

Implementation and Use of an Integrated Digital Antenatal Care Model: A Single-Centre Pilot Study

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Article

Keywords:

Posted Date: October 5th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10823737/v1>

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Additional Declarations: No competing interests reported.

Abstract

Antenatal care is traditionally delivered through frequent in-person visits, but telehealth and remote monitoring can shift key components into the home. We conducted a prospective observational pilot study to evaluate an integrated digital antenatal care platform in a metropolitan maternity service. The digital platform combines wireless fetal heart rate (FHR) monitoring, blood pressure (BP) and weight tracking, mood assessment, app-based antenatal education, automated reminders and alerts, and hybrid consultations within routine care. Among 197 women in the primary analysis, participants completed 2,510 FHR recordings, 1,041 BP measurements, and 1,698 mood ratings remotely. Video telehealth was used by 143 participants. The platform generated 276 alerts, of which 12 (4.3%) required clinical review. Delivery data showed a mean gestation of 39.3 weeks and preterm birth in 4.2%. Mean overall experience was 4.69/5, with 91.7% rating home monitoring positively and 62.5% preferring hybrid care. Findings support larger comparative effectiveness and safety studies.

Introduction

Antenatal care requires repeated assessment of maternal health, fetal well-being, and pregnancy progress. The World Health Organisation recommends a minimum of eight antenatal contacts, although visit schedules vary according to maternal risk, national guidance, and local practice¹. Conventional in-person care is effective but resource-intensive and may be difficult for women because of travel, waiting time, work, caregiving responsibilities, and limited flexibility². Telehealth and home monitoring can move selected components of antenatal care outside the clinic and have achieved high patient satisfaction and clinical outcomes comparable to those of conventional care in appropriately selected populations³. However, many digital models evaluate a single technology, such as home blood pressure, or replace individual visits rather than integrating the monitoring, communication, education, and escalation functions of antenatal care^{4–6}.

Fetal assessment has been more difficult to provide remotely because fetal heart rate (FHR) measurement has traditionally required clinic-based Doppler assessment or cardiotocography (CTG). We previously demonstrated that a wireless, self-guided FHR monitor produced accurate, clinically interpretable recordings comparable with CTG and could be used independently by pregnant women at home, supporting its inclusion as one component of a broader digital service^{7,8}. However, an integrated service must also transmit data for clinical review, support communication and education, and provide appropriate responses to abnormal results. Evidence describing how these components function together in routine maternity practice remains limited^{4,9–11}.

The Connected Maternity Care (CMC) model was developed to address this gap at a metropolitan maternity hospital in Western Australia. Measurements obtained at home were transmitted to the clinical team, supporting both real-time and asynchronous care within a hybrid model of virtual and in-person consultations.

This pilot study evaluated implementation, utilisation, and participant acceptability of the CMC model in routine clinical practice. Secondary objectives were to describe the enrolled population and report maternal and newborn outcomes, including delivery characteristics and unplanned hospital readmissions within 30 days

Methods

Study Design and Setting

A prospective, descriptive, single-centre pilot study was conducted at the antenatal clinic of Joondalup Health Campus, a large metropolitan hospital in Western Australia, from August 12, 2021, to July 30, 2022. The study comprised a cohort quantitative analysis and a participant satisfaction survey.

Participants and Recruitment

Convenience sampling was used. Women were eligible if they were aged 18 years or older, had a singleton pregnancy, and were receiving care through the Joondalup Health Campus antenatal clinic. Women were excluded if they were unable to read English, had a rash or other abdominal skin condition that could be irritated by ultrasound gel, had a pacemaker or other implantable electronic device, or did not have access to a smartphone and internet connectivity. Trained research nurses and clinic midwives explained the study and obtained written informed consent.

Intervention

The Connected Maternity Care model integrated three components within routine antenatal care: home monitoring through a digital platform, hybrid virtual and in-person consultations, and gestation-specific education (Fig. 1).

Remote Monitoring and Clinical Dashboard:

Participants used a maternally administered fetal heart rate monitor (FHRM), measured their blood pressure with home devices where available or at a local pharmacy, and recorded their mood in the app. Measurements were recorded in the patient's smartphone app and transmitted to a browser-based clinician dashboard. The dashboard could be accessed in the clinic or remotely by authorized clinicians.

The wireless, self-guided FHRM recorded fetal and maternal heart rates in real-time and was designed to distinguish the two signals. Fetal heart rate recordings were displayed graphically, analyzed for fetal heart rate characteristics, and stored for later clinical review. Previous studies demonstrated accuracy comparable to that of cardiotocography and independent home use by pregnant women^{12,13}. Data were stored in a secure cloud environment that met the requirements of the Health Insurance Portability and Accountability Act and provided privacy protections.

The clinician dashboard displayed each participant's measurements, app use, alerts, notifications, and communications. It supported synchronous care through video consultations and asynchronous review of stored measurements and messages. This allowed the care team to review data obtained between scheduled consultations and respond when required.

The app prompted weekly mood tracking from 6 weeks of gestation through the postpartum period and scheduled blood pressure, fetal heart rate, weight, and urine checks every 4 weeks from 20 to 32 weeks, every 2 weeks from 34 to 38 weeks, and weekly from 39 weeks. Notifications also identified when ultrasound examinations and blood tests were due, linked participants to relevant education, and reminded them of incomplete tasks within 2 weeks.

Prespecified acceptable ranges were based on Australian clinical practice guidance. When a result was outside the specified range, the app instructed the participant to repeat the measurement or contact the service, and the clinical team received a corresponding notification. Results requiring further assessment could prompt direct

participant contact or review in the antenatal clinic. The app also supported customized self-check questionnaires, a bespoke satisfaction survey, and the Net Promoter Score.

Hybrid Virtual and In-person Consultations:

The model was designed to replace approximately 30% of routine in-person antenatal consultations with video consultations through the app. The planned schedule for low-risk pregnancies is shown in Table 1. A midwife could also provide postnatal and newborn follow-up in person or virtually.

Table 1
Planned consultation schedule for low-risk pregnancies

Visit type	20 wk	24 wk	28 wk	32 wk	34 wk	36 wk	38 wk	39 wk	40 wk	≥ 41 wk	Postnatal/newborn
In person	✓		✓	✓		✓		✓	✓	✓	✓
Virtual		✓			✓		✓				✓

Patient Education:

The app provided antenatal information aligned with Australian standards and organized by gestational week. Content covered symptoms, scheduled assessments, lifestyle, labour, and device training. Participants could search the material by keyword. Topics included medication and alcohol use in pregnancy, first-trimester screening, exercise, early pregnancy care, relaxation, mental health, stillbirth prevention, fetal movements, continence, nutrition, labour and delivery, and breastfeeding.

Data Collection

Data was obtained from the digital platform and hospital medical records. The collected variables described the enrolled population, use of each platform component, delivery and newborn outcomes, readmissions, and participant experience.

Antenatal Data

At enrollment, recorded variables were age, weight, height, gestational age, gravidity, parity, previous cesarean delivery, preexisting clinical and mental health risk factors, and conditions arising during the pregnancy.

From enrollment to delivery, the platform recorded blood pressure, fetal heart rate, maternal heart rate, mood ratings, video-facilitated telehealth consultations, and generated alerts. Prespecified alerts included fetal heart rate greater than 160 or less than 110 beats per minute, systolic blood pressure equal to or greater than 140 mm Hg, and diastolic blood pressure equal to or greater than 90 mm Hg. Mood was rated on a 5-point scale: 1, awful; 2, bad; 3, okay; 4, good; and 5, great.

Delivery and Postpartum Data

Gestational age at delivery, fetal presentation, and mode of delivery.

Newborn sex, birth weight, head circumference, length, Apgar scores at 1, 5, and 10 minutes, need for newborn respiratory support or resuscitation, special care nursery admission, and arterial and venous cord pH.

Delivery date, maternal discharge date, and newborn discharge date.

Maternal and newborn unplanned hospital readmission within 30 days, including principal reason and length of stay.

Participant Satisfaction

Participant experience was assessed using a bespoke satisfaction survey and the Net Promoter Score¹². The survey contained 9 closed-ended and 2 open-ended questions. Five items used a 5-point Likert scale to assess overall experience, support from the care team, explanation of the model, educational material, and feelings of security and safety. Four items asked about home monitoring, virtual consultations, and the management of technical or medical problems. Open-ended questions asked participants to describe positive and negative experiences, suggest improvements, and explain whether the model contributed to peace of mind.

Statistical Analysis

Analyses were descriptive and were performed using IBM SPSS Statistics, version 29. Continuous variables are reported as mean $\pm$ standard deviation and, where relevant, median and interquartile range. Categorical variables are reported as number and percentage. Free-text survey responses were analyzed using content analysis. No comparative hypothesis testing was planned because this was a pilot study without a control group.

Ethics

All participants provided written informed consent. The Ramsay Health Care Human Research Ethics Committee of Victoria and New South Wales approved the study (reference 2020/ETH/0005).

Results

Participant Flow

Of 209 enrolled women, 197 were included in the primary utilization analysis (Fig. 2). Twelve did not continue: 7 consented but subsequently chose not to participate, and 5 used the device once and stopped because they could not synchronize the app. These discontinuations are reported as implementation outcomes but were excluded from the main utilization summaries.

Participant Characteristics

Participant characteristics are shown in Table 2. Mean age at enrolment was 30.4 ± 5.2 years. Most participants (164 of 197; 83.2%) enrolled at 24 weeks of gestation or later. Eighty-five (43.1%) were primigravida, and 110 (55.8%) had no previous births. Pre-pregnancy body mass index was less than 23.5 kg/m^2 in 81 participants (41.1%), 23.5 to 29.9 kg/m^2 in 85 (43.1%), 30.0 to 34.9 kg/m^2 in 23 (11.7%), and at least 35 kg/m^2 in 8 (4.1%).

Among women with available clinical histories, 24 had a previous caesarean delivery, 27 (14.2%) had current anxiety and/or depression, and 4 (2.0%) had previously experienced postpartum depression. Other recorded

gynaecologic or obstetric histories included polycystic ovary syndrome, ovarian cyst, cervical abnormalities or procedures, endometriosis, miscarriage, ectopic pregnancy, in vitro fertilisation, single umbilical artery, precipitous labour, preeclampsia, postpartum haemorrhage, and third-degree perineal tear. Current conditions included gestational diabetes in 17 women (8.9%), advanced maternal age in 33 (16.8%), and iron deficiency and/or anaemia in 91 of 190 women (47.9%); elevated body mass index, hypothyroidism, diabetes, and asthma were also recorded.

Table 2
Demographic and clinical characteristics of the 197 participants

Variable	Minimum	Maximum	Mean	SD	Median	IQR or n (%)
Age at enrollment, years	18	44	30.4	5.2	31.0	27.0–34.0
≤ 25 years						36 (18.3)
26–30 years						62 (31.5)
31–35 years						66 (33.5)
≥ 36 years						33 (16.8)
Gestational age at enrollment, weeks	17	33	26.7	3.3	27.0	25.0–29.0
≤ 23 weeks						33 (16.8)
≥ 24 weeks						164 (83.2)
Pre-pregnancy BMI, kg/m ²	16.3	41.1	25.2	4.6	24.2	21.7–28.3
BMI < 23.5						81 (41.1)
BMI 23.5–29.9						85 (43.1)
BMI 30.0–34.9						23 (11.7)
BMI ≥ 35						8 (4.1)
Gravidity	1	7	2.2	1.4	2.0	1.0–3.0
Gravidity 1						85 (43.1)
Gravidity 2						41 (20.8)
Gravidity ≥ 3						71 (36.1)
Parity	0	4	0.7	0.9	0.0	0.0–1.0
Parity 0						110 (55.8)
Parity 1						50 (25.4)
Parity ≥ 2						37 (18.8)

Platform Utilization

Participants used the platform for 10 to 144 days, with a mean of 85.2 ± 24.9 days (12.2 ± 3.7 weeks). Mean weekly use was 1.1 ± 1.5 fetal heart rate recordings, 0.4 ± 0.5 blood pressure measurements, and 0.7 ± 0.4 mood ratings. Full distributions are shown in Table 3.

Table 3
Duration of enrollment and frequency of remote measurements among 197 participants

Measure	Mean $\pm$ SD	Minimum	Maximum	Median	IQR
Total weeks enrolled	12.2 $\pm$ 3.7	1	21	11.9	10.0–14.3
Total days enrolled	85.2 $\pm$ 24.9	10	144	83.0	70.0–100.0
Fetal heart rate recordings per week	1.1 $\pm$ 1.5	0.1	19.3	0.9	0.6–1.2
Blood pressure measurements per week	0.4 $\pm$ 0.5	0.0	4.2	0.3	0.2–0.6
Mood ratings per week	0.7 $\pm$ 0.4	0.0	2.5	0.7	0.4–1.0

Physiological and Mood Measurements

One participant was not issued a fetal heart rate monitor because no device was available on the day of enrollment. The remaining 196 participants completed 2,510 recordings. The number per participant ranged from 1 to 109, with a mean of 12.7 ± 11.1 and a median of 10.0. The mean fetal heart rate per participant was 140.7 ± 6.2 beats per minute. Recordings lasted a mean of 300.0 ± 165.8 seconds. Table 4 reports the ranges, medians, and interquartile ranges for all signal measures.

Maternal heart rate was recorded simultaneously in the same 196 participants. Mean maternal heart rate per participant was 86.4 ± 7.2 beats per minute, with a range of 69.4 to 104.0 beats per minute.

A total of 1,041 blood pressure measurements were completed by 180 participants. Across all measurements, mean systolic blood pressure was 116.2 ± 12.3 mm Hg and mean diastolic blood pressure was 72.9 ± 10.2 mm Hg. When measurements were averaged for each participant, mean systolic blood pressure was 115.6 ± 9.1 mm Hg and mean diastolic blood pressure was 72.0 ± 7.4 mm Hg. Full distributions are reported in Table 4.

Four participants did not record mood. The remaining 193 participants completed 1,698 ratings, ranging from 1 to 26 per participant. Mean mood score was 3.9 ± 0.6 . Twenty-four participants selected “bad” at least once, accounting for 37 ratings, and 6 selected “awful” at least once, accounting for 8 ratings. One participant selected “bad” 6 times, 3 selected it 3 times, and 2 selected it twice; 2 participants selected “awful” twice.

Table 4
Physiological and mood measurements

Measurement	N	Minimum	Maximum	Mean	SD	Median	IQR
Fetal heart rate recordings per participant	196	1	109	12.7	11.1	10.0	6.0–16.8
Average fetal heart rate, beats/min	196	111.1	155.0	140.7	6.2	141.1	137.0–144.9
Duration of each recording, seconds	196	30	1266	300.0	165.8	286.0	194.3–363.3
Average maternal heart rate, beats/min	196	69.4	104.0	86.4	7.2	86.4	81.4–90.9
Blood pressure measurements per participant	180	1	50	5.5	4.0	5.6	2.0–7.0
Systolic blood pressure, all 1,041 measurements, mm Hg	180	82.0	162.0	116.2	12.3	116	108–123
Average systolic blood pressure per participant, mm Hg	180	95.5	143.3	115.6	9.1	115.6	109.0–121.7
Diastolic blood pressure, all 1,041 measurements, mm Hg	180	40.0	119.0	72.9	10.2	72	66–80
Average diastolic blood pressure per participant, mm Hg	180	52.0	90.7	72.0	7.4	71.7	67.0–77.0
Mood ratings per participant	193	1	26	8.6	5.2	8.0	5.0–12.0
Average mood score	193	2	5	3.9	0.6	3.9	3.6–4.2

Video-Facilitated Telehealth Consultations

Video-facilitated telehealth was used by 143 participants (72.6%) between enrollment and delivery. There were 350 connected calls. Eighty-three lasted less than 2 minutes and were considered too short for a clinically valid consultation; follow-up calls were made. The remaining 267 calls lasted 2.0 to 48.6 minutes, with a mean duration of 11.3 ± 8.1 minutes. Reported consultation frequencies were once for 59 participants, twice for 46, 3 times for 22, 4 times for 6, and 5 times for 4. These categories account for 137 of the 143 telehealth users and require source-data confirmation for the remaining 6 participants.

Alerts Generated by the Platform

The platform generated 276 fetal heart rate and blood pressure alerts. Most, 264 (95.7%), instructed the participant to repeat the measurement or contact the service. Twelve (4.3%) required clinical review. A further 357 reminders were generated for participants who had not logged in for more than 1 week.

Forty-four of 196 participants with a fetal heart rate monitor (22.4%) received 102 fetal heart rate alerts. Ninety-seven prompted repeat measurement or participant contact, and 5 required clinical review. The number of alerts per participant was 1 for 16 participants, 2 for 14, 3 for 4, 4 for 6, 5 for 1, and 6 for 3.

Of 180 participants who recorded blood pressure, 49 (27.2%) received 174 blood pressure alerts. Of these, 167 (96.0%) prompted repeat measurement or participant contact, and 7 (4.0%) required clinical review. The number of

alerts per participant was 1 for 10 participants, 2 for 21, 3 for 4, 4 for 4, 5 for 3, and 6 for 3. One participant each received 8, 9, 11, and 34 alerts.

Delivery and Newborn Outcomes

Delivery and newborn data were available for 190 women and are reported in Table 5. Seven women delivered outside Joondalup Health Campus after relocating overseas ($n = 1$) or to regional Western Australia ($n = 2$), transferring to private care ($n = 2$), transferring to a tertiary maternity hospital because of pregnancy complexity ($n = 1$), or delivering elsewhere because the hospital was on bypass ($n = 1$).

Mean gestational age at delivery was 39.3 ± 1.5 weeks, and 8 newborns (4.2%) were born before 37 weeks. Presentation was vertex in 183 births (96.3%) and breech or compound in 7 (3.7%). There were 80 normal vaginal births (42.1%), 33 assisted vaginal births (17.4%), and 77 caesarean deliveries (40.5%). Assisted vaginal births included vacuum delivery in 17 cases, forceps delivery in 9, and episiotomy in 7. Of the 77 caesarean deliveries, 37 (48.1%) were elective and 40 (51.9%) were emergency procedures. Common indications for emergency caesarean delivery included failure to progress, fetal distress, and preeclampsia.

There were 102 male newborns (53.7%) and 88 female newborns (46.3%). Mean birth weight was $3,386.5 \pm 436.5$ g, and 5 newborns (2.6%) weighed less than 2,500 g. Mean head circumference was 34.6 ± 1.3 cm, and mean length was 50.6 ± 2.4 cm. Arterial cord pH was recorded for 160 newborns and venous cord pH for 168. Mean arterial and venous cord pH values were both 7.3 ± 0.1 .

Mean Apgar scores were 8.3 ± 1.5 at 1 minute, 8.8 ± 0.7 at 5 minutes, and 9.0 ± 0.6 at 10 minutes among the 87 newborns with a 10-minute score recorded. Two newborns had an Apgar score of 6 at 10 minutes. One was born at 32 weeks and 4 days, weighed 1,935 g, and required continuous positive airway pressure. The other was born at 40 weeks and 6 days by caesarean delivery and required intermittent positive airway pressure.

Fifty-four newborns (28.4%) received respiratory support or resuscitation: continuous positive airway pressure in 45 (83.3%), intermittent positive airway pressure in 7 (13.0%), and endotracheal intubation in 2 (3.7%). Of the 54 newborns requiring support, 30 (55.6%) were born by caesarean delivery, including 19 emergency and 11 elective procedures. Thirty-four newborns (17.9%) were admitted to the special care nursery, most commonly for respiratory distress, prematurity, suspected sepsis, hypothermia, or risk of hypoglycaemia.

Mean maternal length of stay was 3.5 ± 1.9 days and mean newborn length of stay was 3.0 ± 2.1 days.

Table 5
Delivery and newborn characteristics among 190 births

Variable	N or category	Minimum	Maximum	Mean	SD	Median	IQR or n (%)
Gestational age at delivery, weeks	190	32.6	41.9	39.3	1.5	39.3	38.4–40.4
Preterm birth	< 37 weeks						8 (4.2)
Term birth	≥ 37 weeks						182 (95.8)
Presentation	Vertex						183 (96.3)
Presentation	Breech or compound						7 (3.7)
Mode of delivery	Normal vaginal						80 (42.1)
Mode of delivery	Assisted vaginal						33 (17.4)
Mode of delivery	Caesarean						77 (40.5)
Caesarean type	Elective						37 (48.1 of caesareans)
Caesarean type	Emergency						40 (51.9 of caesareans)
Newborn sex	Male						102 (53.7)
Newborn sex	Female						88 (46.3)
Birth weight, g	190	1775	4560	3386.5	436.5	3415	3088.8–3681.5
Birth weight	< 2500 g						5 (2.6)
Birth weight	≥ 2500 g						185 (97.4)
Head circumference, cm	190	29.0	38.0	34.6	1.3	34.5	34.0–35.5
Length, cm	190	41.5	58.0	50.6	2.4	51.0	49.0–52.0
Arterial cord pH	160	7.0	7.5	7.3	0.1	7.3	7.2–7.3
Venous cord pH	168	7.1	7.5	7.3	0.1	7.4	7.3–7.4
Apgar score at 1 minute	190	2	9	8.3	1.5	9	8–9
Apgar score at 5 minutes	190	5	10	8.8	0.7	9	9–9
Apgar score at 10 minutes	87	6	10	9.0	0.6	9	9–9
Respiratory support/resuscitation	No						136 (71.6)

Variable	N or category	Minimum	Maximum	Mean	SD	Median	IQR or n (%)
Respiratory support/resuscitation	Yes						54 (28.4)
Type among supported newborns	CPAP						45 (83.3)
Type among supported newborns	IPAP						7 (13.0)
Type among supported newborns	Endotracheal intubation						2 (3.7)
Special care nursery admission	No						156 (82.1)
Special care nursery admission	Yes						34 (17.9)
Maternal length of stay, days	190	1	17	3.5	1.9	3	3–4
Newborn length of stay, days	190	1	20	3.0	2.1	3	2–3

Unplanned Maternal Hospital Readmissions Within 30 Days

Eleven women (5.8% of 191 women with relevant follow-up) experienced an unplanned hospital readmission within 30 days. Ten were readmitted to Joondalup Health Campus after giving birth there. One woman delivered at another hospital because Joondalup Health Campus was on bypass and was subsequently readmitted to Joondalup Health Campus after discharge. The index admission length of stay ranged from 1 to 17 days, with a mean of 3.5 ± 1.9 days. Readmission length of stay ranged from 1 to 8 days, with a mean of 2.2 ± 1.0 days. Principal reasons for readmission were postoperative complications in 5 women, including wound infection, hematoma, and granulation tissue; hypertension in 3; gynaecologic conditions in 2; and chest pain in 1. Management included antibiotics, antihypertensive medication, analgesia, monitoring, and follow-up.

Unplanned Newborn Hospital Readmissions Within 30 Days

Eighteen newborns (9.5%) experienced an unplanned hospital readmission within 30 days. Their index admission length of stay ranged from 1 to 20 days, with a mean of 3.0 ± 2.1 days. Readmission length of stay ranged from 1 to 8 days, with a mean of 2.5 ± 1.7 days. Principal diagnoses were respiratory conditions in 6 newborns, including viral infection and physiologic respiratory conditions such as laryngomalacia; poor feeding in 5; jaundice in 4; constipation in 1; conjunctivitis in 1; and irritability in 1. Management included phototherapy, antibiotics, enteral feeding, monitoring, and follow-up.

Participant Satisfaction

Forty-eight of 197 participants completed the satisfaction survey, giving a response rate of 24.4%. The mean overall experience score was 4.69 out of 5, and 33 respondents (68.8%) gave the highest score of 5. Twenty-six respondents provided narrative comments about the model. Ten described the experience as excellent or stated that they loved the program, and nine reported that the app was easy to use. Positive aspects included remote

monitoring, reminders, and tracking (n = 11); weekly educational information (n = 5); and the ability to hear the fetal heartbeat (n = 5).

Suggestions for improvement included replacing the single mood rating with more specific mental health questions and providing clearer information about normal fetal heart rate limits during device training, because automated alerts could cause anxiety. Participants also described technical challenges, including difficulty locating the fetal heart signal and the need to keep the app active while awaiting a virtual consultation.

Forty-four respondents (91.7%) rated care team support as 4 or 5, with a mean score of 4.70 of 5. Thirty-eight respondents (79.2%) rated the model's explanation and features as 4 or 5, with a mean score of 4.78. Forty-four respondents (91.7%) reported enjoying the home-monitoring experience. Thirty respondents (62.5%) preferred a hybrid model of antenatal visits, whereas 17 (35.4%) preferred in-person visits.

Twenty-four respondents reported a technical issue or medical question, and all stated that the issue was addressed thoroughly and promptly by the care team. Thirty-one respondents (64.6%) gave the educational content the highest score of 5, and the mean educational content score was 4.58. More than 80% rated the model's contribution to peace of mind as 4 or 5, with a mean score of 4.33. Analysis of 36 narrative responses identified five principal sources of reassurance: hearing the fetal heartbeat, particularly when the fetus was quiet, moving frequently, or the participant felt unwell; monitoring and tracking pregnancy between visits; sharing the monitoring experience with a partner; support from the care team; access to hybrid or telehealth care when living remotely or feeling unwell; and weekly educational content.

Discussion

This study provides real-world evidence that an integrated digital antenatal care platform can be incorporated into routine maternity services and used across multiple aspects of pregnancy care. The model brought together home-based maternal and fetal monitoring, mood tracking, video consultations, education, communication, and automated clinical alerts into a single, connected system. The pattern of use suggests that this type of integrated model is practical in routine care, while highlighting implementation issues related to technical performance, participant engagement, clinical workflow, and equity.

Use was substantial across the principal components. Over a mean enrollment period of 85.2 days, participants completed 2,510 fetal heart rate recordings, 1,041 blood pressure measurements, and 1,698 mood ratings. Almost three-quarters used video consultations, and the platform generated 276 physiological alerts, most of which prompted repeat measurement or participant contact rather than direct clinical review. These findings quantify both participant engagement and the data and alert burden generated for the clinical team.

Experience was positive among the 48 survey respondents, who valued home monitoring, education, access to the care team, and the flexibility of hybrid care. However, the 24.4% response rate creates substantial potential for nonresponse bias. Maternal and newborn outcomes were included to characterise the cohort, not to establish effectiveness or safety; the uncontrolled study design prevents attribution of these outcomes to the platform.

Previous studies have shown that selected antenatal visits can be delivered remotely, with high patient satisfaction and outcomes comparable to those of conventional care in appropriately selected populations^{3–5,13–17}. The present study extends this work by evaluating a broader model integrating telehealth with home monitoring, education, communication, automated escalation, and clinical review. This matters because replacing a clinic visit

requires more than a video connection: the service must also collect relevant information, identify abnormal findings, and provide clear pathways for repeat measurement or direct assessment.

The Connected Maternity Care model combined several functions into a single clinical system rather than using separate digital tools. Home fetal heart rate monitoring was one component supported by previous validation studies^{7,8}, alongside blood pressure and weight monitoring, mood tracking, telehealth, education, reminders, alerts, secure communication, and clinician review. The study, therefore, examined how these components functioned together rather than re-evaluating device accuracy. Variable use and synchronisation failures also show that validated technology alone is insufficient; implementation depends on training, technical support, participant engagement, and integration with clinical workflow.

Home blood pressure monitoring may support surveillance for hypertensive disorders^{18,19}, while mood tracking may identify changes in psychological well-being between visits. Their clinical value depends on timely review, appropriate thresholds, and clear participant instructions. Most alerts led to repeat measurement or participant contact rather than immediate clinical intervention. While this approach may reduce unnecessary attendance, frequent or poorly explained alerts may still increase clinical workload or cause participant anxiety. The platform's educational and communication functions are therefore important complements to monitoring, helping participants understand tasks and escalation pathways²⁰.

An integrated platform may be particularly useful when access to conventional antenatal care is constrained by distance, transport, workforce limitations, illness, employment, disability, or caregiving responsibilities. Combining monitoring, telehealth, education, communication, and escalation within a single system may reduce travel and support continuity of care between visits, particularly in rural or remote regions⁹⁻¹¹. These potential benefits were not measured in this metropolitan pilot and should not be assumed.

Potential access benefits do not necessarily produce equity. Participation required English literacy, a compatible smartphone, and internet access, so the findings mainly reflect digitally connected, English-speaking women. Such requirements may exclude women facing language barriers, low health or digital literacy, financial disadvantage, or unstable housing, and may reinforce existing barriers to care²¹. Equitable implementation would require devices and connectivity where needed, multilingual and culturally appropriate information, accessible technical support, and co-design with local communities^{9,10,21}.

Remote care should supplement rather than indiscriminately replace face-to-face assessment. Physical examination, imaging, pathology, and direct observation remain necessary for many visits and clinical circumstances. The most appropriate model is therefore likely to be hybrid and risk-adapted, with rapid access to in-person assessment when symptoms, abnormal results, or clinical risk require it^{9,10,13}. Most survey respondents preferred a hybrid model, but feasibility, safety, cost, and acceptability in remote or resource-limited settings require direct evaluation.

Integrated digital care may improve flexibility and reduce travel or waiting time, but these benefits were not measured here⁹⁻¹¹. It may also shift rather than reduce work, because clinicians must review incoming data, manage alerts, provide technical support, and document virtual interactions. Midwives' experience of remote care is closely related to workflow, technology, professional relationships, and organisational support²². Workload, staffing, response times, visit substitution, and cost-effectiveness should therefore be evaluated before wider implementation.

The platform may support earlier communication when symptoms or measurements change, but this study does not show that it prevented complications or reduced readmissions. Maternal complications are associated with newborn readmission²³, making this a relevant outcome for future trials. The maternal readmission rate of 5.8% was similar to a reported Victorian obstetric rate of 5.5%²⁴, while the newborn rate was 9.5%; comparison with a 4.55% rate across admissions to a tertiary paediatric hospital is limited by major differences in population, setting, follow-up, and definitions²⁵. These results should remain descriptive.

The study has several strengths. It was prospective and embedded in routine care, allowing evaluation under real service conditions. It assessed an integrated model rather than a single digital function and captured longitudinal information across monitoring, mood tracking, telehealth, alerts, education, delivery, readmissions, and participant experience. The volume and range of remote data demonstrate actual platform use over time. A previously validated fetal heart rate monitor was incorporated as one component, enabling the present study to focus on implementing the overall service. A further strength was the reporting of technical failures, variable engagement, and negative participant feedback, rather than limiting the evaluation to successful use and favourable experiences.

Limitations

The principal limitation is the uncontrolled, descriptive design. Without a comparison group, the study cannot determine effects on clinical outcomes, safety, visit frequency, workload, healthcare use, or cost, and it was not powered for uncommon adverse outcomes. No prespecified feasibility or acceptability thresholds were defined, limiting assessment against predetermined criteria.

This was a single-centre convenience sample, and local staffing, workflows, participant characteristics, and enthusiasm for digital innovation may not reflect those in other services. English literacy, smartphone access, and connectivity requirements introduced selection bias and limit generalizability, particularly for culturally and linguistically diverse or socioeconomically disadvantaged populations. Equity should be a prespecified implementation outcome in future studies.

Exposure varied because enrollment occurred between 17 and 33 weeks of gestation. The study did not consistently report completion relative to expected measurements or consultations, making it difficult to separate lower engagement from shorter exposure or clinically directed variation. Twelve women did not continue, including 5 who stopped after one use because of synchronisation problems. Excluding them from the main utilisation cohort may overestimate feasibility; future implementation analyses should retain all enrolled participants and report technical attrition, adherence, and support requirements explicitly.

The satisfaction survey response rate was only 24.4%, creating a substantial risk of nonresponse bias, and the bespoke questionnaire limits comparison with other studies. Some source data were incomplete or internally inconsistent, routine records may not capture care outside the hospital network, and the study did not assess clinician experience, response times, fidelity to the intended visit schedule, or whether remote measurements changed management. These omissions are important because professional acceptance and safety depend on workflow, technology, communication, and organisational support²². The study also occurred during the rapid COVID-19-related expansion of telehealth, which may have influenced uptake and implementation^{4–6,15,16}.

Larger multicentre controlled studies should prespecify recruitment, retention, adherence, technical failure, successful transmission, alert resolution, response time, and acceptability outcomes, and should analyse all enrolled participants. The comparative evaluation should include maternal and neonatal outcomes, unscheduled attendance, visit substitution, travel time, clinician workload, cost-effectiveness, and equity. Future studies should also assess equity prospectively, including differences in access, engagement, usability, and outcomes according to language, digital literacy, socioeconomic circumstances, and geographic location. Qualitative work with women, partners, clinicians, and service managers should refine training, educational content, mood assessment, alert wording, technical support, and the balance between virtual and in-person care.

Conclusion

The Connected Maternity Care model integrated home maternal and fetal monitoring, telehealth, alerts, communication, and education within routine antenatal care. Participants generated substantial longitudinal data, and experience was positive among survey respondents, although technical attrition and the low survey response rate limit interpretation. The findings support larger controlled and equity-focused studies but do not establish comparative safety or effectiveness.

Declarations

Ethics Approval and Consent to Participate

Written informed consent was obtained from all participants. The study was approved by the relevant Human Research Ethics Committee (reference 2020/ETH/0005).

Data Availability

The datasets generated and analysed during the study are not publicly available because they contain potentially identifiable clinical information. Deidentified data may be made available by the corresponding author on reasonable request, subject to institutional, ethical, and data-governance approval.

Competing Interests

HeraMED Limited is a medical technology company that develops digital maternity care and remote monitoring technologies, including the HeraCARE platform and the HeraBEAT fetal heart rate monitor, used as components of the Connected Maternity Care model. The Partnerships for Health Innovation Research Group purchased the software licenses used in the study, and Joondalup Health Campus purchased the fetal heart rate monitoring devices.

HeraMED had no role in the development of the study protocol, statistical analysis, interpretation of the results, preparation or editing of the manuscript, or the study's conclusions. The authors declare no other competing financial or nonfinancial interests.

Funding

The study was supported by the Partnerships for Health Innovation Research Group at Joondalup Health Campus, which supported study design, data collection, and research staff salaries. Joondalup Health Campus provided in-

kind infrastructure and information technology support and purchased the fetal heart rate monitoring devices and software licenses for the HeraCARE platform used during the clinical implementation program.

Author Contributions

P.P. conceptualised the study and contributed to the study design, implementation, interpretation of the findings, and critical revision of the manuscript. H.Z. contributed to the study design, statistical analysis, data interpretation, and critical revision of the manuscript. B.S. contributed to study implementation, participant recruitment, data collection, statistical analysis, interpretation of the findings, and preparation of the original manuscript. C.S. contributed to study implementation, data collection, interpretation of the findings, and critical revision of the manuscript. K.J. contributed clinical obstetric expertise, study implementation, interpretation of the findings, and critical revision of the manuscript. All authors reviewed and approved the final manuscript and accept responsibility for the integrity of the work.

Acknowledgments

The authors acknowledge the women who participated in the Connected Maternity Care pilot, as well as the antenatal clinic staff, midwives, research nurses, and administrative staff who supported its implementation and data collection.

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Figures



Figure 1

Components of the Connected Maternity Care digital antenatal management platform

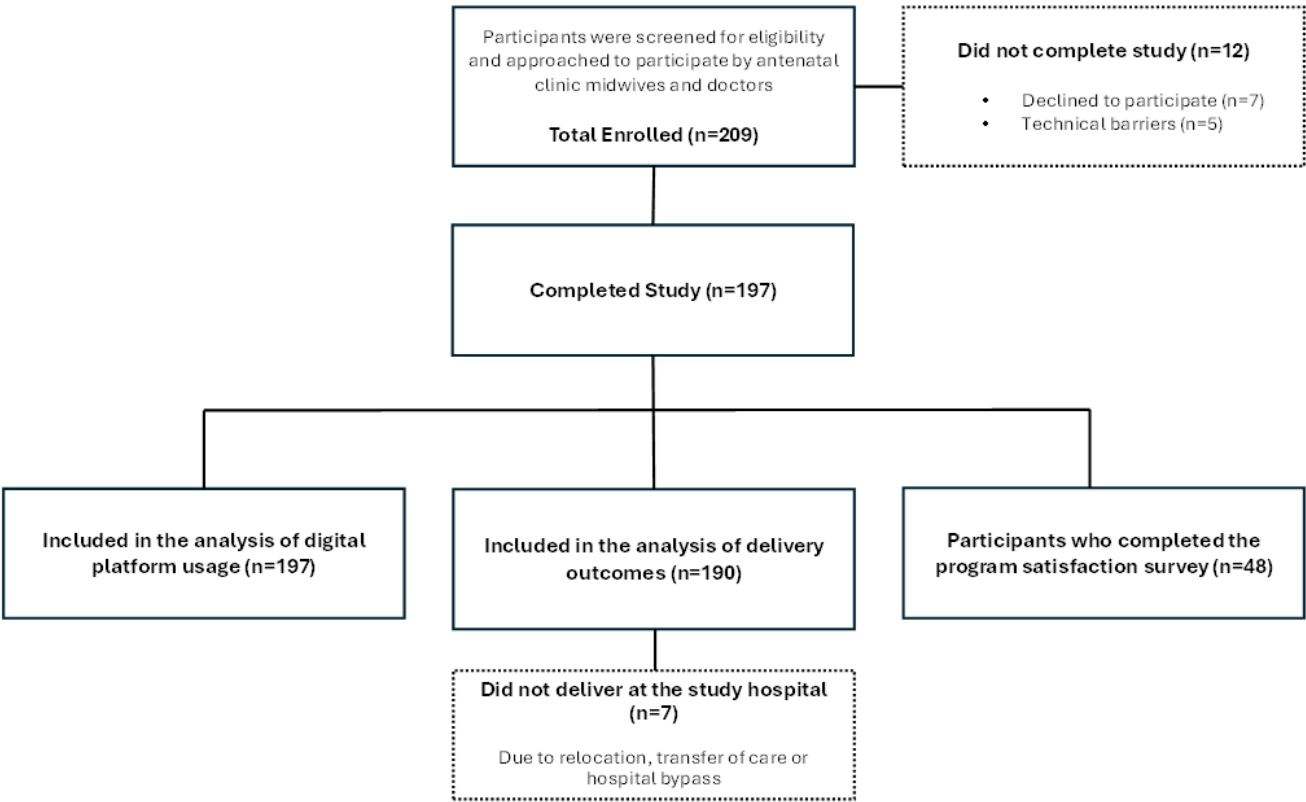


Figure 2

Participant enrollment and analysis flow