHealth solutions in this category.

Doron *et al.* published an article in *Journal of Neonatal Nursing* describing their app "MyPreemie", which has six sections, "each designed to empower parents with

information, easy-to-use tools, support, and a sense of normalization" (16). One unique feature noted in their app is the "Loss Pathway", which allows parents who have experienced the death of a premature infant to access a special Memory Page to memorialize their baby. Even though the MyPreemie app has not been studied in a randomized controlled trial, for example, it may still serve as a helpful template for physicians and researchers who desire ideas for the scope of what a mobile app may offer parents of NICU babies.

In *The Journal for Nurse Practitioners*, Dr. Patricia Biller Krauskopf reviews another mobile app called "My NICU Baby" (17). She reviews the app using the NPMEDAPP criteria created by editors of the journal, which is an acronym that stands for Novel, Potential of Benefit versus Risk, Medically Sound, Ease of Use, Developer, Audience, Price, and Platform. This app was developed and supported by March of Dimes, and features educational videos to review care topics, a comprehensive virtual "textbook", and feeding, weight, and skin-to-skin contact trackers. Overall, this mobile app represents a potential model for the scope of educational and support services that can be provided through this modality of mHealth solution.

In 2017, Dol *et al.* published a systematic review across four major databases (20). They reviewed experimental and epidemiological studies that considered parent-related and neonatal outcomes as a measure of the success of various electronic health (eHealth) interventions. They noted a growing interest in this topic as, at the time, over half of the included studies had been published within the prior two years. The authors chose to explore existing eHealth interventions across multiple domains including web-based platforms, video, SMS, and text messaging intended for education, communication, or both. Ultimately, this work was excluded from the narrative review because none of the articles reviewed were relevant to this present exploration of mobile apps in the NICU setting as they explored other kinds of non-app based mHealth solutions.

Discussion

Through this narrative review, we identified three categories of existing studies related to mobile apps developed for use by parents of babies in the NICU. Of these groupings of studies, each was intended to serve a specific purpose during the app development, evaluation, or critical review process. Most of the studies we reviewed, four in total, were intended to elucidate the process of developing a mobile app, usually

through a process involving key stakeholders like parents and healthcare providers. There were also three articles that detailed research intended to evaluate the relative success of mobile apps in the study population for which they were developed. These studies emphasized the use of both qualitative and quantitative measures for app evaluation. Finally, we identified one systematic review aimed at critical assessment of existing mobile apps intended to support and provide education for parents. Together, these eight articles represent the scope of presently available literature on mobile apps intended for use by parents with babies in the NICU, either in the provision of socioemotional or educational support.

In the process of mobile app development, there are two key steps: design/development followed by testing/ evaluation. The articles presented in this narrative review represent literature intended to address both these steps to produce apps to support parents as their infants complete the transition from NICU to home. In the design and development stage, the articles by Jani *et al.*, Lakshmanan *et al.*, Phagdol *et al.*, and Spargo *et al.*, all emphasized the inclusion of multiple key stakeholders during the development stage of app design. These authors unanimously opted to involve parents themselves in this process. Concepts like "co-design", in which the design process is shared by those trained and untrained individuals, like Jani *et al.* implemented, are not unique to the development of apps for this particular purpose (30). Through this process, mobile apps may be developed that more appropriately address the specific needs and desires of a particular population. Regarding the testing and evaluation of existing mobile apps, our findings suggest that a combination of quantitative and qualitative measures may be most successful. The evaluation process may include assessments of content, usability, and efficacy (31). Quantitative measures used by Garfield *et al.* included the PSOC scores, while Banerjee *et al.* used LOS as a measure of relative mobile app success. Soliciting parent, or user, experience in this process was also an important factor in considering potential app updates, as described by Spargo *et al.*

Potential challenges to app development

The process of mobile app development, especially in the medical and clinical settings, may be complicated by a variety of factors. One such issue is that of "pilotitis" which refers to the inability of mHealth projects to progress from pilot stage to their accessibility and use on public platforms (32).

This discrepancy between the quality and quantity of apps in the developmental stages versus in final production and available in public mobile app stores is highlighted by our own findings that very few well-vetted and critically assessed mobile apps exist on the public mobile app market for families with NICU babies.

Another important consideration to the development of mHealth solutions, especially in a clinical research setting, include concerns surrounding data security and privacy. If protected health information (PHI) will be available or shared within the app, how the app's data will be stored and transferred must meet Health Insurance Portability and Accountability Act (HIPAA) standards. Finally, most app developers are not well-accustomed to developing apps for a clinical or research setting. If anticipated flow and pace of a project is unfamiliar, frequent communication between the medical professional members of a team and the external, software development members is essential (33).

Strengths and limitations

By starting with broad search criteria for this narrative review, we were better able to demonstrate the full scope of mobile apps intended for use in the NICU. These include, but are not limited to, apps for clinical purposes, apps for educating and supporting nursing and physician trainees, and apps to facilitate the incorporation of qualitative experiences of parents and caregivers in the NICU. We also believe that this work represents a novel investigation into the currently available mobile apps for use by parents of NICU babies that have either been developed in collaboration with physicians and parents and/or have been systematically vetted using research methods to assess the measurable impact of these apps on NICU babies and their parents.

We do also recognize that the use of broad search terms may be limitation in our study. For example, we selected to use terms like "neonatolog*" and "NICU" due to the importance of admission to a NICU as our primary population of study but, in selecting broad search terms, we may have missed articles that instead utilize other keywords to describe babies and infants with medical complexity or who were born premature. We also recognize that, in general, the narrative review format is less systematic and thorough than a systematic review, and we therefore may have neglected to include other articles detailing apps developed for parents with NICU babies.

A main limitation of this narrative review is the rapid development of new technological advances and developments in the mHealth space that continue to occur. We therefore recognize that between the time we performed our systematic searches of three major databases in mid-November 2022 and the time at which this work will be published, there will likely be additional contributions to this area of study. In fact, in the process of preparing this manuscript, we identified a study published within two weeks following our database searches in the *American Journal of Perinatology*. This article by Erdei *et al.* describes a novel app called "My Brigham Baby" that was developed to enhance the parental experience in a local NICU (34). Their pilot study had promising results, whereby measures of discharge readiness and parental confidence were both improved in the intervention group that utilized this mobile app.

Future research

Although this narrative review does not necessarily reflect the entire scope of existing mobile apps intended for use by parents in the NICU, we can ascertain from the relatively short list of studies that have critically developed and evaluated apps for this purpose that the number of apps that would be deemed medically accurate and appropriate to both educate and support families during the transition from NICU to home is relatively few. Therefore, we suggest that future research directed towards the development, evaluation, and implementation of mobile apps intended to support parents with babies in the NICU include a combination of qualitative and quantitative research aimed at soliciting the perspectives of a variety of important stakeholders. We also recommend that future studies utilize critical evaluation methods, including the randomized controlled trial, to ensure that newly developed mobile apps achieve their intended purpose of both providing support and accurate educational materials to ease the transition for parents from NICU to home. Depending on the exact population under study and the desired outcome with use of a mobile app, a variety of different measures including LOS, parenting self-efficacy, anxiety or depression scores, and time to access outpatient services like Early Intervention could all be used in this process of critical app evaluation.

Conclusions

This narrative review serves as an important summary of the existing mobile apps available to support parents as their babies complete the transition from NICU to home.

Through this review, we have highlighted some of the different stages of app development and dissemination. Development of novel mobile app solutions may include structured interviews with relevant stakeholders, including parents and physicians, and a multistage iterative process of designing and piloting app prototypes. The studies presented here also emphasize the importance of population specific app development. In the case of apps intended to educate and support parents with babies in the NICU, understanding both individual needs, which may be variable depending upon SES and education level, as well as the health systems with which parents and their neonates will be interacting are important to the development of appropriate and successful mobile apps.

Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://mhealth.amegroups.com/article/view/10.21037/mhealth-23-10/rc

Peer Review File: Available at https://mhealth.amegroups.com/article/view/10.21037/mhealth-23-10/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://mhealth.amegroups.com/article/view/10.21037/mhealth-23-10/coif). AL serves as an unpaid editorial board member of *mHealth* from November 2022 to October 2024. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Hebballi NB, Kerl CG, Garcia EI, et al. Barriers to Transition to Home From the Neonatal Intensive Care Unit: A Qualitative Perspectives of Parents and Healthcare Providers. J Perinat Neonatal Nurs 2021;35:340-9.

2. Aydon L, Hauck Y, Murdoch J, et al. Transition from hospital to home: Parents' perception of their preparation and readiness for discharge with their preterm infant. J Clin Nurs 2018;27:269-77.

3. Berman L, Raval MV, Ottosen M, et al. Parent Perspectives on Readiness for Discharge Home after Neonatal Intensive Care Unit Admission. J Pediatr 2019;205:98-104.e4.

4. McGowan EC, Abdulla LS, Hawes KK, et al. Maternal Immigrant Status and Readiness to Transition to Home From the NICU. Pediatrics 2019;143:e20182657.

5. Orr E, Ballantyne M, Gonzalez A, et al. The Complexity of the NICU-to-Home Experience for Adolescent Mothers: Meleis' Transitions Theory Applied. ANS Adv Nurs Sci 2020;43:349-59.

6. Saeed SA, Masters RM. Disparities in Health Care and the Digital Divide. Curr Psychiatry Rep 2021;23:61.

7. Rodriguez JA, Saadi A, Schwamm LH, et al. Disparities In Telehealth Use Among California Patients With Limited English Proficiency. Health Aff (Millwood) 2021;40:487-95.

8. Walker DM, Hefner JL, Fareed N, et al. Exploring the Digital Divide: Age and Race Disparities in Use of an Inpatient Portal. Telemed J E Health 2020;26:603-13.

9. Weems MF, Graetz I, Lan R, et al. Electronic communication preferences among mothers in the neonatal intensive care unit. J Perinatol 2016;36:997-1000.

10. Orr T, Campbell-Yeo M, Benoit B, et al. Smartphone and Internet Preferences of Parents: Information Needs and Desired Involvement in Infant Care and Pain Management in the NICU. Adv Neonatal Care 2017;17:131-8.

11. Dol J, Richardson B, Boates T, et al. Learning to parent from Google? Evaluation of available online health evidence for parents of preterm infants requiring neonatal intensive care. Health Informatics J 2019;25:1265-77.

12. Williams L, I'Anson J, Malarkey M, et al. Information sharing in neonatal intensive care: Parental perceptions and preferences. J Paediatr Child Health 2020;56:1121-5.

13. Davis DW, Logsdon MC, Vogt K, et al. Parent Education

is Changing: A Review of Smartphone Apps. MCN Am J Matern Child Nurs 2017;42:248-56.

14. Covidence systematic review software. Melbourne, Australia. Available online: https://www.covidence.org/

15. Blackburn S. Internet resources. J Perinat Neonatal Nurs 2014;28:12-3.

16. Doron MW, Trenti-Paroli E, Linden DW. Supporting parents in the NICU: A new app from the US, 'MyPreemie': A tool to provide parents of premature babies with support, empowerment, education and participation in their infant's care. J Neonatal Nurs 2013;19:303-7.

17. Krauskopf PB. Pneumonia Guide and My Neonatal Intensive Care Unit (NICU) Baby Mobile Apps. J Nurs Pract 2018;14:e171-2.

18. Rau NM, Hasan K, Ahamed SI, et al. Designing a tablet-based prematurity education app for parents hospitalized for preterm birth. Int J Med Inform 2020;141:104200.

19. Motlagh Z, Heidarzadeh M, Hashemi Moghadam R, et al. Design and Implementation of a Mobile Application for Premature Babies. Shiraz E Med J 2018;19:e66346.

20. Dol J, Delahunty-Pike A, Anwar Siani S, et al. eHealth interventions for parents in neonatal intensive care units: a systematic review. JBI Database System Rev Implement Rep 2017;15:2981-3005.

21. Lakshmanan A, Sunshine I, Calvetti S, et al. Designing a Mobile Health Solution to Facilitate the Transition from NICU to Home: A Qualitative Study. Children (Basel) 2022;9:260.

22. Phagdol T, Nayak BS, Lewis LE, et al. Designing a mobile health intervention for preterm home care: Application of conceptual framework. Public Health Nurs 2022;39:296-302.

23. Mburu S, Franz E, Springer T. A conceptual framework for designing mHealth solutions for developing countries. Proceedings of the 3rd ACM MobiHoc workshop on Pervasive wireless healthcare; Bangalore, India: Association for Computing Machinery; 2013:31-6.

24. Jani SG, Nguyen AD, Abraham Z, et al. PretermConnect: Leveraging mobile technology to mitigate social disadvantage in the NICU and beyond. Semin Perinatol 2021;45:151413.

25. Spargo P, de Vries NK. 'Babble': A smartphone app for parents who have a baby in the neonatal unit. J Paediatr Child Health 2018;54:121-3.

26. Banerjee J, Aloysius A, Mitchell K, et al. Improving infant outcomes through implementation of a family integrated care bundle including a parent supporting mobile application. Arch Dis Child Fetal Neonatal Ed 2020;105:172-7.

27. Garfield CF, Lee YS, Kim HN, et al. Supporting Parents of Premature Infants Transitioning from the NICU to Home: A Pilot Randomized Control Trial of a Smartphone Application. Internet Interv 2016;4:131-7.

28. Garfield CF, Kerrigan E, Christie R, et al. A Mobile Health Intervention to Support Parenting Self-Efficacy in the Neonatal Intensive Care Unit from Admission to Home. J Pediatr 2022;244:92-100.

29. Richardson B, Dol J, Rutledge 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:e11620.

30. Noorbergen TJ, Adam MTP, Teubner T, et al. Using Co-design in Mobile Health System Development: A Qualitative Study With Experts in Co-design and Mobile Health System Development. JMIR Mhealth Uhealth 2021;9:e27896.

31. Muro-Culebras A, Escriche-Escuder A, Martin-Martin J, et al. Tools for Evaluating the Content, Efficacy, and Usability of Mobile Health Apps According to the Consensus-Based Standards for the Selection of Health Measurement Instruments: Systematic Review. JMIR Mhealth Uhealth 2021;9:e15433.

32. Chamberlain S. Pilot-Itis: What's the Cure? BBC Blogs: Media Action 2012. Available online: https://www.bbc.co.uk/blogs/bbcmediaaction/entries/e00fc35a-0c0f-3e35-8280-38d048c34487

33. Chettri S, Wang V, Balkin EA, et al. Development of a Mobile App for Clinical Research: Challenges and Implications for Investigators. JMIR Mhealth Uhealth 2022;10:e32244.

34. Erdei C, Forde M, Cherkerzian S, et al. "My Brigham Baby" Application: A Pilot Study Using Technology to Enhance Parent's Experience in the Neonatal Intensive Care Unit. Am J Perinatol 2023. doi: 10.1055/a-1990-2414.