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The feasibility of implementing a digital pregnancy and postpartum support program in the Midwestern United States and the association with maternal and infant health

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ABSTRACT

Objective: The benefits of mobile applications in the prenatal period remain understudied. This study assessed associations between the Pregnancy Postpartum Support Program (PPSP), a digital wraparound service, and maternal and infant outcomes in a Medicaid population.
Methods: A retrospective analysis was conducted on pregnant patients with Medicaid insurance who received care and delivered in a Midwestern United States healthcare system between 8/1/2022–8/15/2023, comparing outcomes among those who did versus did not opt for PPSP enrollment. Enrolled patients were offered a mobile device app providing weekly education, "twenty-four seven" support from a clinical team, and telehealth provider visits. Adjusted multiple covariate analyses were completed using linear and logistic regressions. Patient engagement, vendor-based interaction and perception of care data were also examined.
Results: 1912 patients were evaluated: 397 in the PPSP and 1515 in the control group. PPSP cohort inclusion was associated with 4 % lower maternal length of stay (LOS) ($p = 0.05$), 14 % lower infant LOS ($p < 0.01$), higher mean infant birthweight ($p < 0.01$), lower odds of birthweight <2500 g ($p = 0.05$) and lower odds of preterm birth ($p = 0.04$). Nearly 85 % of all enrolled reported being "very satisfied" with the program.
Conclusions: Overall, the program was positively received by PPSP participants. Favorable outcomes associated with enrollment may be due to the program, unmeasured variables, or both. Our study shows the feasibility of offering digital support to pregnant women who voluntarily enrolled in the PPSP and adds to the evidence evaluating virtual care strategies.

1. Introduction

While the cadence and content of prenatal care have been debated (Kilpatrick et al., 2017; Peahl et al., 2021), recent guidelines recommend a first prenatal appointment between seven and 10 weeks of gestation (Peahl et al., 2021). Research has shown that women who receive early prenatal care (Mallampati et al., 2022) and prenatal coordination (Pflugeisen and Mou, 2017) overall have better maternal and infant outcomes (Wu et al., 2021). However, according to Healthy People 2030 in 2021, 30.3 % of Hispanics or Latinos, 31.6 % of African Americans, and 22.7 % of white women did not receive early and adequate prenatal care.

Abbreviations: PPSP, Pregnancy and Postpartum Support Program; ICD-10, International Classification of Diseases, Tenth Revision; ADI, Area Deprivation Index; RUCA, Rural Urban Commuting Area codes classification of U.S. census tracts; LBW, low birthweight; LOS, length of stay; IQR, Interquartile range.

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Limited prenatal care can result in underlying health issues such as diabetes and hypertension (HTN) not being diagnosed or managed, increasing the risk for poor birth outcomes (Greiner, 2017), and reducing opportunities for support and education. Women in the United States (U.S.) face numerous challenges accessing prenatal care because of provider shortages, travel distance and transportation, long wait times, and insurance coverage (Leighton et al., 2019). Those barriers can be exacerbated among low-income women because of issues such as housing, childcare, stress, co-morbidities, social isolation, and racism (National Academies of Sciences [NAS], Engineering, and Medicine, 2020). Even when women receive prenatal care, some women have reported support and education as unspecific to their needs (Dalstrom, 2020), feeling rushed and unheard, and in some situations, discriminated against (Novick, 2009).

Unfortunately, prenatal care access has been dropping nationally while the increased incidence of preterm births, maternal mortality, and severe maternal complications during birth has been increasing (Healthy People 2030, 2024). This has led to a U.S. maternal health crisis (McSpedon, 2024), necessitating the need for different approaches to prenatal care. Studies have identified approaches, (e.g., home visiting, birth centers, and case management programs), that have improved birth outcomes (Dubay et al., 2020; Hillemeier et al., 2015). However, these programs can be costly, time intensive, and difficult to scale in rural and underserved areas (Leighton et al., 2019).

Research shows that prenatal telehealth programs can increase access to prenatal care by reducing some well-documented barriers to care (e.g., transportation, childcare, time, and provider availability) (Konnyu et al., 2023; Wu et al., 2021) and may improve disease monitoring and education (Dixon-Shambley and Gabbe, 2021). Interest in maternal telehealth continues to grow, though feasibility depends on resources to support technology access (Konnyu et al., 2023; Morgan et al., 2022). Some telehealth programs have helped manage diabetes, positively impacting pregnancy-induced HTN, preterm births, and cesarean rates (Xie et al., 2020). Others have noted that telehealth is more effective than managing hypertensive disorders of pregnancy in the clinic (Fazal et al., 2020; Kalafat et al., 2020). Nevertheless, research gaps remain for assessing the effectiveness of maternal telehealth programs on hypertension, health equity, or other pregnancy-related conditions, mainly due to fewer studies with these foci (Cantor et al., 2022). Thus, more research is needed on telehealth programs, their feasibility, and maternal and infant outcomes (Hawkins, 2023).

2. Methods

2.1. Pregnancy and postpartum support program overview

In 2022, Illinois awarded funding to *OSF (Order of Saint Francis) HealthCare, an integrated non-profit healthcare system,* and four Federally Qualified Health Centers ([FQHCs], community-based primary care centers for underserved populations) to establish the Medicaid Innovation Collaborative (Klein et al., 2024; Wicklund, 2022). As part of that endeavor, *OSF OnCall* developed the Pregnancy and Postpartum Support Program (PPSP), a digital program that provides weekly education and "twenty-four seven" support by a team of virtual nurses and advanced practice providers (nurse practitioners, midwives, and physician assistants) as early as eight-weeks' gestation through the six-week postpartum period. The program is administered through a customizable digital care management platform, serving as a supplement rather than a replacement for prenatal care visits. Program enrollment can occur through self-enrollment (posted fliers, advertisements with phone number, Quick Response code), provider referrals, and by FQHC or program staff contacting eligible patients directly. Upon enrollment, an "episode" is created within the electronic health record (EHR) allowing pregnancy data to be linked together as one care "episode". Women are placed into a prenatal or postpartum 'loop' (similar to a care plan) based on their due date. 'Loop' content is specific to pregnancy trimesters (one – three) and the postpartum period (Fig. 1). Participants then download a vendor-based software application ("app") to a phone/tablet. Participants are offered a free blood pressure device that is delivered to their home. Social determinants of health (SDoH) needs and depression screening occur at enrollment via the app, with repeat depression screening at the beginning of each loop. Weekly check-ins and educational resources tailored to trimesters (one – three "prenatal loops"), or postpartum loop are delivered via the app. The weekly check-ins prompt symptom and blood pressure reading reporting with set parameters to trigger "red" (urgent) or yellow" (less urgent) alerts that are managed and triaged by nurses with telehealth visits as needed/requested. This pragmatic study aimed to assess (a) the feasibility and use (including patient satisfaction) of a digital pregnancy support program designed specifically for the Medicaid population; and (b) to investigate the associations between exposure to a digital support program during pregnancy and maternal/child health outcomes.

2.2. Study design and conceptual framework

This retrospective analysis addressed one research quantitative aim within a program (PPSP) evaluation using Chuo et al.'s (2020) strategies for telehealth evaluation and measurement framework (Klein et al., 2024). The study is an observational model cohort design (additional information available at ClinicalTrials.gov NCT 05555095).

2.3. Study population

Both program and control cohorts were drawn from pregnant women with Medicaid and those who received care and delivered at an OSF facility between August 1, 2022, and August 15, 2023. The digital program cohort included pregnant women of any age opting to enroll in the PPSP. Program cohort (PPSP) subjects needed to read and understand English or read translated materials in languages provided (e.g., Spanish). The control cohort included all those who, for any reason, did not enroll in the program in the prenatal period but did deliver at an OSF facility during the same period.

Otherwise, eligible patients were excluded if any of the following were true: missing data for pregnancy start/end dates, residence outside of the state of Illinois, pregnancy with more than one fetus, and any covariates used by any regression were missing. Those eligible for the program cohort were excluded if any of the following were true: missing dates for start of program enrollment, an enrollment date for any program loop initiation that did not align with their trimester, or an enrollment date for the third trimester that occurred on the day of delivery.

2.4. Data collection

Upon program enrollment, current pregnancy, estimated date of confinement, and prior obstetrical historical information were collected/reviewed by PPSP registered nurses and entered into the EHR. Patient data were obtained from the patient, EHR, and the app. The external vendor-sourced data was provided either directly or as part of the digital program and brought into the health system's enterprise data warehouse. Patient characteristics including maternal and infant birth data were obtained from the EHR and an internal obstetric quality database used for state-reported metrics. International classification of diseases (ICD)-10 diagnosis coding was used for determining characteristics of pre-existing hypertension, gestational hypertension, and determination of diabetes types (ICD 10 Data, 2024). Prior research studies using relevant diagnosis code groups for pregnancy and diabetes also informed the research team's choice for inclusion (Stanhope et al., 2021).

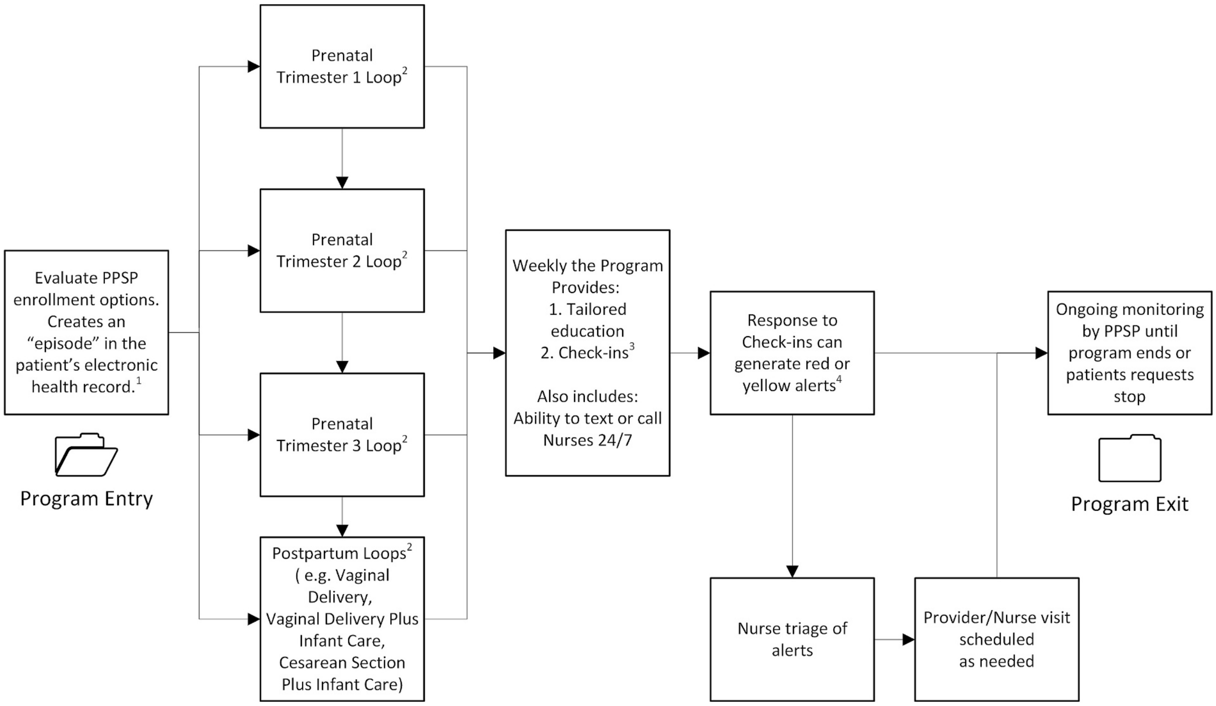

Fig. 1. Program entry and workflow diagram for the digital pregnancy and postpartum support program at a Midwestern healthcare system, United States.
[1] Staff outreach, advertisements with phone numbers, or quick response codes in printed materials can trigger enrollment. Vendor software tracks engagement touchpoints. An "episode" is created in electronic health record allowing for pregnancy data to be linked together as one care "episode".
[2] Loops are defined as "similar to a care plan" with content specific to pregnancy trimesters. Loop enrollment based on the due date (or postpartum) allows the mother to get appropriate guidance for the pregnancy trimester.
[3]Check-ins consist of electronic prompts for reporting symptoms and blood pressure. Nurses respond to all check-ins and questions posed by patients.
[4]Yellow alerts are less urgent, red alerts are urgent, both are based on blood pressure parameters and/or other symptoms. PPSP = Pregnancy and postpartum support program.

2.5. Measures

2.5.1. Primary outcomes

Maternal Outcomes: The primary maternal outcome included was maternal hospital length of stay (LOS) in days for the delivery admission. Maternal mortality was also explored.

Infant Outcomes: Infant outcomes included infant LOS, birthweight, low birthweight (LBW), defined as <2500 g, and preterm birth, defined as a gestational age at delivery of <37 weeks (Cutland et al., 2017). Low birthweight was selected due to its frequent utilization in public health studies of birth outcomes (Cross-Barnet et al., 2022; Dubay et al., 2020; Mallampati et al., 2022).

2.5.2. Secondary outcomes

Engagement with PPSP: An engagement rate was developed by operational leaders for program evaluation/real-time assessment of program connectivity through a dashboard created with Power Business Intelligence. The dashboard engagement rate was defined as "Weeks engaged" (the number of weeks a patient responded to at least one check-in or sent one comment through the app) divided by "Weeks enrolled" (the number of weeks between loop activation and its explicit closure date if available, otherwise its calculated closure date (defined as 90 days after a patient's last recorded activity date). The dashboard metric was applied to the PPSP prenatal study population, which did not account for patient-level data. Therefore, we calculated engagement rates in three ways: 1) at the overall group level over the study period; 2) at the overall group level per month and 3) at patient-level, presented using descriptive statistics (median, interquartile range [IQR] and range values). We included data at the patient's level to get a better understanding of how long a person is enrolled and how long they were engaged.

Interaction with PPSP: Interaction data collected by the vendor for PPSP patients included invitations for participation, enrollment activation, patient comments, practice comments, and alerts reported. Vendor data were not distinguishable between prenatal and postpartum loops and were reported monthly in aggregate, without distinction between included/excluded patients for study purposes.

Patient Perceptions of Care: Perceptions of care questions were delivered via the app. Patients were asked four such questions at the end of the program. These data were analyzed for all patients enrolled in the PPSP, whether or not they met the inclusion criteria for the study. Standardized patient experience surveys from the telehealth visits of providers were not part of this analysis.

2.5.3. Individual confounders

Expert review identified several potentially confounding variables (see Table 1) that were included in all adjusted analyses. Demographic confounders included maternal age group (categorized into less than 20, 20–34 years old, and 35 or older), race/ethnicity (grouped into white or Caucasian, black or African American, and other/unknown/missing), and tobacco use (classified as never, yes, and quit) (Leighton et al., 2019; Pflugeisen et al., 2016). National area deprivation index (ADI) ranking and rural-urban commuting area (RUCA) codes were also included to address patient socioeconomic status and rurality. ADI ranges from one to 100 with higher rankings indicating areas of greater socioeconomic disadvantage (Kind and Buckingham, 2018). RUCA codes are a numeric variable ranging from one to 10 with 10 indicating the highest rural area (U.S. Department of Agriculture, 2023). We dichotomized RUCA with values three or less as metropolitan, and RUCA values of four or more, as non-metropolitan. Comorbidity confounders included HTN and diabetes. Hypertension was defined as the presence of any preexisting or pregnancy-related hypertension ICD code during pregnancy, and

Table 1
Descriptive statistics of demographics and clinical characteristics by study population of pregnant women at a Midwestern healthcare system from August 2022–August 2023, United States.

Demographics	Not Enrolled $n = 1515$	Enrolled $n = 397$	*p-value*
Maternal Age Group			0.37
Under 20	159 (10.5 %)	44 (11.1 %)	
20 to 34	1177 (77.7 %)	316 (79.6 %)	
35 or Older	179 (11.8 %)	37 (9.32 %)	
Race/Ethnicity:			0.35
White or Caucasian	805 (53.1 %)	218 (54.9 %)	
Black or African American	466 (30.8 %)	108 (27.2 %)	
Other/Unknown/Missing	244 (16.1 %)	71 (17.9 %)	
RUCA Category			< 0.01
Metropolitan	1014 (66.9 %)	214 (53.9 %)	
Non-metropolitan	501 (33.1 %)	183 (46.1 %)	
Marital Status:			0.16
Other/Unknown	76 (5.02 %)	11 (2.77 %)	
Married	278 (18.3 %)	74 (18.6 %)	
Single	1161 (76.6 %)	312 (78.6 %)	
Tobacco Use:			0.01
Never	954 (63.0 %)	255 (64.2 %)	
Quit	339 (22.4 %)	105 (26.4 %)	
Yes	222 (14.7 %)	37 (9.32 %)	
Obstetrical History			
Gravida Count	3.0 [2.0;4.0]	3.0 [1.0;4.0]	0.06
Para Count	1.0 [0.0;2.0]	1.0 [0.0;2.0]	0.36
Previous Cesarean section	268 (17.7 %)	64 (16.1 %)	0.51
Previous Preterm Birth	198 (13.1 %)	49 (12.3 %)	0.76
Comorbidities			
Any Diabetes	104 (6.9 %)	36 (9.1 %)	0.16
Any Hypertension Code	283 (18.7 %)	95 (23.9 %)	0.02

Note. Median [interquartile range] is reported for numeric variables for consistency; p-values for the comparison between enrollment groups were calculated using Wilcoxon rank sum tests. Frequencies and proportions are reported for binary/categorical variables; *p*-values for the comparison between enrollment groups were calculated using chi-square test. Abbreviations: RUCA = Rural Urban Commuting Area; *p*-value = probability value, $p < 0.05$ is considered significant.

diabetes was defined as the presence of an ICD code for Type 1, Type 2 or gestational diabetes. History of a previous cesarean section was also included as a potential confounding variable.

2.6. Statistical analysis

Unless otherwise noted, the median and IQR range were reported for numeric variables to minimize the potential effects of outliers and the skewed distributions of LOS. Unadjusted comparisons between groups were conducted using Wilcoxon rank sum tests. Frequencies and proportions are reported for categorical and binary variables. Chí-square or Fisher's exact tests were used for unadjusted comparisons between groups, dependent upon the minimum expected cell count. A Holm-Bonferroni correction was used to correct pairwise comparisons for multiple comparisons.

Adjusted analysis of maternal and infant LOS was performed using multiple linear regression with the log transformed LOS as the outcome variable (log transformed because both variables were right skewed). Due to the use of log transformation, exponentiated coefficients (exp [coef.]) and 95 % CI are reported for this analysis and adjusted estimates are reported as the geometric mean LOS. In addition to group enrollment and the potential confounding variables listed previously, current pregnancy delivery method (vaginal or cesarean section) was included as potential confounder in the analysis of maternal and infant LOS. Multiple linear regression was also used for the analysis of infant birthweight, and the outcome variable (birthweight) was not transformed. Multiple logistic regression was used for the analysis of LBW and preterm birth. All statistical analyses were performed using R (v4.4.0; R Core Team 2024) and assumed a two-sided, 5 % level of significance.

2.7. Ethics

This research study (Ref. #1876230) received expedited approved by the University of Illinois College of Medicine Peoria Institutional Review Board-1, thus meeting the institution's guidelines for human subjects' protection.

3. Results

3.1. Descriptive statistics

Study data included 1912 patients, with 397 patients (20.8 %) in the enrolled group and 1515 in the control group (79.2 %). No significant differences between groups were noted for maternal age group, race/ethnicity, marital status, prior cesarean delivery, or prior preterm birth. A significantly higher proportion of enrolled patients (46.1 %) were in a non-metropolitan RUCA category compared to control (33.1 %), $p < 0.01$. Pairwise comparisons, using a Holm-Bonferroni correction for multiple comparisons, found a significantly higher proportion of tobacco users in the control group (14.7 %) versus the enrolled group (9.32 %), $p = 0.02$. Additionally, the proportion of enrolled patients with a hypertension diagnosis (23.9 %) was significantly higher than the control group (18.7 %), p = 0.02. Comparisons are presented in Table 1.

3.2. Maternal and infant birth related outcomes

Adjusted maternal and infant outcomes by enrollment group are presented in Table 2. Enrollment in a prenatal loop was associated with lower maternal LOS by 4 % (exp[coef.]: 0.96 [95 % CI: 0.92, 1.00]) and a lower infant LOS by 14 %(exp[coef.]: 0.86 [95 % CI: 0.79, 0.95]). Program enrollment was also associated with higher mean infant birthweight (coef.: 98.15 [95 % CI: 33.78, 162.52]) after adjusting for potential confounders (**Supplemental Fig. 1**), lower OR of a birthweight less than 2500 g (OR: 0.64 [95 % CI: 0.41, 0.98]) and lower odds of a preterm birth (OR: 0.67 [95 % CI: 0.45, 0.97]), after adjusting for

Table 2
Regression adjusted outcomes of pregnant women (enrolled versus non-enrolled study group) following delivery at a Midwestern healthcare system from August 2022–August 2023, United States.

PPSP	Not Enrolled n = 1515		Enrolled n = 397	
Outcome	Adjusted Value	95 % CI	Adjusted Value	95 % CI
Geometric Mean Maternal LOS (days)[1]	2.2	(2.11, 2.28)	2.1	(2.00, 2.22)
Geometric Mean Infant LOS (days)[1]	1.9	(1.70, 2.02)	1.6	(1.43, 1.80)
Mean Birthweight (grams)[2]	3282.5	(3222.21, 3342.87)	3380.7	(3300.15, 3461.24)
Low Birthweight Rate (%)[3]	6.9	(4.82, 9.83)	4.6	(2.70, 7.63)
Preterm Birth Rate (%)[3]	9.1	(6.69, 12.37)	6.3	(3.98, 9.75)

Note. All adjusted outcomes were estimated using multiple regression models, all of which adjusted for maternal age group, area deprivation index, rural urban commuting area code category (metropolitan or non-metropolitan), previous cesarean section, race/ethnicity, diabetes, hypertension and tobacco use. 1. Maternal and infant length of stay was analyzed using multiple linear regression with a log transformation and delivery type was added as a control variable. 2. Birthweight was analyzed with multiple linear regression. 3. Low birthweight and preterm birth were analyzed using multiple logistic regression. LOS = length of stay; PPSP = Pregnancy and postpartum support program; % = percent.

potential confounders (Table 2). Maternal mortalities were rare within the study sample, with only one in the control group and none in the enrolled group.

3.3. Engagement and interaction descriptive statistics

The overall engagement rate (defined in Section 2.5.2) calculated at the study group level, over the entire study period, was approximately 33.5 %. The data are also presented by month in **Supplemental Fig. 2**, whereas descriptive statistics for the engagement rate, calculated at a patient level, are available in Table 3. Additionally, descriptive statistics for vendor-provided monthly, aggregated metrics for interaction with the PPSP for all patients (including those otherwise excluded) regardless of loop (prenatal or postpartum) are reported in Table 3.

3.4. Patient perceptions of care metrics

The proportion of positive (highest) responses given by all patients that responded to the perception of care question, regardless of study inclusion or enrollment in a prenatal or postpartum loop, are presented in Table 4. Total count of responses varied by question, ranging from 89 for the care instruction compliance item to 241 for recommendation of the program item. Positive response rates were high, ranging from 71.4 % for the recommendation of the program item to 84.9 % for the patient satisfaction item.

4. Discussion

In accord with past work (Duryea et al., 2021; Leighton et al., 2019; Wu et al., 2021), our study revealed that most program enrollees responding to questions about the program had strongly positive perceptions of their virtual care experience: nearly 85 % reported they were "very satisfied" with the program, nearly 80 % reported they were "extremely likely" to feel better knowing that they could message their care team at any time, and over 70 % reported they would be "extremely likely" to recommend the program to others. These findings demonstrate the importance of access to high quality education/information (Marshall et al., 2023).

After controlling for multiple confounders, enrollment into the PPSP prenatal loop within our study was associated with lower preterm rates, lower low birthweight rates, and higher average birthweights. Better prenatal care for the Medicaid enrollees' population is essential for reducing preterm birth and improving the health outcomes of mothers and babies, yet few studies with larger populations indicate how this care should be delivered to achieve these outcomes (Cantor et al., 2022; Cross-Barnet et al., 2022). Since the prenatal loop intends to help address issues of access to care and factors thought to affect outcomes, our study was designed to identify promising associations between the PPSP prenatal loop and favorable outcomes to inform future research. Our study was not designed to provide evidence that the PPSP prenatal loop was responsible for the improved outcomes. There can be many underlying causes for preterm and lower birthweight deliveries (Cutland et al., 2017), and the positive outcomes associated with PSPP enrollment may be due to unmeasured variables associated with both enrollment and outcomes. Given our findings, follow-up research is warranted to determine if programs such as the PPSP prenatal loop improve prenatal and maternal outcomes.

This study's program cohort had a significantly higher percentage of patients in the non-metropolitan RUCA category compared to the control group. Patients in rural areas have been reported to experience health disparities compared to those in urban areas, including higher rates of pregnancy-related mortality, higher predicted probability of severe maternal morbidity, higher rates of infant mortality, higher rates of singleton preterm births, and often reduced access to obstetric services (Rural Health Information Hub, 2024). Prior work in Illinois demonstrated that a lack of providers was associated with interest in telehealth to overcome transportation barriers (Weinzimmer et al., 2021). Our study demonstrated that virtual care can be delivered to a pregnant population from diverse areas, and as noted, many women reported feeling better knowing that the program provided an ability to message their care team at any time. Further study is warranted to determine if differences in enrollment related to rurality are due to differences in subjects' needs and their anticipations regarding the program's impact on their ability to access care. Further study is also warranted to determine whether the program had an impact on subjects' ability to access care, and whether that impact differs by level of rurality.

Table 3
Descriptive statistics of patient engagement and vendor reported interaction for pregnant/postpartum women at a Midwestern healthcare system from August 2022–August 2023, United States.

(a) Organizational Metrics – Summary of Study Patient Engagement with PPSP (n = 397)				
Metric	Median	IQR	Min.	Max.
Engagement Rate[c]	28.0 %	(9.1 %, 66.7 %)	0 %	100 %
Weeks Enrolled	15.0	(8.0, 21.0)	1	34
Weeks Engaged	2.0	(1.0, 6.0)	0	32
(b) Vendor Metrics – Summary of All Interactions with PPSP per Month				
Metric	Median	IQR	Min.	Max.
Invites[d]	264	(238.8, 283.8)	226	348
Activation Rate[e]	84.5 %	(78.7 %, 87.5 %)	70.2 %	92.7 %
Patient Comments[f]	1038	(936.3, 1306)	348	1459
Practice Comments[g]	2663	(2123.8, 2881.3)	1106	3920
Alerts[h]	219.5	(204.3, 240.3)	147	286

Note. PPSP = pregnancy and postpartum support program; IQR = interquartile range; Min. = Minimum; Max. = Maximum.
(a) Summary of prenatal engagement, calculated at a patient level, in all study enrolled patients.
(b) Vendor provided summary of all interactions with PPSP aggregated at a monthly level in all patients regardless of study eligibility, including prenatal and postpartum loops (defined as "similar to a care plan", with content specific to pregnancy trimesters). Vendor data were not available for August 2022.
[c] Patient-level engagement rate is defined as "weeks engaged" (patient responded to at least 1 check-in or sent at least 1 comment) divided by "weeks enrolled" in the PPSP.
[d] The number of patients invited to enroll in a loop.
[e] The proportion of patients that were invited to enroll who activated their account.
[f] Number of comments or questions sent by the patient.
[g] Number of comments or questions sent by the practice.
[h] Number of alerts generated by the vendor.

Table 4
Descriptive statistics of enrolled women's perceptions of care for the pregnancy and postpartum support program – vendor collected and reported metrics at a Midwestern healthcare system from September 2022–August 2023, United States.

Question	Total Responses	Positive Responses	
		n	%
Accessing Messaging Service[1]	239	190	79.5 %
Care Instruction Compliance[2]	89	68	76.4 %
Patient Satisfaction[3]	93	79	84.9 %
Recommendation of Program[4]	241	172	71.4 %

[1] A positive response for accessing messaging service was a response of "extremely likely" to the question "How likely were you to feel better knowing that you could message your care team at any time?".
[2] A positive response for Care Instruction Compliance was a response of "yes" to the question "By using this digital care program, I was reminded of and followed care instruction that I would have otherwise forgotten.
[3] A positive response for patient satisfaction was a response of "Very satisfied" to the question "How satisfied are you using this digital care program?"
[4] A positive response to recommendation of program was a response of "extremely likely" to the question, "How likely are you to recommend this digital care program to others?"

Using virtual prenatal care may strengthen patient-centered relationships through frequent communication and convenient access to care, helping overcome some of the challenges (e.g., lack of community resources and care managers) reported by Cross-Barnet et al. (2022) and improve maternal and infant outcomes. Our study differed from several prior studies of virtual prenatal care by supplementing in-person visits in the Medicaid population with both messaging and optional "twenty-four seven" telephone access to a nurse or provider. In a scoping review by McCoy et al. (2024), only 19 studies examined asynchronous interactions with providers, with even fewer evaluating text-messaging or app-based programs. Three studies noted by McCoy focused on one specific texting program (Evans et al., 2012a; Evans et al., 2012b; Evans et al., 2014). Other telehealth studies centered on changing self-reported attitudes and behaviors, (e.g., reduced smoking or healthy behaviors) though no behavior changes were reported (Abroms et al., 2017; Evans et al., 2012b; Evans et al., 2014).

Asynchronous support with optional telehealth support should, in theory, be less resource intensive. Researchers have explored reducing in-person visits or replacing visits using virtual care, and the relationship of those changes to care and quality, but with limited data and/or lacking statistical power to evaluate maternal outcomes (Marko et al., 2019; Pflugeisen and Mou, 2017; Tobah et al., 2019). Our study's PPSP was intended to supplement standard care. At this time, we do not know if the PPSP was associated with reduced use of healthcare resources given limitations to data availability. If improved outcomes result in lower resource utilization, the association found may warrant further research.

The definition and measurement of engagement in virtual care lacks clarity, with only a few studies reporting user engagement (Bush et al., 2017; Evans et al., 2015; Marko et al., 2016; Marko et al., 2019), each with different reported metrics. The number of interactions may serve as one measure of engagement. Self-reported patient survey data, rather than actual message counts, were used in prior research for evaluating text messaging use (Moniz et al., 2015). Our study used certain app interactions, finding an overall engagement rate of 33.5 %. However, engagement analysis was significantly limited by the vendor's control of data extraction/detail for patient-level reporting. For example, it is not clear whether the engagement rate was due to a lower percentage of women having very consistent interactions, a higher percentage of women having moderately consistent interactions, or some other pattern. It was also not possible to assess associations of levels of engagement with outcomes, nor to assess some types of engagement, such as whether PPSP participants read the weekly material. It does, however, demonstrate feasibility and usage of the PPSP program by patients.

4.1. Limitations

This research was not randomized and not designed to determine a causal relationship between enrollment and maternal and fetal outcomes. Selection bias must be considered, as program participants may be different from those who were not enrolled. The program did not capture reasons for declination that might help assess the potential for selection bias. External vendor data collection and availability affected data analysis of interaction data at the individual patient level. The proportion of patients that provided any response to the perception of care questions was unable to be calculated because the vendor only provided data for patients that responded to the questions, without data inclusion for non-responding patients. The proportion of patients responding regarding perception of care could not be calculated.

The PPSP described in our study sought to identify SDoH needs of those who engage in the program. Missing self-reported data for SDoH questions, though not uncommon (Chen et al., 2023; Tully et al., 2022) prevented us from examining some confounding factors such as food, housing insecurity, financial strain, depression, and social support and their association with maternal and infant health outcomes. In future analyses, better data availability at the individual patient level would facilitate examination of SDoH and their effect on pregnancy-related health outcomes.

The study considers only patients who delivered at one healthcare system in one state, thus results may not be generalizable. A strength is that our study provides measurement of patient engagement in virtual care, which has not been consistently reported for obstetrical patients (Auxier et al., 2023).

5. Conclusion

Our results demonstrate that virtual care with asynchronous messaging can be used within Medicaid populations as a supplemental method, and most women responding to questions about their experiences with the program responded very positively. Participation was associated with lower rates of preterm and low birthweight births, suggesting the potential value of research to assess whether participation is responsible for these outcomes. Future work will include program optimization, refinements in data collection, and expansion of the program to underserved rural communities.

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CRediT authorship contribution statement

Colleen J. Klein: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Matthew Dalstrom:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **William F. Bond:** Writing – review & editing, Methodology, Conceptualization. **Jeremy McGarvey:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Melinda Cooling:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Katelyn Zumpf:** Writing – review & editing, Visualization, Methodology, Formal analysis, Conceptualization. **Lisa Pierce:** Writing – review & editing, Methodology, Conceptualization. **Brad Stoecker:** Writing – review & editing, Methodology, Conceptualization. **Jonathan A. Handler:** Writing – review & editing, Methodology, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Dr. Jonathan Handler is chief executive officer and a shareholder in Keylog Solutions LLC; has received funding from Pfizer; is a shareholder in other healthcare companies including Whispersom Corporation, EmOpti LLC, HealthLab LLC, and Baxter Healthcare; serves in an advisory role to Whispersom Corporation, EmOpti LLC, and HealthLab LLC; and has various patents that have been granted or are pending. For the remaining authors all declare no interests to disclose.

Data availability

The data that has been used is confidential.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2024.102953.

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