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Perinatal support for breastfeeding using mHealth: A mixed methods feasibility study of the My Baby Now app

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Abstract

Despite the well-known benefits of breastfeeding, breastfeeding rates remain suboptimal, particularly for women with lower socioeconomic position. Although popular, breastfeeding apps are often poor quality; their impact on breastfeeding knowledge, attitudes, confidence and intentions is unknown. A mixed method pre-post feasibility study was conducted to: 1) explore the feasibility of the My Baby Now app in providing perinatal breastfeeding support; 2) examine the impact on breastfeeding knowledge, attitudes, confidence and intentions; 3) to examine any differences in acceptability and impact of the app according to maternal education. The My Baby Now app was offered to pregnant women 20–30 weeks gestation. Breastfeeding knowledge and intentions were collected at baseline (T1) and 36–38 weeks gestation (T2); attitudes and confidence were collected at baseline, T2 and T3 (8–12 weeks post-partum). App engagement was measured via app analytics. Qualitative interviews were conducted with a purposeful sample following T3. Of 266 participants recruited, 169 (64%) completed T2 and 157 (59%) completed T3. Mothers without university education rated the app to be higher quality, more useful and impactful than mothers with university education. From T1–T2, breastfeeding knowledge (59.6% vs. 66.5%, $p < 0.001$) and exclusive breastfeeding intentions (76.6% vs. 80.9%, $p < 0.001$) increased. Breastfeeding attitudes and confidence scores also increased significantly across T1–T2 and T1–T3. App engagement during pregnancy predicted changes in breastfeeding attitudes from T1–T2 among participants without university education. App engagement did not predict changes in breastfeeding knowledge, confidence or intentions. Future randomised controlled studies should examine the effectiveness of mHealth interventions on breastfeeding outcomes.

KEYWORDS

breastfeeding, infants, mHealth, pregnancy

1 | INTRODUCTION

Breastfeeding has many well-established health benefits for both infants (Horta et al., 2015) and mothers (Chowdhury et al., 2015), as well as economic (Bartick & Reinhold, 2010), social and environmental (Karlsson et al., 2019) benefits. The Australian Infant Feeding Guidelines (National Health and Medical Research Council, 2012) recommend that infants be exclusively breastfed until around 6 months of age when solid foods are introduced, and that breastfeeding be continued until 12 months of age and beyond, 'for as long as the mother and child desire'. The latest National Health Survey results from 2017 to 2018 (Australian Bureau of Statistics, 2018a) indicate that most (93%) Australian mothers initiate breastfeeding at birth; however, less than 1 in 3 (29%) infants are exclusively breastfeed to 6 months of age. There is also a clear socioeconomic gradient in breastfeeding rates: 70% of mothers living in the most advantaged areas exclusively breastfeed to at least 4 months of age, compared with 53% of mothers in the most disadvantaged areas (Australian Institute of Health and Welfare, 2020).

While maternal demographic factors such as age, education and employment are important predictors of breastfeeding outcomes (Chimoriya et al., 2020), these are not amendable to change in response to behaviour change interventions. Prospective longitudinal research has shown knowledge of breastfeeding benefits and recommendations (Xu et al., 2022) and breastfeeding intentions (Donath & Amir, 2003; Donnan et al., 2013; Xu et al., 2022) during pregnancy and early post-natal support (Gavine et al., 2022) to be key modifiable predictors of breastfeeding initiation and duration. Breastfeeding intentions can, in turn, be influenced by breastfeeding self-efficacy, attitudes and subjective norms (the extent to which others would approve of the behaviours) (Guo et al., 2016). In research among low-income women, those who intended to breastfeed had higher breastfeeding knowledge, higher self-efficacy, and reported fewer barriers, compared with those who did not (Mitra et al., 2004). It has also been acknowledged that financial constraints may limit women's ability to access timely breastfeeding support (Tomori, 2022). This highlights the importance of accessible freely available interventions targeting psychosocial factors during the antenatal period to improve breastfeeding outcomes.

Women are increasingly relying on online sources of support for breastfeeding, particularly those accessible via mobile phone (mHealth), including social media and mobile phone apps (Lupton & Pedersen, 2016). A 2016 survey of Australian mothers found that three-quarters had used at least one app during pregnancy and half reported using at least one app post-partum (Lupton & Pedersen, 2016).

Despite the growing popularity of apps, research suggests that the quality of apps providing breastfeeding support is poor (Cheng et al., 2020; Musgrave et al., 2020; Sidhu et al., 2019). A recent review (Musgrave et al., 2020) of the top 10 freely available pregnancy apps in Australia found that while all provided information on breastfeeding, this was often incomplete, inaccurate or did not follow best practice guidelines. The use of behaviour change techniques was low, while some had links to commercial interests including companies that sell breast milk substitutes (Musgrave et al., 2020). Similarly, an audit of 41 breastfeeding apps found that most were developed by large for-profit organisations and did not contain features to promote breastfeeding self-efficacy (Sidhu et al., 2019). In line with this, a systematic review of infant feeding apps (Cheng et al., 2020) found that most apps were commercially developed, nearly two-thirds (64%) had no or low coverage of Australian guidelines on infant feeding and more than half had incorrect or incomplete information. Of concern was that the credibility of the information contained in the apps had not improved over a 5-year period since an earlier audit of infant feeding apps (Cheng et al., 2020; S Taki et al., 2015).

Research into the development and testing of evidence-based mHealth interventions for breastfeeding is growing. A recent systematic review and meta-analysis (Qian et al., 2021) of 15 randomised controlled trials (RCT) of mHealth breastfeeding interventions found that these interventions significantly increased exclusive breastfeeding rates at 1, 2, 3 and 6 months post-partum and improved breastfeeding self-efficacy, though not breastfeeding attitudes. Nearly half ($n = 7$) of these studies were in low- to middle-income countries: most used SMS and/or telephone support as the main delivery mode, two used web-based interventions, and none used a mobile phone app. An RCT of a smart phone educational app in Iran (Seyyedi et al., 2021) among new mothers (infants less than 3 months of age) found that the intervention group had significantly higher knowledge, attitudes and self-efficacy scores at 3 months post-partum compared with the control group. There is a lack of studies examining the feasibility of using apps to provide perinatal support for breastfeeding particularly in high-income countries and among women with lower socioeconomic position.

Key points

- Women are increasingly relying on apps as a source of breastfeeding support. However, the quality of apps available is poor.
- The My Baby Now app provides a credible evidence-based source of breastfeeding support across the perinatal period that is acceptable and perceived to be useful, particularly for women with lower levels of education.
- Randomised controlled trials are needed to examine the effectiveness of mHealth interventions on breastfeeding outcomes, particularly among mothers from lower socioeconomic backgrounds.
- Future research is also needed to explore how best to embed evidence-based apps, such as My Baby Now, into existing antenatal services to provide an integrated model for breastfeeding support across the perinatal period.

In 2015–2018, the authors (RL, EDW, and KL) developed and tested an app called 'Growing healthy' (Laws et al., 2018), which provided support for optimal infant feeding practices from birth to 9 months, including breastfeeding. A quasi-experimental trial of the app found no impact on any breastfeeding outcomes at 6 and 9 months of age (Laws et al., 2018), with a major limitation being infant age at enrolment: with study initiation at 7–8 weeks infant age, the critical period for breastfeeding support during the early post-partum period was missed which research has shown to be vital to improving breastfeeding outcomes (Gavine et al., 2022). In qualitative feedback, mothers reported making decisions about infant feeding before app use (Litterbach et al., 2017), consistent with research suggesting that maternal breastfeeding plans are made antenatally (Donath & Amir, 2003). As a result, the authors (RL, EDW, and KL) developed a revised version of 'Growing healthy', called 'My Baby Now', which included an antenatal component focusing on providing anticipatory guidance for breastfeeding.

This study had three main aims: First, to examine the feasibility and acceptability of the My Baby Now app in providing breastfeeding support to women during pregnancy and the early post-partum period; Second to examine the impact of the intervention on women's breastfeeding knowledge, attitudes, confidence and intentions and thirdly to examine any differences in acceptability and impact of the app according to maternal education as a key indicator of socioeconomic position.

2 | METHODS

2.1 | Ethics

The study was approved by a University Human Ethics Research Committee (reference 2020/486) on 2 November 2020. Study procedures followed the approved protocol.

2.2 | Participant recruitment

Participants were eligible if they were first-time expectant mothers between 20 and 30 weeks of pregnancy, with a singleton pregnancy; had access to a smartphone; were residing in Australia; did not have any health conditions that contraindicated breastfeeding; and with sufficient English understanding to consent to participate and use the app. Due to a simultaneous rollout of the My Baby Now app in Victoria as part of the scale-up of the INfant Feeding Active play and NutriTion (INFANT) programme, participants residing in Victoria were asked not to participate in this study. However, residence in Victoria was not an exclusion criterion and these participants were permitted to enrol and were not excluded from the analysis as INFANT programme intervention did not commence until 3 months of age and thus did not impact this study results.

Participant recruitment was undertaken through targeted online Facebook advertising over two rounds. The first round of Facebook advertising in February to March 2021 targeted individuals aged 18 years and older, with Facebook profile interests: 'baby' or 'family'. After disproportionate initial recruitment of participants with high educational attainment (78% with university education), a second round of Facebook online advertising in April to May 2021 targeted women without a university-level education, using ads directed to users with postcodes in the lowest quintile of the Socioeconomic Index for Areas (an area level indicator of relative socioeconomic advantage and disadvantage) (Statistics, 2018b). This was to ensure a sample of women of varying levels of education were recruited to enable any differences in app acceptability and impact to be examined by maternal education. Upon completing an online eligibility checklist, participants enroled in the study by providing informed consent and completing the baseline online survey administered using REDCap electronic data capture tool (Harris et al., 2009).

2.3 | The My Baby Now App

After completing the baseline survey, participants received a text message and email with an access code and instructions to download the My Baby Now app from the App Store or Google Play. My Baby Now is a hybrid app available in both Android and iOS operating systems. We used a hybrid development approach so that the app's design language and content are consistently rendered using Web technologies. This method reduces development time and is also cost-effective by targeting mobile platforms and access on traditional settings, such as a desktop or laptop browser. The 'operating system'-specific experience is then achieved by integrating the Web code with native code to deliver 'operating system'-specific functionalities, such as app updates, push notifications, data analytics, and OS-specific guidelines to operating behaviour (e.g., iOS data privacy requirements).

The app provides evidence-based information and support on infant feeding and active play from pregnancy to 18 months of age in line with Australian Infant Feeding Guidelines (National Health and Medical Research Council, 2012) and 24 h Movement Guidelines for Early Years (Australian Government Department of Health, 2017). The breastfeeding component included anticipatory guidance for breastfeeding during pregnancy and post-partum. This consisted of written articles, videos, interactive activities such as quizzes (e.g., milk supply quiz) and tools (breastfeeding goals) to provide personalised and tailored feedback designed to enhance users breastfeeding knowledge and efficacy as well as the development of positive attitudes towards breastfeeding. A facilitated forum to share experiences with other users and pose questions was also provided in the app. The forum was facilitated by a member of the research team with expertise in infant feeding and nutrition and consisted of proactive 'posts' aligned with the push notifications to reinforce key messages as well as responding to user questions. During pregnancy, users received two push notifications per week: the first focused on week by week pregnancy guide; the second focused on anticipatory

guidance for breastfeeding. Post-partum users received three push notifications per week tailored to feeding mode and baby's age and stage of development.

The app is informed by extensive formative research with both parents (Russell et al., 2016) and practitioners (Laws et al., 2015) and a feasibility study of an earlier version of the app, 'Growing healthy' (Laws et al., 2018). As previously reported (Laws et al., 2018), the development of the app content and features was guided by the Behaviour Change Wheel and the Capability, Opportunity and Motivation (COM-B) model of behaviour change (Michie et al., 2011). For breastfeeding content, key barriers to breastfeeding were identified using prior formative work (Laws et al., 2015; Russell et al., 2016) and literature and mapped to app content, features and push notifications.

2.4 | Study design and data collection

This was a feasibility study using a mixed methods pre-post design, consisting of: online surveys administered via REDCap at three-time points: T1 (baseline 20–30 weeks gestation); T2 (before birth at 36–38 weeks gestation) and T3 (8–10 weeks post-partum based on the most recent due date provided in T1 or T2 surveys or date of birth at T2 if baby born at this time point); analysis of app analytics; and qualitative semi-structured interviews with a purposeful sample of participants post-partum. In this concurrent mixed methods study (Hanson et al., 2005), the 'mixing of methods' occurring during data analysis (qualitative data was explored to help explain survey findings) and during the interpretation (quantitative and qualitative data were triangulated to provide a more complete understanding of engagement with and impact of the app on breastfeeding knowledge, confidence, attitudes and intentions).

Follow-up survey invitations were sent via text message and email, with non-responders receiving two reminders 1 week apart. To compensate participants for the time involved, participants received a $20 gift voucher following completion of T3 survey and a $30 voucher for participating in a qualitative interview.

2.4.1 | Assessment of participant demographics

Sociodemographic characteristics collected at T1 included age, country of birth, language spoken at home, Aboriginal and Torres Strait Islander status, the highest level of education, eligibility for health care card (a government concession card available to low-income people), and postcode of residence.

2.4.2 | Assessment of feasibility and acceptability

Measures of feasibility and acceptability used in this study included:

- participant retention rates at T2 and T3;
- participant assessment of the quality of the app at T2 using the valid and reliable User Version of the Mobile Application Rating Scale (uMARS) (Stoyanov et al., 2016);
- acceptability and suitability of the app push notification in terms of number received, time of day received and content measured at T2 on a 5-point Likert scale from 'strongly agree' to 'strongly disagree';
- app usefulness measured at T2 and T3 on a 5-point Likert scale from 'not at all useful' to 'highly useful'; and whether participants would recommend the app to a friend measured on a 5-point Likert scale from 'not at all - no one' to 'definitely - everyone';
- app comprehensiveness measured at T2 and T3 using a single item, 'The app covered all the things about infant feeding', on a 5-point Likert scale from 'strongly agree' to 'strongly disagree';
- open-ended question at T2 and T3: 'Do you have any other comments or suggestions about My Baby Now?'

Feedback on app usefulness and acceptability was also explored in the qualitative interviews as described below.

2.4.3 | App usage and engagement

App usage and engagement were calculated for each user using an Engagement Index, which expanded on our previous research (Taki et al., 2016). The index comprised four subindices that measure (1) click depth, the average number of app pages a user viewed per day, (2) loyalty, the total number of days a user engaged with the app, (3) recency, the average number of days between app use, and (4) diversity, the number of different app features used per day (i.e. topic articles, forums, push notifications, and tools). Subindices were normalised by rescaling values between 0 and 100 so that each would have equal weight. The Engagement Index was then calculated as the athematic mean of the four subindices. Engagement Index calculations were carried out using Python 3 (Van Rossum & Drake, 2009).

2.4.4 | Assessment of breastfeeding impacts

2.4.4.1 | *Breastfeeding intentions and knowledge*

Breastfeeding intentions were measured at T1 and T2 using a single item, 'How are you planning to feed your baby when she or he is born?', with response options: breastfeeding only; mostly breastfeeding and some water; mostly breastfeeding and some juice; mostly breastfeeding and topping up with formula; mostly formula feeding with some breastfeeding; equally breast and formula feeding; formula feeding only; other—please specify; not yet decided. For analysis purposes breastfeeding intention categories were collapsed into 'exclusive breastfeeding' and 'nonexclusive breastfeeding/undecided'.

Knowledge of World Health Organization (WHO) recommendations on exclusive breastfeeding duration was assessed at T1 and T2 using a single item, 'From what you've heard and read, what do you

understand to be the recommended age to which babies should ideally be exclusively breastfed?'; participants replied in terms of weeks, months or 'don't know'. The WHO definition of exclusive breastfeeding was provided before the question. Responses were categorised as 'correct' or 'not correct/don't know'.

2.4.4.2 | *Breastfeeding confidence*

Breastfeeding confidence was measured at T1, T2 and T3 using the 10-item breastfeeding control scale of the Breastfeeding Attrition Prediction Tool (Janke, 1994). The breastfeeding control items measure perceived control over internal and external barriers to breastfeeding, e.g. knowledge, skills, emotional readiness, accessing help. These items are appropriate to use prenatally and post-partum and have good construct and predictive validity (Janke, 1994). Responses were on a 6-point Likert scale ('strongly disagree' 'disagree', 'slightly disagree' 'slightly agree' 'agree' 'strongly agree'). A sum of the 10 items indicate a measure of perceived breastfeeding control, with higher scores indicate greater perceived breastfeeding control.

2.4.4.3 | *Breastfeeding attitudes*

Breastfeeding attitudes were measured at T1, T2 and T3 using the 17 items of Iowa Infant Feeding Attitudes Scale (Mora et al., 1999). This tool has been used widely to provide a reliable and valid assessment of maternal attitudes towards infant feeding (Casal et al., 2017). Participants indicate on a 5-point Likert scale ('strongly disagree' 'disagree', 'neutral' 'agree' 'strongly agree') their opinion on the 17 statements, which include common perceptions of the advantages and disadvantages of breast and formula feeding, for example, 'formula feeding is more convenient than breastfeeding', 'babies fed breast milk are healthier than babies who are fed formula'. The attitude score was obtained by reverse scoring the negatively worded items and summing up the scores to all items. Higher scores indicate more positive attitudes towards breastfeeding.

2.4.4.4 | *Perceived impact of the app on breastfeeding*

Participants were asked at T2 and T3 about the perceived impact of the app using a 5-point Likert ('strongly disagree' 'disagree', 'neutral' 'agree' 'strongly agree') on: their awareness of the importance of breastfeeding (T2); knowledge of breastfeeding (T2); attitudes towards breastfeeding (T2); their intention/motivation to breastfeed (T2); encouragement to seek help to solve breastfeeding problems (T2, T3), breastfeeding practices (T2, T3). The impact of the app on breastfeeding outcomes was also explored in the qualitative interviews as described below.

2.4.4.5 | *Breastfeeding initiation and exclusivity*

Breastfeeding initiation was assessed by asking participants at T3, 'Has your baby ever had breast milk (this includes colostrum, expressed breast milk, and breast milk from a donor or donor milk bank)?'. Consistent with WHO definitions of exclusive breastfeeding (World Health Organization, 2008), this was determined at T3 by the question, 'Apart from breast milk, has your baby ever had any other fluids or food? This includes given in any amount or frequency. NB This does NOT include oral rehydration solution or drops/syrups of vitamins, minerals or medicines)'. Those answering 'yes' were asked to indicate the infant's age in weeks when other fluid or food was introduced.

2.5 | Qualitative interviews

Participants for the qualitative component of the study were selected from those who indicated interest (during the T3 survey) in participating in a semi-structured interview about their experiences using the app. Of those expressing interest, a purposeful sample of participants were selected to examine a range of feeding modes, education levels and perceptions of the app at T2 and T3, and invited by their nominated method (mobile or email) to participate. Interviews were conducted via telephone and commenced with verbal consent to participate. Three female researchers conducted the interviews: two midwives and one social scientist. Interviews were conducted at a time convenient to the participant. The interviews explored two main areas corresponding to the study aims: 1) participants' perception of the usefulness and acceptability of the app including questions on app use (both during pregnancy and post-natally); and factors influencing use including app functionality, navigation, aesthetics and the quality and quantity of app content informed by uMARS domains (Stoyanov et al., 2016); 2) perceived impact of the app on participants' capacity, opportunity and motivation to breastfeed as informed by the COM-B model of behaviour change (Michie et al., 2011). All interviews were recorded with participants' permission and transcribed verbatim.

2.6 | Data analysis

All quantitative data were analysed using RStudio v1.4.1106 (RStudio). Survey data on app acceptability and perceived impact was analysed descriptively and compared by level of educational attainment using Pearson's chi-squared test or Linear-by-Linear-Association for ordinal data. In line with recommending scoring procedure (Stoyanov et al., 2016), mean and standard deviation were calculated for each subscale of uMARS, with an objective score being the mean of uMARS subscales Engagement, Functionality, Aesthetics and Information. uMARS subscales were compared by participants' level of educational attainment, using the student's t-test. Changes in breastfeeding knowledge and intentions from T1 to T2 were assessed using the chi-squared test or Fisher's exact test. Changes in breastfeeding confidence and attitudes from T1 to T2 and T1 to T3 were assessed using paired t-tests.

Logistic regression was used to examine if app engagement during pregnancy was an independent predictor of knowledge of breastfeeding guidelines (correct/incorrect) at T2 after controlling for key covariates and breastfeeding knowledge at T1. Similarly, Logistic regression was used to examine if app engagement during pregnancy

was an independent predictor of breastfeed intentions at birth at T2 ('exclusive breastfeeding' and 'nonexclusive breastfeeding/undecided) after controlling for key covariates and breastfeeding intentions at T1. Linear regression was used to examine if app engagement was an independent predictor of changes in breastfeeding attitudes and confidence from T1 to T2 and from T1 to T3, after controlling for key covariates. To address aim three of the study, separate models were run for those with and without university education (with the exception of breastfeeding intentions where there was insufficient variation to allow for a stratified analysis). Co-variates included in all stratified models were age, country of birth and geographical location, with university educational attainment included in the model not stratified by education.

Qualitative interviews were professional transcribed verbatim and checked for accuracy against the recording, anonymised and uploaded to NVivo (version 11 Pro) qualitative data analysis software (QSR International, 2020) for management and coding. An initial analytic framework was developed based on both the uMARS instrument (for questions related to app usefulness and acceptability) and COM-B model (for questions related to participants' capability, opportunities and motivation in relation to infant feeding) as interview topics were structured around these models. Two researchers (CR and HC) conducted coding in NVivo using a combination of deductive coding using the analytical framework and inductive coding of data that did not fit the framework constructs. The two researchers compared their coding on two interviews (using the inter-rater reliability function in NVivo) and achieved a rating of 82.9%–100%. Five other researchers (RL, KK, EDW, DS and PC) also reviewed transcripts, and collectively contributed to the coding framework. For the current study, the qualitative data are presented to elaborate and help explain the quantitative findings, illustrating typical experiences among participants in using the app. Selected extracts from interviews are presented, identified only by the interview ID, participants' education level and feeding method at T3.

3 | RESULTS

3.1 | Participant characteristics

A total of 266 eligible participants enroled in the study: 169 (63.5%) completed T2 survey with 168 (63.2%) eligible for analysis; 157 (59.0%) completed T3 survey with 155 (58.3%) eligible for analysis (Figure 1). A total of 78 participants expressed interest in participating in a qualitative interview; from which a purposeful sample of 45 participants were selected to examine a range of feeding modes, education levels and perceptions of the app at T2 and T3. Of the 45 invited, 24 participated in qualitative interviews which ranged in duration from 18 min to 42 min, the remainder did not respond ($n = 20$) or did not attend the scheduled interview ($n = 1$). There was no significant difference in any of the measured sociodemographic characteristics between those invited participants who took part in an interview and those that did not (data not shown).

Baseline characteristics of study participants are reported in Table 1. Participants were predominantly Australian-born, English-speaking, university educated and living in a major city. However, nearly 30% of survey respondents held healthcare concession cards. One in 10 mothers or their babies identified as Aboriginal or Torres Strait Islander. Compared with participants who completed T2 and/or T3 surveys, participants lost to follow-up after baseline were more likely to have a high school as the highest educational attainment ($\chi^2 = 9.62$, $p = 0.02$); no other significant differences in baseline characteristics were found.

3.2 | App usage

Based on app analytics, 52.3% (139/266) of all participants used the app at least once, with 50.8% (135/266) using it during pregnancy and 32% (85/266) using it after birth. Of those participating in interviews, 14 out 24 had used the app in pregnancy and were still using it at the time of the interview. There were varying experiences among the remaining 10, including 5 who had stopped usage after birth and 2 who stopped using the app during pregnancy. The main reason for not using the app were participants forgot, were too busy after the baby was born, or they did not like the format or experienced technical difficulties. The pattern of app usage also changed during the study period, with the level of engagement increasing as users approached their reported due date and then falling through to 12 weeks post-partum (Online Supporting Information File 1). App engagement then increased during the remainder of the study period, that is, after the final survey (between 10 and 28 weeks post-partum). The types of app features used also changed antenatally versus post-partum, with users tending to interact mostly with push notifications in the post-partum period and relying less on articles, tools, and forums. Post-partum users also appeared to check in more frequently (i.e., a higher loyalty subindex) but spend less time on the app (as evidenced by a lower click depth). A total of 61.4% of those using the app accessed the pregnancy topic and 37.4% accessed the breastfeeding topic with the most accessed articles, activities and push notifications shown in Online Supporting Information File 1. While only 3.5% of all push notifications sent were opened by participants, the most popular push notifications were accessed by up to 40% of participants and related to introduction of solids, breastfeeding in public and expressing breast milk (Online Supporting Information File 1).

3.3 | Feasibility and acceptability

3.3.1 | User rating of app quality, usefulness and comprehensiveness

The uMARS scores (Table 2) revealed that participants rated quality as 'moderate'. Compared with participants with university education, those without university education had higher uMARS ratings on all subscales, with the exception of the Information subscale. In line with this, a higher proportion of participants without university education found the app to be comprehensive ('cover all the things about infant

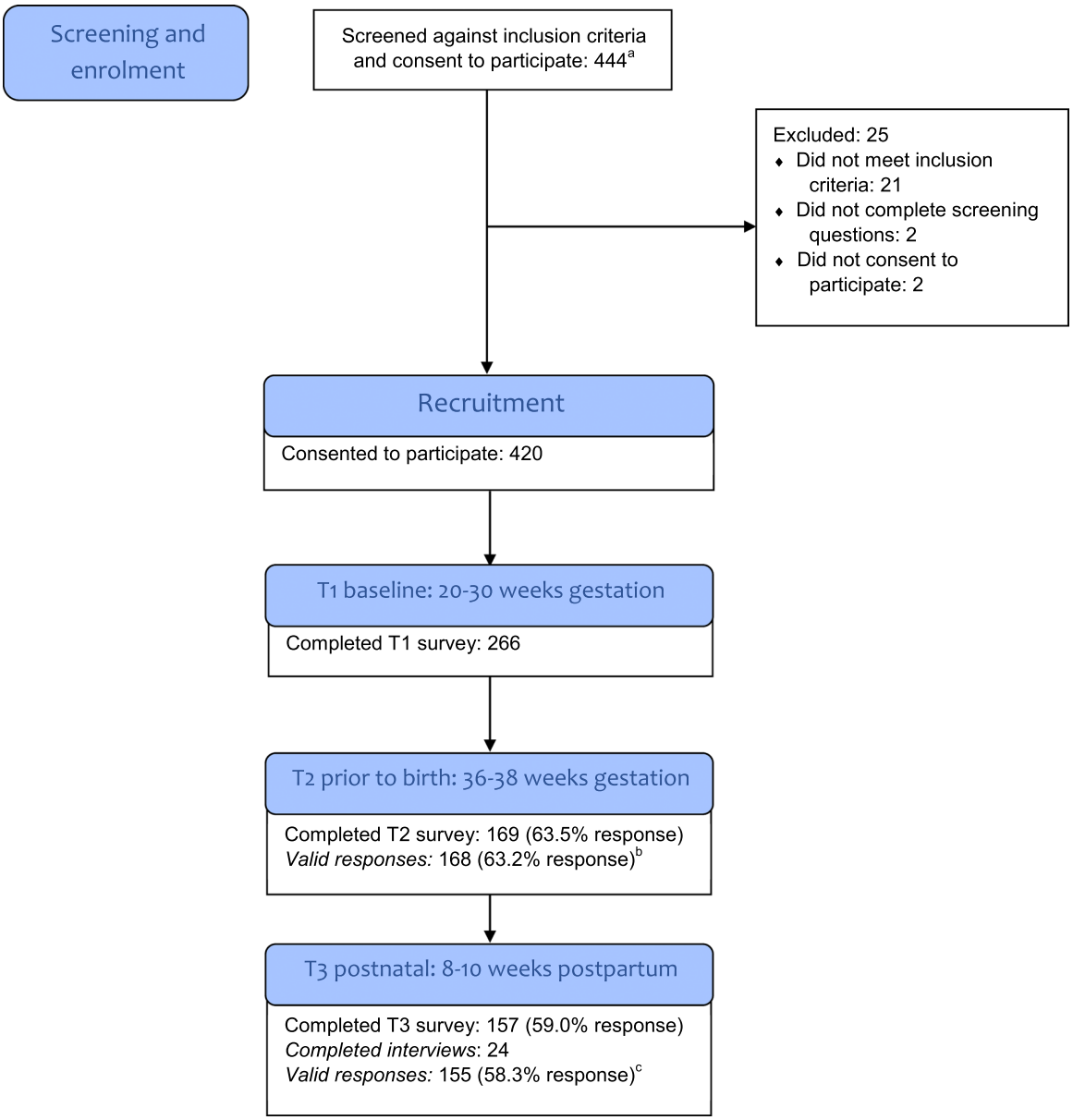

FIGURE 1 Participant recruitment and retention: CONSORT Diagram. [a]This number may be artificially low. The format of the screening questions on the online data collection instrument immediately informed respondents if they were ineligible – if these respondents closed the survey after receiving the ineligibility message, their response would not have been recorded. [b]*n* = 1 removed from analysis: completed T2 response after 36–38 week gestational age window. [c]*n* = 2 removed from analysis: completed T3 response after infant 8–10 week age window.

feeding that I wanted'), found the push notifications timely and helpful, and would recommend it to others, compared with participants with university education (Table 3).

uMARS ratings were highest and lowest for the Information and Engagement subscales, respectively. This was reflected in the qualitative interviews where participants discussed that the credibility of the information in the app as being an important driver of app use. Particularly, participants valued evidence-based app content, the alignment of Australian content with health professional advice, and the app development by university researchers.

> *I was probably more inclined to go with the information through the app because I know it… had a bit more maybe research behind it and it was from the Deakin University and not …bit of a random Google search… I'd probably go more to My Baby Now because I felt like it was more maybe aligned with me and obviously being Australian. (Participant #21 High school education)*

Participants identified that the app helped to fill a void in breastfeeding information during pregnancy, with mothers reporting

TABLE 1 Participant characteristics.

Maternal characteristics	Survey participants *n* = 266 - baseline	Interview participants *N* = 24
Age (mean ± SD, range)	30.32 ± 4.89, 18–42	31.17 ± 5.19, 22–40
Country of birth (*n*, %)		
Australia	210 (79.3)	20 (83.3)
Outside of Australia	56 (20.7)	4 (16.7)
Main language/s spoken at home (*n*, %)		
English	256 (96.2)	23 (95.8)
Other[a]	15 (5.6)	0 (0)
Aboriginal or Torres Strait Islander identity (*n*, %)		
Mother identifies as Aboriginal and/or Torres Strait Islander	14 (5.3)	2 (8.3)
Mother not, but child will be Aboriginal and/or Torres Strait Islander origin	12 (4.5)	2 (8.3)
Neither mother or child Aboriginal or Torres Strait Islander identity	240 (90.2)	20 (83.3)
Educational attainment (*n*, %)		
High school education	57 (21.4)	4 (16.7)
Trade certificate or diploma	54 (20.6)	8 (33.3)
Bachelor degree	84 (31.0)	7 (29.2)
Postgraduate degree or qualification	71 (26.7)	5 (20.8)
Health Care Card holder (*n*, %)		
Yes	78 (29.3)	4 (16.7)
No	188 (70.7)	20 (83.3)
Location - Geographical remoteness area (*n*, %)		
Major city	188 (70.7)	16 (66.7)
Inner regional	50 (18.8)	6 (25.0)
Outer regional, remote or very remote	28 (10.5)	2 (8.3)
Feeding at T3 survey (*n* = 160)		
Exclusive breastfeeding	99 (61.9)	17 (70.8)
Mostly breastfeeding with formula top-up	35 (21.9)	4 (16.7)
Mostly formula feeding with breast milk top-up	4 (2.5)	1 (4.2)
Formula feeding only	18 (11.3)	2 (8.3)
Other	4 (2.5)	0
Infant characteristics (T2, T3 data *n* = 161)[b]		
Gender		
Boy	87 (54.0)	12 (50.0)
Girl	74 (46.0)	12 (50.0)
Gestational age		
<37 weeks	12 (7.5) = 7 (T2) + 5 (T3)	2 (8.3)
≥37 weeks	148 (91.3) = 2 (T2) + 146 (T3)	22 (91.7)

[a]Does not add up to 100%: participants may speak more than one language as main language/s spoken at home. Other languages: Arabic, Cantonese Chinese, Filipino, Hungarian, Malayalam, Mandarin Chinese, Polish, Punjabi, and Tagalog.

[b]1 missing response at T3.

TABLE 2 User rating of app quality at T2 (User version of the Mobile Application Rating Scale), by the highest level of education.

uMARS ratings (mean ± SD)	All (*n* = 163–164)	Non-university	University	*p*-value[a]
Engagement subscale	3.20 ± 0.69	3.43 ± 0.71	3.06 ± 0.64	$p < 0.001$
Functionality subscale	3.66 ± 0.78	3.85 ± 0.65	3.55 ± 0.84	$p = 0.011$
Aesthetics subscale	3.55 ± 0.72	3.70 ± 0.69	3.47 ± 0.72	$p = 0.043$
Information subscale	3.98 ± 0.60	4.03 ± 0.52	3.95 ± 0.64	$p = 0.398$
Objective uMARS score	3.60 ± 0.61	3.75 ± 0.57	3.51 ± 0.62	$p = 0.011$
Subjective uMARS score	2.84 ± 0.79	3.06 ± 0.76	2.71 ± 0.79	$p = 0.006$

Note: Objective uMARS score: mean of uMARS subscales Engagement, Functionality, Aesthetics and Information. Ratings are scored from 1 to 5; higher ratings indicate more positive responses. Subgroups: 'Non-university' and 'university' indicate high school and trade diploma/certificate or university degree as the highest educational attainment, respectively.

[a]Between-group comparison of participants with and without university.

TABLE 3 App acceptability and impact by the highest level of education.

	No (%) Agree/strongly agree			
	All	Non-university	University	*p*-value
Acceptability				
The app covered all the things about infant feeding that I wanted it to (T2)	67 (41.6)	33 (55.0)	34 (33.7)	$p = 0.004$
The app covered all the things about infant feeding that I wanted it to (T3)	62 (41.3)	31 (51.7)	31 (34.4)	$p = 0.021$
Satisfied with time of day push notifications were sent (T2)	59 (53.6)	24 (72.7)	35 (45.5)	$p = 0.005$
Found notifications helpful (T2)	56 (50.9)	24 (72.7)	32 (41.6)	$p = 0.003$
Would definitely recommend My Baby Now to everyone who might benefit (T2)	18 (11.0)	11 (18.0)	7 (6.9)	$p < 0.001$
Would definitely recommend My Baby Now to everyone who might benefit (T3)	16 (10.7)	11 (18.3)	5 (5.6)	$p = 0.017$
Perceived impact				
This app has increased my awareness of the importance of breastfeeding (T2)	61 (40.4)	28 (46.7)	33 (32.7)	$p = 0.074$
This app has increased my knowledge/understanding of breastfeeding (T2)	57 (35.4)	27 (45.0)	30 (29.7)	$p = 0.093$
As a result of this app, I feel more positive about breastfeeding (T2)	57 (35.4)	27 (45.0)	30 (29.7)	$p = 0.017$
This app has increased my intentions/motivation to breastfeed (T2)	47 (29.2)	22 (36.7)	25 (24.8)	$p = 0.086$
Push notifications helped infant feeding decisions (T2)	31 (28.2)	16 (48.5)	15 (19.5)	$p < 0.001$
This app would encourage me to seek further help to address breastfeeding problems (T2)	84 (52.2)	36 (60.0)	48 (47.5)	$p = 0.047$
I think this app will help me to breastfeed (T2)	74 (46.0)	35 (58.3)	39 (38.6)	$p = 0.034$
This app helped me with breastfeeding (T3)	48 (33.1)	25 (45.5)	23 (25.6)	$p = 0.010$
This app encouraged me to seek help to address breastfeeding problems (T3)	38 (36.2)	17 (43.6)	21 (31.8)	$p = 0.133$

that antenatal appointments and pregnancy literature focused on labour and birth:

> *But there's really not that much out there that the doctors or the hospitals or anything give you. So, apps like My Baby Now are great because there's so many breastfeeding questions mums have (Participant #10, trade certificate/diploma, exclusive breastfeeding).*

Participants discussed that app content was easy to understand, comprehensive and in one place:

> *I know it's got a bunch of good information in one easy access place, rather than having to go to a hundred different websites. It kind of makes it easy in that sense. It wasn't really super technical medical jargon, which is always a bonus (Participant #14, high school education, exclusive breastfeeding).*

Consistent with mean uMARS rating, participants felt the app could be more visually appealing and engaging. Some described app appearance as 'bland' and 'dated'. Suggestions for improvement included the use of less text, more

pictures, graphics and videos, with greater 'movement and colour'.

In terms of engagement, participants liked the interactive quizzes and the push notifications as timely and useful reminder of relevant content.

> *'The notifications themselves are good…They're not asking too much of you. Yeah, they're concise. I'd say they give you the right information. And to be honest, they're a good reminder… If you're not prompted to use something you forget about it' (Participant #3, post-graduate degree/qualification, exclusive breastfeeding)*

However, not all participants were aware of the push notification feature, and participants wanted to customise the frequency of push notifications. Suggestions for improving engagement included having more tools and tracking devices, active parenting forums to create a sense of community, organising content around pregnancy stage or baby age, and including a search function to facilitate access to specific content to solve common problems, for example, mastitis.

> *'There was a feeling that it was a bit stagnant, the app, and I think that the ones [other apps] that really caught my attention were ones where I got alerts … even daily, little reminders and bits of information that were unveiled as you went along almost, which kept me engaged and interested' (Participant #1, bachelor degree, exclusive breastfeeding)*

Unfortunately, a number of participants reported experiencing technical difficulties in app use, including push notifications not working, the app being 'laggy' and the app crashing. Although this functional problem was rectified, it negatively impacted the experience of users early in the trial, some of whom discontinued using the app because of technical difficulties.

3.4 | Breastfeeding outcomes

3.4.1 | Perceived impact of the app on breastfeeding

At T2, 40.4%, 35.4% and 29.2% of participants perceived the app to have a positive impact on breastfeeding awareness, knowledge, and intentions respectively (Table 3). Interestingly, a higher proportion of participants without university education agreed that the app had positive impacts on breastfeeding outcomes, compared with their university-educated counterparts, which reached statistical significance for the impact of push notifications in making infant feeding decision in pregnancy, encouraging participants to seek help to address breastfeeding problems and helping participants to breastfeed (Table 3).

In interviews, some participants discussed that they were strongly committed to breastfeeding before accessing the app.

> *I don't think it really influenced one way or the other. I was pretty settled on breastfeeding…although it [the app] did have good information about it…I already knew what I was going to do. (Participant #14, high school education, exclusive breastfeeding)*

Others, particularly those who had no experience of breastfeeding in their personal networks, reported gaining new information from the app which changed their feeding intentions:

> *I think originally I was all completely against breastfeeding, and I had the idea of doing mixed feeding. But, I was more so ready to give up breastfeeding in a heartbeat. But, I think the app kind of convinced me the benefits of breastfeeding. (Participant # 19, Bachelor degree/speaks language other than English at home, breastfeeding with formula top-up).*

Others discussed the value of the app in providing anticipatory guidance on what to expect with breastfeeding that increased their confidence, strengthening their intention to breastfeed:

> *…[the app] made me understand a bit more about what to expect and some of the difficulties that might come up, which they did for me. So it was nice reading this sort of information and I didn't feel like it was overwhelming…. (Participant #11, postgraduate degree/qualification, breastfeeding with formula top-up)*

Some participants were actively seeking out information on how to feed during pregnancy and felt they had more time to do this before birth, while others felt that this information was more relevant when the baby was born, taking a 'needs-to-know' approach to information seeking. Irrespective of the differences in these approaches to app use, being aware of the app content and where to access support was useful once the baby arrived.

> *…I was so focused on the actual pregnancy…I don't think I've really done a deep amount of research into breastfeeding. I knew that your app was there for when I needed it, but I didn't necessarily access from that readily in the lead-up. (Participant #1, Bachelor degree, exclusive breastfeeding)*

After birth, the information gained from the app provided reassurance to some participants, particularly around milk supply, boosting confidence to continue breastfeeding:

> *And the challenge that it helped with was the milk supply…when I was starting to worry about that, when*

he had his three weeks growth [spurt]. And then again at five weeks, and it seemed like I wasn't keeping up… with him, but going through and reading that. And that was based on a prompt that I got when the milk supply article popped up. It came up as a notification, and so I read it then and there, but then I went back and read it again when I was having trouble because I thought, "Oh, I do remember reading that somewhere." (Participant #10, trade certificate/diploma, exclusive breastfeeding)

Participants also reported using the app to troubleshoot specific breastfeeding problems, providing sources of additional support:

I found, my milk didn't come in…and so I went to the Australian Breastfeeding Association for assistance, which is linked through the app, which was fantastic (Participant #3, Postgraduate degree/qualification, exclusive breastfeeding)

A common theme discussed was the non-judgemental source of support from the app, which often contrasted to their perceptions of health professional advice:

So you could just read it at your own leisure without feeling judged… it didn't feel like it was just a push that was the agenda to make sure you did breastfeed. It felt like it was more providing evidence-based information and trying to support the person so that they could breastfeed. (Participant #11, postgraduate degree/qualification, breastfeeding with formula top-up)

3.4.2 | Changes in breastfeeding knowledge, attitudes, confidence and intentions

There were significant increases in breastfeeding knowledge, confidence, attitudes and intentions to exclusively breastfeed at birth from baseline to T2 in late pregnancy (Table 4). In stratified analysis, these changes were significant for both university and non-university educated participants, with the exception of changes in breastfeeding knowledge for non-university educated participants, which did not reach statistical significance. There were also significant increases in breastfeeding attitudes and confidence from T1 to T3 post-partum (Table 5). Similarly, these differences were significant for both university and non-university educated participants, with the exception that changes in attitudes did not reach statistical significance for those without university education.

In linear regression models (Online Supporting Information File 2), after controlling for covariates, app engagement during pregnancy significantly predicted changes in breastfeeding attitudes from baseline to post-partum among participants without university education ($\beta = 0.13$, 95% confidence interval [CI] 0.01–0.26, $F = 4.79$, $p = 0.037$). However, app engagement during pregnancy did not predict changes in breastfeeding knowledge, confidence or intentions to breastfeed at birth from T1 to T2 or changes in confidence from T1 to T3 in participants with or without university education.

TABLE 4 Changes in breastfeeding knowledge, attitudes, confidence and intentions to breastfeed at birth from T1 to T2 by level of education.

	All participants ($n = 188$)			Non-university ($n = 72$)			University ($n = 116$)		
	T1[a]	T2	*p*	T1[a]	T2	*p*	T1[a]	T2	*p*
Correct EBF knowledge *n* (%)	112 (59.6)	125 (66.5)	<0.001	32 (44.4)	38 (52.8)	0.215	80 (69.0)	87 (75.0)	<0.001
EBF intention *n* (%)	144 (76.6)	152 (80.9)	<0.001	55 (76.4)	60 (83.3)	0.005	89 (76.7)	92 (79.3)	<0.001
Breastfeeding attitude score mean (SD)	62.57 ± 7.19	64.21 ± 7.82	<0.001	60.50 ± 7.32	62.61 ± 7.12	0.007	63.85 ± 6.82	65.20 ± 8.11	0.001
Breastfeeding confidence score Mean (SD)	37.28 ± 6.67	39.86 ± 7.18	<0.001	38.50 ± 6.60	40.61 ± 7.13	0.006	36.52 ± 6.62	39.40 ± 7.20	<0.001

[a]T1 responses limited to people who responded to T2.

TABLE 5 Changes in breastfeeding attitudes and confidence from T1 to T3 (post-partum) by level of education.

	All participants ($n = 152–156$)			Non-university ($n = 61–63$)			University ($n = 91–93$)		
	T1[a]	T3	*p*	T1[a]	T3	*p*	T1[a]	T3	*p*
Breastfeeding attitude score mean (SD)	62.22 ± 7.10	64.37 ± 8.44	<0.001	60.57 ± 7.05	62.21 ± 8.22	0.060	63.34 ± 6.95	65.84 ± 8.31	<0.001
Breastfeeding confidence score Mean SD)	37.74 ± 6.82	45.41 ± 8.14	<0.001	39.27 ± 6.86	44.87 ± 9.03	<0.001	36.71 ± 6.63	45.78 ± 7.52	<0.001

[a]T1 responses limited to people who responded to T3.

4 | DISCUSSION

This is one of the first studies in Australia and indeed internationally to examine the feasibility and preliminary impact of an app-based intervention delivered across the perinatal period to support women with breastfeeding. A key finding of this study was the differential perceived quality, usefulness and impact of the app by maternal education with participants without university education rating the app as higher quality, more useful and impactful than their university-educated counterparts. This is an important finding given the disparity in breastfeeding rates by maternal education (Austalian Institute of Health and Welfare, 2020). Mothers with lower educational attainment are also those who are likely to benefit most from breastfeeding support and the least likely to access health professional advice (Segura-Pérez et al., 2021). Apps with curated, high-quality evidence-based content may be more useful for mothers with lower levels of education, who have reported difficulty navigating and deciphering the quality of information available on the internet and in commercially available apps (Guerra-Reyes et al., 2016).

Our qualitative findings also highlighted that the app was valuable during pregnancy among mothers with limited family or social experiences with breastfeeding. Given the socioeconomic gradient in breastfeeding rates, this is more likely to be the case among mothers with lower levels of education. Current research indicates that antenatal breastfeeding knowledge (Xu et al., 2022) and intentions (Donath & Amir, 2003; Donnan et al., 2013; Xu et al., 2022) have a significant influence on initiation and duration of breastfeeding. Providing antenatal and post-natal breastfeeding support to women has also demonstrated an increase in duration and exclusivity (Gavine et al., 2022). Having ready access to trustworthy evidenced-based support during both pregnancy and in the early post-partum period may help to break the intergenerational cycle of formula feeding.

Our study also highlights the important role that mHealth interventions can play in addressing the gap in antenatal breastfeeding support, with participants discussing the perceived lack of information and support on breastfeeding provided in routine antenatal care and pregnancy information. In Australia, anticipatory guidance for breastfeeding is recommended in National Competency Standards for Childbirth and Early Parenting Educators (Childbirth And Parenting Educators of Australia, 2018), however, there is no requirement for providers to adhere to these standards and no evaluation of antenatal education provided in Australia. The provision and content of these classes varies by hospital and region and is not universally provided free of charge (Shand et al., 2022).

The findings also support the role of mHealth interventions in providing continuity of breastfeeding support from pregnancy to post-partum. While participants' engagement with the app varied, qualitative insights revealed that being aware of the app content during pregnancy helped with troubleshooting breastfeeding problems post birth. Systematic review evidence (Laws et al., 2022) shows that breastfeeding interventions are more likely to be effective if there is continuity in support across the perinatal period. This remains a challenge for health service consumers, as antenatal care is provided by a different set of health professionals (e.g. midwives, obstetricians) in hospital settings, while post-natal care is provided largely in the community by primary care practitioners such as GPs, Child and Family Nurses/Health Visitors. Evidence-based apps such as My Baby Now can help provide 'joined up' care during this critical time but how they integrate with health professional care requires further research.

A novel finding of this study was that participants perceived the app as providing 'non-judgemental' 'agenda free' support for breastfeeding and some contrasted this with health professional advice that was perceived to be 'pushing breastfeeding'. It is important to point out that the My Baby Now app also included topics on formula feeding and mixed feeding as our research has shown that parents who don't breastfeed find it difficult to access best practice advice on these topics (Appleton et al., 2020) and sub optimal formula feeding practices have been shown to lead to rapid weight gain and overweight and obesity (Appleton et al., 2018). This finding is consistent with our previous research (Houston et al., 2017) with Aboriginal and Torres Strait Islander families who also discussed that the non-judgmental support provided by the app enabled them to access infant feeding information that they would not have sought from a health professional because of fear of judgement.

A key challenge with mHealth interventions is creating apps that parents want to use and for engagement with the app to be sufficient to promote behaviour change. Despite study registration, just under half of the participants did not use the app. This might reflect our recruitment via social media, with our previous research (Taki et al., 2017) with an earlier version of the app showing that app engagement is higher if recommended by a health professional compared with when the app was accessed via social media. This highlights the important role health professionals play in endorsing app use. In line with this, a key driver of app use in this study was the perceived credibility of the source, being Australian and the alignment of the app content with health professional advice. Interactive features such as the quizzes, push notifications and forum also appeared to be important in encouraging app use. While only 3.5% of all push notifications sent were opened, some push notifications were accessed by 40% of participants using the app. To receive push notifications, participants need to opt in to receiving push notifications when first downloading the app. In qualitative interviews, some participants reported automatically turning off push notifications for all apps, others were not aware of the push notification feature. Further consideration should be given to how messages are delivered (e.g via push notifications or SMS) and option to personalise delivery mode and frequency. Other key areas for improvement include reducing text, adding more videos, graphics and organising content by pregnancy/baby age and development. Though there is consensus that mHealth

behaviour change interventions require sufficient user engagement (Short et al., 2018) what constitutes 'sufficient' engagement and the relationship between engagement with various app features and efficacy remains unclear and requires further research (Short et al., 2018).

While this study was not designed to examine the efficacy of the app in improving breastfeeding outcomes, there was some evidence of an association between app usage during pregnancy and improvements in breastfeeding attitudes post-partum among participants without a university education. This aligns with our qualitative findings highlighting higher perceived impact of the app in participants with less education. Despite significant improvements in breastfeeding knowledge, intentions and confidence from baseline to late pregnancy in all participants, app engagement was not associated with these changes. This may reflect a lack of power to detect effects with high baseline knowledge and exclusive breastfeeding intentions and modest changes in confidence scores. It may also reflect the limited impact of the app on these breastfeeding mediators, given multiple sources of breastfeeding input.

Few studies internationally have examined the feasibility and effectiveness of apps in improving breastfeeding outcomes in high income countries. In line with our findings, a small pilot study of 29 women in rural Victoria (Wheaton et al., 2018) reported high acceptability and usefulness of a breastfeeding app, although impact on breastfeeding outcomes was not assessed. An RCT (Lewkowitz et al., 2021) among low-income women in the United States found that a breastfeeding app provided in late pregnancy did not improve breastfeeding initiation or duration of exclusive breastfeeding at 6 months despite the app being perceived by participants as the best source of support. Likewise, the Milk Man app, which focused on engaging fathers to start conversations about breastfeeding, was an acceptable source of breastfeeding information and support (White et al., 2019) and generated breastfeeding conversations in half of all fathers; but did not find a measurable impact on their partners' infant feeding decision and breastfeeding self-efficacy, compared with a father focused antenatal breastfeeding class or usual antenatal parenting class (Scott et al., 2021). There is evidence (Miremberg et al., 2022) that apps used as a platform to facilitate two-way communication between mothers and lactation counsellors can improve breastfeeding rates, along with telehealth-type interventions (Hubschman-Shahar, 2022). These types of interventions are, however, more intensive and costly than app-only approaches. Further research is required to examine the efficacy of app-based interventions to improve breastfeeding outcomes, particularly when designed to maximise user engagement and endorsed by healthcare providers.

This study has a number of strengths and weaknesses. The mixed method design enabled the triangulation of data to provide a more complete picture of the feasibility and acceptability of the intervention. The recruitment of mothers with a range of educational levels enabled us to explore the differential acceptability and perceived impact by maternal education, an important proxy for socioeconomic position. Participants predominantly had English as their first language, limiting the extent to which findings can be generalised to culturally and linguistically diverse mothers. It is likely that those retained in the study were more engaged and positive about the app, although there were no significant differences in baseline characteristics between those retained and those lost to follow-up with the exception that those lost to follow up were more likely to be high school educated. Further, the qualitative interviews revealed a range of views about the app, both positive and negative, although it is acknowledged that participants with low app engagement were potentially less likely to volunteer for the interview phase of the study. Technical difficulties with the app early in the study may have contributed to loss to follow-up and negatively impacted acceptability. As a feasibility study, this study was not designed or powered to examine intervention effects, which would be best done using an RCT. We acknowledge that the measurement of breastfeeding intention did not take into account the use of expressed breast milk or how long women intended to breastfeed for, just whether they planned to breastfeed at birth (exclusively, non exclusively or not at all). This may have been less sensitive to detecting changes in breastfeeding intentions during pregnancy and the impact of app engagement on this outcome. We also did not collect data on the model of pregnancy care women received. This may be an important unmeasured covariant that may have influenced women's breastfeeding knowledge, confidence and intentions.

5 | CONCLUSION

Mobile phone apps provide a feasible and acceptable source of anticipatory guidance for breastfeeding during the perinatal period, with higher perceived usefulness and impact among women with lower levels of education. Future randomised controlled studies could examine the effectiveness of perinatal mHealth interventions on breastfeeding outcomes.

AUTHOR CONTRIBUTIONS

Rachel A. Laws and Elizabeth Denney-Wilson lead the development of the My Baby Now app, conceptualised the study with input from other authors and provided funding support for the study from their respective institutions. Rachel A. Laws wrote the first draft of the manuscript. Konsita Kuswara provided input regarding breastfeeding measurement tools and led the recruitment strategy. Heilok Cheng developed the online survey tools in REDCAP, managed quantitative data management and analysis under the direction of Rachel A. Laws and Elizabeth Denney-Wilson. Chris Rossiter provided administrative support for the study and managed qualitative data collection and analysis with contributions from Heilok Cheng, Donna Size and Patricia Corcoran and under the direction of Rachel A. Laws and Elizabeth Denney-Wilson. Donna Size and Patricia Corcoran

conducted interviews. Kok-Leong Ong is the app developer and provided access to the app analytics. Brittany Reese Markides analysed the app analytics to produce an engagement index. All authors contributed to the writing of this manuscript and approved the final manuscript for submission.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Appleton, J., Fowler, C., Laws, R., Russell, C. G., Campbell, K. J., & Denney-Wilson, E. (2020). Professional and non-professional sources of formula feeding advice for parents in the first six months. *Maternal & Child Nutrition*, *16*(3), e12942. https://doi.org/10.1111/mcn.12942

Appleton, J., Russell, C. G., Laws, R., Fowler, C., Campbell, K., & Denney-Wilson, E. (2018). Infant formula feeding practices associated with rapid weight gain: A systematic review. *Maternal & Child Nutrition*, *14*(3), 12602. https://doi.org/10.1111/mcn.12602

Australian Bureau of Statistics. (2018a). National Health Survey: Breastfeeding 2017–2018. Retrieved from Canberra.

Australian Bureau of Statistics. (2018b). Socio-Economic Indexes for Areas. Retrieved from: https://www.abs.gov.au/websitedbs/censushome.nsf/home/seifa

Australian Government Department of Health. (2017). 24-hour movement guidelines for early years (birth to 5 years), Canberra.

Australian Institute of Health and Welfare. (2020). Australian Institute of Health and Welfare 2020. Australia's children. *Cat. no. CWS 69*. Retrieved from Canberra.

Bartick, M., & Reinhold, A. (2010). The burden of suboptimal breastfeeding in the United States: a pediatric cost analysis. *Pediatrics*, *125*(5), e1048–e1056. https://doi.org/10.1542/peds.2009-1616

Casal, C. S., Lei, A., Young, S. L., & Tuthill, E. L. (2017). A critical review of instruments measuring breastfeeding attitudes, knowledge, and social support. *Journal of Human Lactation*, *33*(1), 21–47. https://doi.org/10.1177/0890334416677029

Cheng, H., Tutt, A., Llewellyn, C., Size, D., Jones, J., Taki, S., Rossiter, C., & Denney-Wilson, E. (2020). Content and quality of infant feeding smartphone apps: Five-Year update on a systematic search and evaluation. *JMIR mHealth and uHealth*, *8*(5), e17300. https://doi.org/10.2196/17300

Childbirth And Parenting Educators of Australia. (2018). *National competency standards for childbirth and early parenting educators* (2nd Ed.). Childbirth And Parenting Educators of Australia.

Chimoriya, R., Scott, J. A., John, J. R., Bhole, S., Hayen, A., Kolt, G. S., & Arora, A. (2020). Determinants of full breastfeeding at 6 months and any breastfeeding at 12 and 24 months among women in Sydney: Findings from the HSHK birth cohort study. *International Journal of Environmental Research and Public Health*, *17*(15), 5384. https://doi.org/10.3390/ijerph17155384

Chowdhury, R., Sinha, B., Sankar, M. J., Taneja, S., Bhandari, N., Rollins, N., Bahl, R., & Martines, J. (2015). Breastfeeding and maternal health outcomes: A systematic review and meta-analysis. *Acta Paediatrica*, *104*(467), 96–113. https://doi.org/10.1111/apa.13102

Donath, S., & Amir, L. (2003). Relationship between prenatal infant feeding intention and initiation and duration of breastfeeding: A cohort study. *Acta Paediatrica*, *92*(3), 352–356.

Donnan, P. T., Dalzell, J., Symon, A., Rauchhaus, P., Monteith-Hodge, E., Kellett, G., Wyatt, J. C., & Whitford, H. M. (2013). Prediction of initiation and cessation of breastfeeding from late pregnancy to 16 weeks: The feeding your baby (FYB) cohort study. *BMJ Open*, *3*(8), e003274. https://doi.org/10.1136/bmjopen-2013-003274

Gavine, A., Shinwell, S. C., Buchanan, P., Farre, A., Wade, A., Lynn, F., & McFadden, A. (2022). Support for healthy breastfeeding mothers with healthy term babies. *Cochrane Database of Systematic Reviews*, (10)). https://doi.org/10.1002/14651858.CD001141.pub6

Guerra-Reyes, L., Christie, V. M., Prabhakar, A., Harris, A. L., & Siek, K. A. (2016). Postpartum health information seeking using mobile phones: Experiences of Low-Income mothers. *Maternal and Child Health Journal*, *20*(1), 13–21. https://doi.org/10.1007/s10995-016-2185-8

Guo, J. L., Wang, T. F., Liao, J. Y., & Huang, C. M. (2016). Efficacy of the theory of planned behavior in predicting breastfeeding: Meta-analysis and structural equation modeling. *Applied Nursing Research*, *29*, 37–42. https://doi.org/10.1016/j.apnr.2015.03.016

Hanson, W. E., Creswell, J. W., Clark, V. L. P., Petska, K. S., & Creswell, J. D. (2005). Mixed methods research designs in counseling psychology. *Journal of Counseling Psychology*, *52*, 224–235. https://doi.org/10.1037/0022-0167.52.2.224

Harris, P. A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., & Conde, J. G. (2009). Research electronic data capture (REDCap)--A metadata-driven methodology and workflow process for providing translational research informatics support. *Journal of Biomedical Informatics*, *42*(2), 377–381. https://doi.org/10.1016/j.jbi.2008.08.010

Horta, B. L., Loret de Mola, C., & Victora, C. G. (2015). Long-term consequences of breastfeeding on cholesterol, obesity, systolic blood pressure and type 2 diabetes: A systematic review and meta-analysis. *Acta Paediatrica*, *104*(467), 30–37. https://doi.org/10.1111/apa.13133

Houston, A., Laws, R., Askew, D., Saldanha, T., & Denney-Wilson, E. (2017). Exploring the cultural appropriateness and usefulness of a mHealth promotion program for infant feeding in an Urban Aboriginal Health Service: A qualitative study. *Australian Indigenous HealthBulletin*, *17*(3), Australian Indigenous HealthBulletin 1 7(3).

Hubschman-Shahar, L. E. (2022). lactation telehealth in primary care: A systematic review. *Breastfeeding Medicine*, *17*(1), 6–21. https://doi.org/10.1089/bfm.2021.0105

Janke, J. R. (1994). Development of the Breast-Feeding attrition prediction tool. *Nursing Research*, *43*(2), 100-104.

Karlsson, J. O., Garnett, T., Rollins, N. C., & Röös, E. (2019). The carbon footprint of breastmilk substitutes in comparison with breastfeeding. *Journal of Cleaner Production*, *222*, 436–445. https://doi.org/10.1016/j.jclepro.2019.03.043

Laws, R., Adam, M., Esdaile, E., Love, P., & Campbell, K. J. (2022). What works to improve nutrition and food sustainability across the first 2000 days of life: A rapid review. *Nutrients*, *14*(4), 731. https://www.mdpi.com/2072-6643/14/4/731

Laws, R., Campbell, K. J., van der Pligt, P., Ball, K., Lynch, J., Russell, G., Taylor, R., & Denney-Wilson, E. (2015). Obesity prevention in early life: an opportunity to better support the role of Maternal and Child Health Nurses in Australia. *BMC Nursing*, *14*, 26. https://doi.org/10.1186/s12912-015-0077-7

Laws, R., Denney-Wilson, E., Taki, S., Russell, C. G., Zheng, M., Litterbach, E., & Campbell, K. (2018). Obesity prevention in infants using mHealth: Key lessons and impact of the growing healthy program on milk feeding, timing of introduction of solids and infant growth. *JMU*, 2018 (in press).

Lewkowitz, A. K., López, J. D., Werner, E. F., Ranney, M. L., MacOnes, G. A., Rouse, D. J., Savitz, D. A., & Cahill, A. G. (2021). Effect of a novel smartphone application on breastfeeding rates among low-income, first-time mothers intending to exclusively breastfeed: Secondary analysis of a randomized controlled trial. *Breastfeeding Medicine*, *16*(1), 59–67. https://doi.org/10.1089/bfm.2020.0240

Litterbach, E.-K., Russell, C. G., Taki, S., Denney-Wilson, E., Campbell, K. J., & Laws, R. A. (2017). Factors influencing engagement and behavioral determinants of infant feeding in an mHealth program: Qualitative evaluation of the growing healthy program. *JMIR mHealth and uHealth*, *5*(12), e196. https://doi.org/10.2196/mhealth.8515

Lupton, D., & Pedersen, S. (2016). An Australian survey of women's use of pregnancy and parenting apps. *Women and Birth*, *29*(4), 368–375. https://doi.org/10.1016/j.wombi.2016.01.008

Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, *6*(1), 42. https://doi.org/10.1186/1748-5908-6-42

Miremberg, H., Yirmiya, K., Rona, S., Gonen, N., Marom, O., Pohol, A., Kovo, M., Bar, J., & Weiner, E. (2022). Smartphone-based counseling and support platform and the effect on postpartum lactation: A randomized controlled trial. *American Journal of Obstetrics & Gynecology MFM*, *4*(2), 100543. https://doi.org/10.1016/j.ajogmf.2021.100543

Mitra, A. K., Khoury, A. J., Hinton, A. W., & Carothers, C. (2004). Predictors of breastfeeding intention among low-income women. *Maternal and Child Health Journal*, *8*(2), 65–70. https://doi.org/10.1023/B:MACI.0000025728.54271.27.

Mora, A., Russell, D. W., Dungy, C. I., Losch, M., & Dusdieker, L. (1999). The Iowa Infant Feeding Attitude Scale: Analysis of reliability and validity. *Journal of Applied Social Psychology*, *29*(11), 2362–2380. https://doi.org/10.1111/j.1559-1816.1999.tb00115.x

Musgrave, L. M., Kizirian, N. V., Homer, C. S. E., & Gordon, A. (2020). Mobile phone apps in Australia for improving pregnancy outcomes: Systematic search on app stores. *JMIR mHealth and uHealth*, *8*(11), e22340. https://doi.org/10.2196/22340

National Health and Medical Research Council. (2012). Infant Feeding Guidelines.

Organization, W. H. (2008). Indicators for assessing infant and young children feeding practices conclusions of a consensus meeting held 6–8 November 2007 in Washington USA.

Qian, J., Wu, T., Lv, M., Fang, Z., Chen, M., Zeng, Z., Jiang, S., Chen, W., & Zhang, J. (2021). The value of mobile health in improving breastfeeding outcomes among perinatal or postpartum women: Systematic review and meta-analysis of randomized controlled trials. *JMIR mHealth and uHealth*, *9*(7), e26098. https://doi.org/10.2196/26098

QSR International. (2020), NVivo (released in March 2020). https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Van Rossum, G., & Drake, F. L. (2009). *Python 3 reference manual*. CreateSpace.

Russell, C. G., Taki, S., Azadi, L., Campbell, K. J., Laws, R., Elliott, R., & Denney-Wilson, E. (2016). A qualitative study of the infant feeding beliefs and behaviours of mothers with low educational attainment. *BMC Pediatrics*, *16*(1), 69. https://doi.org/10.1186/s12887-016-0601-2

Scott, J. A., Burns, S. K., Hauck, Y. L., Giglia, R. C., Jorgensen, A. M., White, B. K., Martin, A., Robinson, S., Dhaliwal, S. S., Binns, C. W., & Maycock, B. R. (2021). Impact of a face-to-face versus smartphone app versus combined breastfeeding intervention targeting fathers: Randomized controlled trial. *JMIR Pediatrics and Parenting*, *4*(2), e24579. https://doi.org/10.2196/24579

Segura-Pérez, S., Hromi-Fiedler, A., Adnew, M., Nyhan, K., & Pérez-Escamilla, R. (2021). Impact of breastfeeding interventions among United States minority women on breastfeeding outcomes: A systematic review. *International Journal for Equity in Health*, *20*(1), 72. https://doi.org/10.1186/s12939-021-01388-4

Seyyedi, N., Rahmatnezhad, L., Mesgarzadeh, M., Khalkhali, H., Seyyedi, N., & Rahimi, B. (2021). Effectiveness of a smartphone-based educational intervention to improve breastfeeding. *International Breastfeeding Journal*, *16*(1), 70. https://doi.org/10.1186/s13006-021-00417-w

Shand, A. W., Lewis-Jones, B., Nielsen, T., Svensson, J., Lainchbury, A., Henry, A., & Nassar, N. (2022). Birth outcomes by type of attendance at antenatal education: An observational study. *Australian and New Zealand Journal of Obstetrics and Gynaecology*. https://doi.org/10.1111/ajo.13541

Short, C. E., DeSmet, A., Woods, C., Williams, S. L., Maher, C., Middelweerd, A., Müller, A. M., Wark, P. A., Vandelanotte, C., Poppe, L., Hingle, M. D., & Crutzen, R. (2018). Measuring engagement in eHealth and mHealth behavior change interventions: Viewpoint of methodologies. *Journal of Medical Internet Research*, *20*(11), e292. https://doi.org/10.2196/jmir.9397

Sidhu, S., Ma, K., & Sadovnikova, A. (2019). Features and educational content related to milk production in breastfeeding apps: Content analysis informed by social cognitive theory. *JMIR Pediatrics and Parenting*, *2*(1), e12364. https://doi.org/10.2196/12364.

Stoyanov, S. R., Hides, L., Kavanagh, D. J., & Wilson, H. (2016). Development and validation of the user version of the Mobile Application Rating Scale (uMARS. *JMIR mHealth and uHealth*, *4*(2), e72. https://doi.org/10.2196/mhealth.5849

Taki, S., Campbell, K. J., Russell, G., Elliott, R., Laws, R., & Denney-Wilson, E. (2015). Infant feeding websites and apps: A systematic assessment of quality and content. *Interactive Journal of Medical Research*, In press.

Taki, S., Lymer, S., Ong, K., Campbell, K., Russell, C. G., Laws, R., & Denney -Wilson, E. (2016). The development and application of an engagement index on the participants use of an infant feeding app: The Growing healthy program Paper presented at the 2nd Behaviour Change Conference: Digital Health and Wellbeing London, February 2016.

Taki, S., Lymer, S., Russell, C. G., Campbell, K., Laws, R., Ong, K.-L., Elliott, R., & Denney-Wilson, E. (2017). Assessing user engagement of an mHealth intervention: Development and implementation of the growing healthy app engagement index. *JMIR mHealth and uHealth*, *5*(6), e89. https://doi.org/10.2196/mhealth.7236

Tomori, C. (2022). Overcoming barriers to breastfeeding. *Best Practice & Research Clinical Obstetrics & Gynaecology*, *83*, 60–71. https://doi.org/10.1016/j.bpobgyn.2022.01.010

Wheaton, N., Lenehan, J., & Amir, L. H. (2018). Evaluation of a breastfeeding app in rural Australia: Prospective cohort study. *Journal of Human Lactation*, *34*(4), 711–720. https://doi.org/10.1177/0890334418794181

White, B., Giglia, R. C., White, J. A., Dhaliwal, S., Burns, S. K., & Scott, J. A. (2019). Gamifying breastfeeding for fathers: Process evaluation of the milk man mobile app. *JMIR Pediatrics and Parenting*, *2*(1), e12157. https://doi.org/10.2196/12157

Xu, H., Marshall, S., Jones, J. M., Phongsavan, P., & Wen, L. M. (2022). Modifiable predictors of breastfeeding status and duration at 6 and 12 months postpartum. *Birth*, *49*(1), 97–106. https://doi.org/10.1111/birt.12578

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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