Drug and Alcohol Dependence 195 (2019) 33–39

Contents lists available at ScienceDirect

Drug and Alcohol Dependence

journal homepage: www.elsevier.com/locate/drugalcdep

Full length article

An ecological momentary assessment study examining posttraumatic stress disorder symptoms, prenatal bonding, and substance use among pregnant women

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ARTICLE INFO

Keywords:
Posttraumatic stress disorder
Prenatal
Substance use
Ecological momentary assessment
Prenatal fetal
Bonding

ABSTRACT

Background: Substance use disorder (SUD) during pregnancy requires efficacious interventions based on understanding the ebb and flow of risk and protective factors for substance use across time. To assess how these fluctuations are associated temporally with substance use, we used ecological momentary assessment (EMA) to evaluate substance use risk (posttraumatic stress disorder [PTSD] symptoms) and protective (prenatal fetal bonding) factors and their associations with prenatal substance use recorded in real time.

Methods: Pregnant women in SUD treatment ($N = 33$) with prior trauma exposure received smartphones with an EMA application that queried them thrice daily for 28 days about PTSD symptoms, prenatal bonding, and substance use.

Results: Nearly all ($N = 32$) provided EMA data resulting in 2049 EMA reports (74% compliance). Most participants reported tobacco (72%), alcohol (22%), heroin (41%), and/or other illicit drug (6%–31%) use at least once via EMA. There were moderate associations (average $\beta = 0.23$) between greater daily peak PTSD symptoms and substance use with significant effects on illicit drug ($\beta = 0.37$), cannabis ($\beta = 0.35$) and cigarette use ($\beta = 0.24$). Prenatal bonding subscales were modestly associated with substance use, with daily intensity of attachment low point associated with lower heroin ($\beta = -0.34$), but higher alcohol ($\beta = 0.24$) use. Quality of attachment low point was associated with higher cigarette use ($\beta = 0.06$).

Conclusions: Despite the SUD severity and social instability of this sample, we observed high rates of compliance. We found preliminary support suggesting daily PTSD symptoms as a risk factor and less consistent support for prenatal bonding as a protective factor for prenatal substance use.

1. Introduction

Approximately 5% of women entering treatment for a substance use disorder (SUD) are pregnant (Substance Abuse and Mental Health Services Administration (SAMHSA, 2013). Between 1999 and 2014, the rate of opioid use disorder documented at in-hospital births quadrupled (Haight et al., 2018). Socially vulnerable and stigmatized, many pregnant women with SUD lack access to resources and face high risks for negative prenatal and postpartum consequences, including homelessness, loss of child custody, preterm delivery, stillbirth, infant death, and child abuse and neglect (Kahila et al., 2010; King et al., 2015). Furthermore, women with deliveries complicated by alcohol/drugs are 38 times more likely than other women to die within nine years of giving birth (Kahila et al., 2010). High rates of posttraumatic stress disorder (PTSD) symptoms disproportionately affect these women (Erickson and Tonigan, 2008; Moylan et al., 2001). Finally, the recent U.S. increase of opioid use corresponds with a marked increase in neonatal abstinence syndrome (NAS) (Patrick et al., 2015), the severity of which can be decreased by medication assisted treatment (MAT) (Reddy et al., 2017). However, pregnancy is associated with poor treatment outcomes (Davie-Gray et al., 2013; Delano et al., 2013; Wilder et al., 2015).

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https://doi.org/10.1016/j.drugalcdep.2018.11.019
Received 23 May 2018; Received in revised form 5 November 2018; Accepted 13 November 2018
Available online 08 December 2018

Factors associated with substance use during prenatal SUD treatment must be determined so the specific needs of pregnant women can be better addressed. Many people are exposed to the types of traumatic events that can cause PTSD, but only about 10% of these individuals will ultimately develop PTSD (Kessler et al., 2005, 1995). Evidence suggests that symptoms of PTSD (Linden et al., 2013; Seng et al., 2014) are an important risk factor for substance use in this population, whereas positive prenatal bonding (i.e., the relationships/feelings pregnant women develop toward their fetuses) may be protective against substance use (Lindgren, 2001; Massey et al., 2015). However, the more precise temporal interactions of these factors are not known. It is therefore necessary to more closely examine the association between PTSD symptoms, prenatal bonding, and substance use in this population.

Because symptoms of PTSD are expected to fluctuate (Possemato et al., 2015), and individuals may use substances on some days but not others, we used an ecological momentary assessment (EMA) design to pinpoint how these constructs are associated with each other across time. EMA uses mobile devices (e.g., smartphones) to collect information (e.g., symptoms, emotions, substance use) multiple times per day in real-time. Thus, EMA is used to assess how symptoms and emotions temporally predict substance use (Morgenstern et al., 2014). EMA is less prone to retrospective bias error than traditional surveys and is ideal for identifying targets for precision health interventions. Because emotions and well-being can fluctuate greatly during pregnancy, it has been suggested that EMA may be a better method for measuring prenatal mood than traditional single time-point surveys (Belisario et al., 2017; Newham and Martin, 2013). EMA has been used successfully during pregnancy to examine mood and tobacco use (Allen et al., 2018), cortisol (Entringer et al., 2011), stress (Walsh et al., 2015), and movement (Faherty et al., 2017). Daily fluctuations in prenatal bonding and PTSD symptoms in pregnant women with SUD have not been determined, but if substance use risk factors such as PTSD interfere with prenatal bonding (a potential protective factor against substance use), then prenatal bonding may also be unstable across time in this population. Such instability in PTSD and/or prenatal bonding may be associated with substance use. EMA captures these complex relationships.

1.1. Purpose

The present study had four primary objectives: 1) characterize EMA compliance rates among treatment-engaged pregnant women with SUD, 2) characterize their substance use, 3) examine the convergent validity of EMA and retrospective measures of PTSD symptoms and prenatal bonding, and 4) examine whether PTSD symptoms and prenatal bonding are proximally associated with prenatal substance use. We hypothesized that higher peak daily PTSD symptoms would be associated with higher substance use at the daily level, while lower prenatal bonding daily low points (quality of attachment, intensity of attachment) would be associated with higher substance use at the daily level.

2. Method

2.1. Participants

Pregnant women ($N = 33$) with SUD and prior trauma exposure were recruited and assessed. All women were recruited from a comprehensive program for prenatal, maternity, and neonatal care integrating medical and SUD treatment in the clinical setting of a public-sector hospital associated with an academic institution in the southwest United States (see Fig. 1 for participant flow).

Inclusion criteria were (1) clinic enrollment, (2) prior exposure to DSM-5 Criterion A traumatic events - actual or threatened death, serious injury, or sexual violation (American Psychiatric Association, 2013), (3) pregnancy between 20–35 weeks gestation at baseline, (4) 18 years or older, (5) able to read, write, and speak English. Fetal gestational age was restricted at the lower end to 20-weeks at baseline to maximize fetal bonding, which is typically measureable by 10 weeks gestation (Caccia et al., 1991) and increases throughout gestation (Grace, 1989). The upper-end cutoff of 35 weeks was set to increase likelihood of study completion (4 weeks) before childbirth. Exclusion criteria were (1) acute psychosis, (2) acute and uncontrolled severe mental illness or suicidality, (3) inability to provide informed consent, (4) pregnancy complications likely to interfere with study involvement (e.g., planned hospitalization), (5) immediate plans to relocate from the area, or (6) current incarceration. We also did not approach individuals who were (1) enrolled in other studies that potentially conflicted with our protocol, (2) at the clinic for postpartum visits, or (3) engaged in medical treatment that rendered them unable to participate.

2.2. Recruitment and consent

Prospective participants were clinic patients either approached in private rooms at the prenatal or opioid treatment program clinics while waiting to see medical providers, or who contacted our offices after learning about the study via fliers at the clinics or word-of-mouth. At the prenatal clinic, study staff attempted to screen all eligible patients on recruitment days. Study staff were trained to maintain a compassionate and non-judgmental approach. After obtaining verbal consent, study staff administered a brief screening form while patients waited in private exam rooms for medical providers. Other interested clinic patients contacted study staff for screening via telephone or in person at study offices. Eligible participants were scheduled for baseline appointments and given consent forms to review at screening. Informed consent included statements that the study was protected by a Certificate of Confidentiality from NIH, that staff was required by state law to report suicidal and homicidal intent and child or elder abuse, but that drug or alcohol use during pregnancy was not mandated to be reported in this region, and thus this information would remain confidential. All participants gave written informed consent prior to baseline assessments, and the IRB at the university approved the protocol.

2.3. Assessment process

2.3.1. Baseline assessment

Including informed consent, baseline assessments lasted 4–5 hours and were conducted in one continuous visit with intermittent breaks. Baseline PTSD diagnostic assessments were conducted by the licensed psychologist or comprehensively-trained master's-level clinicians under supervision (as recommended by the measure). All other parts of the baseline assessment were conducted by either the aforementioned licensed psychologist or a rigorously-trained and supervised staff research assistant (RA) with a psychology bachelor's degree (as recommended for those measures). Statistical comparisons found no systematic differences in diagnoses associated with educational level of test administrators (data not shown).

2.3.2. Ecological momentary assessment (EMA)

At the end of baseline assessments, participants were given smartphones with the EMA application already installed and instructed how to operate the application. They completed their first assessment in the office with opportunities for questions. Participants were asked to complete three surveys per day for 28 days, and each survey took 5–10 minutes to complete. During the EMA survey, participants saw one question at a time on the screen, and all responses were multiple-choice buttons. The smartphone alarm application delivered one audiovisual prompt to complete each survey labeled by time of day (e.g., "morning assessment"). To provide flexibility for this population, there was no time-limit for completing assessments following prompts. All responses were timestamped by the EMA application, and data were

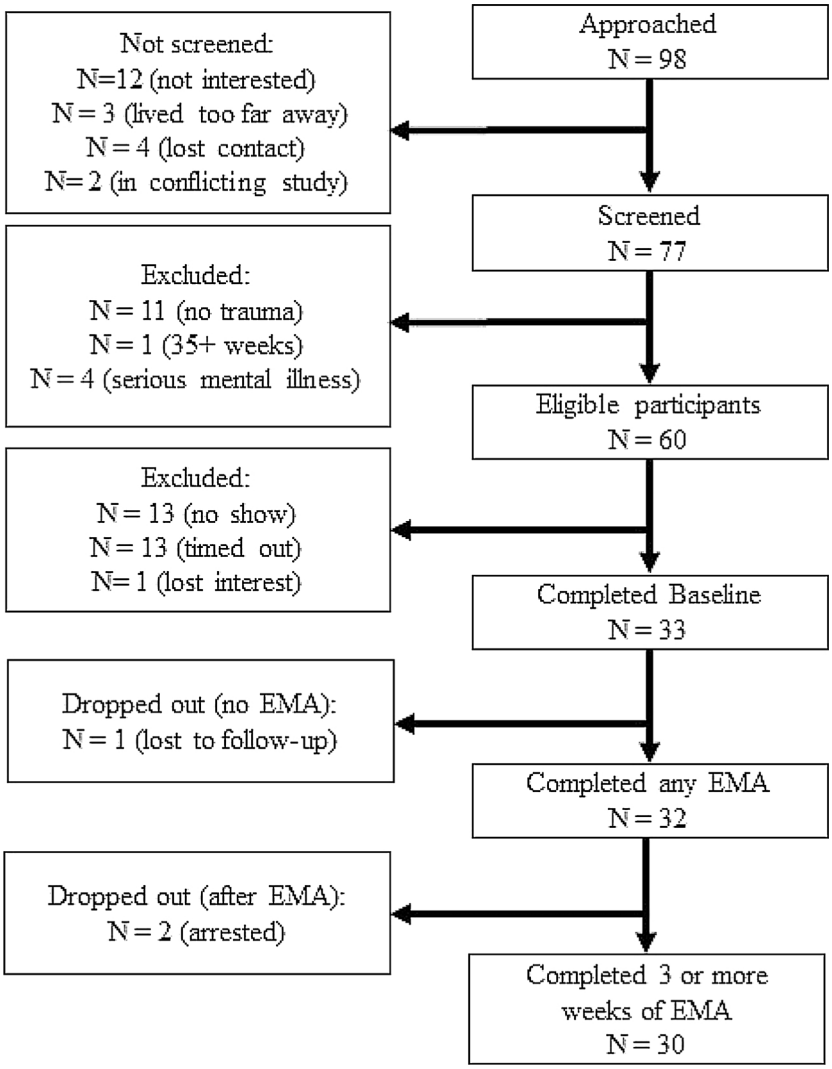

Fig. 1. Participant flow from recruitment to study end. EMA = Ecological momentary assessment; *N* = number.

cleaned using these timestamps prior to analysis to eliminate duplicate entries. We asked participants to identify set times that worked best for them for survey completion (e.g., not driving, not feeding children) corresponding to 1) upon waking, 2) afternoon around 2 pm, and 3) before bedtime. Participants could neither change answers nor access surveys already completed. Data uploaded whenever the phone connected to Wi-Fi. For most participants this only occurred at study offices, but some had data upload via Wi-Fi at home. The smartphones, which participants were allowed to keep after study completion, were not connected to phone, text, or data plans during the EMA phase.

2.4. Measures

2.4.1. PTSD severity, diagnosis, and symptomatology

The Clinician Administered PTSD Scale-5 (CAPS-5: Weathers et al., 2013a) - the gold-standard for PTSD diagnosis - was used to determine baseline PTSD severity and diagnosis. We used the well-validated National Women's Study Event History-PTSD Module (Resnick, 1996) to collect a detailed list of prior traumatic experiences. For EMA data collection, the PTSD Checklist (PCL-5: Weathers et al., 2013b) was administered. The PCL-5 is a well-validated measure consisting of a list of PTSD symptoms to assess current PTSD severity. We calculated the highest reported PTSD symptom severity daily (peak PTSD symptoms), because we expected high PTSD symptom severity to be associated with substance use.

2.4.2. Prenatal bonding

The Maternal Antenatal Attachment Scale (MAAS) is a validated measure of attachment (Condon, 1993), and we used the full scale to measure prenatal fetal bonding at baseline. This scale consists of two factors, (a) "quality of attachment," which represents quality of maternal affective experiences (e.g., closeness/distance, positive/negative, tenderness/irritation) and (b) "time spent in attachment mode," which represents intensity of preoccupation with the fetus (based on amount of time a woman spends thinking about, talking to, or palpating her fetus). We then used the three highest loading items as reported in Condon (1993) of each of the subscales for the EMA survey, and these were queried at each EMA report. We calculated the lowest reported prenatal bonding scores for each scale daily (Quality of Attachment Low and Intensity of Attachment Low), because we expected low prenatal bonding to be associated with substance use. Thus, a lower score for "quality of attachment low" on a particular day indicates that when the participant was feeling *the least attached that day* she felt more distant, negative, and irritated towards the fetus than she did on days with higher scores when she felt closer, more positive, and more tender during her least attached periods those days (i.e., lower lows represent less bonding, while higher lows represent more bonding).

2.4.3. Alcohol, tobacco, and other drug use

Substance use disorders were determined at baseline using the Structured Clinical Interview for DSM5 Disorders, Section E (First et al.,

Table 1
Sample versus Non-Participants.

Measure	Screened-out (*N* = 16) Mean (*SD*)	Screened-in but did not participate (*N* = 28) Mean (*SD*)	Final Participants (*N* = 33) Mean (*SD*)	*F* (*p*)	Partial Squared eta
Age	27.4 (5.54)	26.8 (4.52)	27.8 (4.8)	0.36 (0.68)	0.01
Mental Health Diagnoses[a]	0.8 (0.98)	1.6 (1.04)	1.58 (1.30)	2.97 (0.06)	0.08
Gestation (weeks at baseline)	22.6 (7.73)	21.7 (8.59)	22.5 (6.44)	0.10 (0.91)	0.00
				χ^2(*p*)	Cramer's V
Hispanic	68.8%	67.9%	66.7%	0.02 (0.99)	0.02
Caucasian	87.5%	85.7%	78.8%	0.79 (0.67)	0.10
African American	6.3%	3.6%	3.0%	0.31 (0.86)	0.06
Native American	6.3%	10.7%	21.2%	2.43 (0.30)	0.18
MAT (reported at screening)	None 20.0% Methadone 20.0% Suboxone 60.0%	None 3.6%% Methadone 57.1% Suboxone 39.3%	None 6.3% Methadone 43.8% Suboxone 50.0%	7.49 (0.11)	0.22
Prior reported PTSD[a]	18.8%	59.3%	48.7%	7.40 (0.03)[b]	0.31
Prior reported Depression[a]	25.0%	59.3%	50.0%	5.20 (0.07)	0.07

Note: N = Number, SD = Standard Deviation, MAT = Medication Assisted Treatment, PTSD = Posttraumatic Stress Disorder.
[a] Mental health diagnoses were self-reported at screening.
[b] Differences were expected between the screened out and screened in groups on PTSD, as prior trauma exposure was inclusion criteria.

2015). The Fagerstrom Test for Nicotine Dependence (FTND; Heatherton et al., 1991), a well-validated measure, was used to determine severity of nicotine dependence at baseline. Substance use was assessed at each EMA survey with an item that queried any use of drugs (heroin, benzodiazepines, amphetamines, cocaine, cannabis, or other drugs) since the previous EMA session. Alcohol use was assessed during each EMA survey with an item asking number of standard drinks since the previous EMA session, and tobacco use was assessed at the same times via an item asking number of cigarettes smoked.

2.4.4. Participant profile

A study-specific demographics-history questionnaire administered at baseline assessed age, race, ethnicity, education, criminal justice, and socioeconomic variables.

2.5. Participant compensation

Participants were compensated with merchant gift cards based on appointment type and EMA completion rate: $50 for the 4-5-hour baseline appointment, $10-40 for each EMA download (dependent upon EMA completion rate), and $25 extra for the final EMA download. Some participants also received an additional $25 for an extra interview. Including the 4-5-hour baseline assessment, the weekly download and survey sessions, and the 28-day EMA reporting task, participants could earn a maximum of $260.00 for participation.

2.6. Analytic approach

We compared three groups of participants 1) screened out, 2) screened in/did not enter the study, and 3) screened in/consented at baseline. These analyses used ANOVA and chi square analyses in SPSS (IBM Corp., 2017). We conducted multilevel models in M*plus* 8 (Muthén and Muthén, 1998–2017) using a Bayesian estimator with non-informative priors to examine the effects of peak daily PTSD symptoms and daily prenatal bonding subscale lows (Quality of attachment low and Intensity of attachment low) on six same-day substance use outcomes aggregated across time for each day: any drug use (0 = no, 1 = any drug use except alcohol/tobacco), cannabis use (0 = no, 1 = yes), heroin use (0 = no, 1 = yes), benzodiazepine use (0 = no, 1 = yes), alcohol use (continuous number of drinks), and cigarette use (continuous number of cigarettes) (see Table 3). "Other" drug use, cocaine use, and amphetamine use were not examined due to low endorsement rates. Statistical significance was reported based on a 95% credibility interval not containing zero. At level 1 (within-subjects), predictors were person-mean centered (n = 813 days); at level 2 (between-subjects), predictors were grand-mean centered (n = 32 participants). This centering results in the ability to examine independent within-subject and between-subject effects (Raudenbush and Bryk, 2002).

3. Results

3.1. Recruitment of sample

Study flow is illustrated in Fig. 1. We contacted 98 patients, 12 were not interested in participating, 3 lived too far away, 2 were in a conflicting study, and we lost contact with 4 interested participants before screening. Of the 77 participants screened, we found 60 eligible patients, of whom 33 participated in the study. As shown in Fig. 1, about half the participants who screened in but did not participate failed to show up for baseline appointments, while the other half repeatedly rescheduled until they became ineligible due to gestational age past 35-weeks (timed-out). We compared all tracking variables collected at screening between ineligible individuals, eligible individuals who did not participate, and participants. We found no significant differences between groups on age, race, ethnicity, gestational age, MAT type, number of reported mental health diagnoses, or reported depression. Ineligible patients, as a group, had less reported prior PTSD diagnoses than patients who screened in (see Table 1). This was as expected, because trauma exposure was an inclusion criterion.

3.2. Participant profile

On average, participants were in the late 2nd trimester (*M* = 26.8 weeks, *SD* = 5.29 weeks, range 18–35 weeks), 27.8 years of age (*SD* = 4.48, range 21–38), and predominantly Hispanic (67%, see Table 2). The majority were unemployed (70%), never married (55%), and had annual household incomes below $20,000 (55%). Nearly half (49%) had been homeless at some point in the last 12-months. Most participants had some college education (61%) and had prior pregnancies (88%). Almost half the participants had other children living with them (42%), and many had children not in their custody (39%). Nearly all (91%) had been arrested, with a mean of 6.6 arrests (SD = 7.13, range 1–30) and 36% reported incarceration during a pregnancy.

Nearly half (46%) the sample met criteria for PTSD, with a wide range of PSTD severity (Table 2) associated with PTSD diagnosis, $t(31) = 10.1$, $p < 0.0001$, $d = 3.47$. The majority reported an opioid use disorder (91%), and many had current non-opioid SUD (64%). Of

Table 2
Sample Profile.

Measure (range of scale or norms where available)	Range	Mean	*SD*
Age	21–38	27.8	4.48
Gestational age of fetus (weeks)	18–35*	26.8	5.29
	Percentage (%)**		
Non-Hispanic Caucasian/White	27		
Hispanic/Latina	67		
American Indian/Alaska Native	15		
African American/Black	4.5		
	Range	Mean	*SD*
PTSD Severity (CAPS5) (range 0–80)	0-61	25.1	19.22
Maternal Antenatal Attachment Scale (MAAS, Norm 75.7, *SD* 8.1)	50-94	77.9	10.73
MAAS Quality of Attachment (Norm 49.2, *SD* 4.9)	33-50	44.6	4.79
MAAS Time Spent in Attachment Mode (Norm 26.5, *SD* 4.8)	13-39	28.7	6.38
Anxiety Sensitivity Index (> 17 = moderate to high anxiety sensitivity)	0-55	18.7	16.43
Difficulty in Emotion Regulation Scale (Women Norm 78, *SD* 20.7)	10-126	87.7	26.47
	Percentage (%)		
Alcohol Use Disorder (Current)	27		
Opioid Use Disorder (Current or in remission on MAT)	91		
Substance Use Disorder - Non-opioid (Current)	64		
Subutex (at baseline - Buprenorphine)	45.5		
Methadone (at baseline)	45.5		

Note: * Gestational age was recalculated by medical staff in one case between screening and baseline, resulting in one baseline at 18 weeks. ** Multiracial identification was allowed.
PTSD = Posttraumatic stress disorder; CAPS5 = Clinician-Administered PTSD Scale for DSM5; MAAS = Maternal Antenatal Attachment Scale; MAT = Medication Assisted Treatment; *SD* = Standard deviation.

those being treated with MAT (91% of participants), half were prescribed buprenorphine and half methadone. Sixty-one percent used tobacco, with nicotine dependence ranging from low to high severity (M = 3.6, SD = 2.42) as measured by the FTND. At baseline, prenatal bonding and difficulty in emotion regulation were in the normal range, while anxiety sensitivity was in the moderate-to-high range (see Table 2).

3.3. Compliance rates

Of 33 participants who consented and completed baseline assessments, 32 provided EMA data. Each subject was asked to complete three EMA reports per day for 28 days (84 expected reports per person). Thus, 100% compliance would have resulted in a total 2772 EMA reports from 33 participants. Over the 4-week periods, a final total 2049 EMA reports were collected (74% compliance).

3.4. Alcohol, tobacco, and other drug (ATOD) use EMA reports

About one-third (34.4%) of the sample reported no illicit drug use during the study period, leaving 65.6% of the sample reporting at least one day of drug use (a total of 149 use days, 18.3% of days). Of these, 37.5% of participants reported heroin (32 use days, 3.9% of days), 28.1% reported cannabis (62 use days, 7.6% of days), 18.7% reported amphetamine (45 use days, 5.5% of days), 12.5% reported benzodiazepine (29 use days, 3.6% of days), 6.2% reported cocaine (2 use days, 0.2% of days), and 3.1% reported "other" drug use (3 use days, 0.4% of days). Some participants used multiple drugs on the same day. Most of this sample (71.9%) reported cigarette use (431 use days, 53% of days), and 18.7% reported alcohol use (45 use days, 5.5% of days).

3.5. Convergent validity

We examined the degree to which baseline retrospective assessment scores converged with EMA assessment scores. Baseline PTSD severity scores were strongly correlated with averaged EMA PTSD severity scores, r = 0.741. Similarly, baseline MAAS subscale scores correlated strongly with averaged EMA-adapted MAAS subscale scores (quality of attachment, r = 0.733; intensity of attachment r = 0.681).

3.6. Alcohol, tobacco, and other drug use outcomes

We observed moderate associations (average β = 0.23) between daily peak PTSD symptoms and substance use at a daily level (see Table 3) with significant effects on drug use (β = 0.37), cannabis use (β = 0.35) and cigarette use (β = 0.24), and non-significant (though directionally consistent) effects on heroin use (β = 0.09) and alcohol use (β = 0.11). The effects of prenatal bonding subscales on substance use were more modest and less consistent across models with intensity

Table 3
Models Predicting Drug Use, Alcohol Use, and Cigarette Use from Peak PTSD Symptoms and Prenatal Bonding Low (Quality of Attachment and Intensity of Attachment).

	Drug Use			Cannabis Use			Heroin Use		
WITHIN-SUBJECTS	β	B	95% CI	β	B	95% CI	β	B	95% CI
Peak PTSD Symptoms	**.37**	**.39**	**.05, .71**	**.35**	**.37**	**.10, .57**	.09	.09	−.22, .28
Quality of Attachment Low	.00	.01	−.31, .31	−.02	−.04	−.22, .02	.02	.07	−.09, .14
Intensity of Attachment Low	−.09	−.08	−.34, .22	−.22	−.21	−.36, .11	**−.34**	**−.32**	**−.50, -.04**
BETWEEN-SUBJECTS	β	B	95% CI	β	B	95% CI	β	B	95% CI
Peak PTSD Symptoms	.15	.25	−.45, .97	.27	.84	−.04, 1.0	−.07	−.08	−.41, .42
Quality of Attachment Low	−.07	−.38	−1.4, .59	−.09	−1.2	−1.5, .30	−.16	−.54	−1.5, .30
Intensity of Attachment Low	−.19	−.31	−1.1, .37	−.01	−.37	−.44, .56	.04	.05	−.35, .56

	Alcohol Use (cont)			Cigarette Use (cont)		
WITHIN-SUBJECTS	β	B	95% CI	β	B	95% CI
Peak PTSD Symptoms	.11	.02	−.01, .06	**.24**	**.08**	**.02, .16**
Quality of Attachment Low	.04	.02	−.01, .04	**.06**	**.06**	**.01, .10**
Intensity of Attachment Low	**.24**	**.04**	**.02, .07**	.05	.02	−.03, .05
BETWEEN-SUBJECTS	β	B	95% CI	β	B	95% CI
Peak PTSD Symptoms	.17	.06	−.16, .18	−.20	−.19	−.50, .12
Quality of Attachment Low	.07	.09	−.40, .57	−.31	−.98	−2.3, .26
Intensity of Attachment Low	−.30	−.09	−.22, .04	−.04	−.03	−.35, .31

Note: CI = Bayesian Credibility Interval. Drug use, cannabis use, and heroin use were modeled as categorical variables (0 = no use, 1 = use) with a probit link function, alcohol use and cigarette use were modeled as continuous variables (number of drinks, number of cigarettes, respectively). Statistically significant effects (95% CI not including zero) are in bold typeface for emphasis.

of attachment low predicting higher alcohol ($\beta = 0.24$), but lower heroin ($\beta = 0.34$), use at the daily level. Quality of attachment low was significantly associated with higher cigarette use, although this effect was quite small ($\beta = 0.06$).

4. Discussion

We collected EMA data with a sample of pregnant women with prior trauma exposure and SUD enrolled in a comprehensive prenatal, maternity, neonatal, and SUD treatment program to examine associations between PTSD symptoms, prenatal bonding, and substance use. Although our participants on average had relatively severe SUD, economic and social instability (i.e., low income, single, unemployed mothers with justice system involvement; see Section 3.2) and childcare responsibilities (i.e., almost half had other children in their care; see Section 3.2), compliance and retention rates were high. Our compliance rate of 74% was close to rates in less disadvantaged samples (e.g., binge eaters 76%–92% [Haedt-Matt and Keel, 2011], children/adolescents 78%, [Wen et al., 2017]), other samples of pregnant women, (e.g., pregnant ex-smokers 84% [Allen et al., 2018] and pregnant women with depression 72% [Faherty et al., 2017]).

More than two-thirds of our sample reported illicit drug use via EMA, nearly one-fifth reported drinking alcohol, and nearly three-fourths reported use of tobacco. Despite legitimate concerns pregnant women may otherwise have about disclosing prenatal substance use, our participants appeared willing to disclose substance use during EMA. Substance use disclosure rates might differ in regions with mandatory reporting laws for prenatal substance use or where cannabis laws are different. State law in this region did not mandate this reporting, and medical use of cannabis was legal (but recreational cannabis use was not). Additionally, our research was covered by a Certificate of Confidentiality from the U.S. Federal Government, which protected participants' identities from subpoena, and all participants were notified of this during informed consent. Substance use disclosure rates might also be lower when EMA is collected for clinical purposes instead of research, since demand characteristics or consequences might be greater in that context.

At the within-subject level, we observed associations between PTSD symptoms and substance use with effects ranging from small to moderate. This supports the plausibility of PTSD symptoms as a temporally proximal risk factor for same-day substance use in this population. Given that these substances differ in prevalence, treatment approaches, and teratogenicity, additional research is needed to determine how PTSD symptoms may place pregnant women at immediate risk for using specific substances.

Our results were less clear regarding the potential role of prenatal bonding as a temporally proximal protective factor against prenatal substance use. Lower intensity of attachment low points was significantly associated with more alcohol use, but less heroin use. It is possible that this discrepancy related to treatment approach. Women with opioid use disorders received MAT, but there was no equivalent MAT for prenatal alcohol use disorders. Overall, associations between prenatal bonding and substance use were weaker and less consistent across substance use outcome, highlighting the need to conduct additional research with greater statistical power.

As shown in Table 1, our participant sample did not significantly differ on tracking variables from patients who did not participate nor from those who screened out, except on variables that reflected eligibility criteria, i.e., PTSD requires prior trauma exposure (American Psychiatric Association, 2013). Although participants who opted not to be screened for the study were likely different from those who were interested in participation, our finding reduces concerns that interested pregnant women who were able to participate were substantially and systematically different from individuals who were initially interested but did not participate. Our results showed that pregnant women with SUD were willing and able to adhere to an EMA protocol. Baseline PTSD severity and prenatal bonding were strongly correlated with the average of corresponding EMA reports, supporting the convergent validity of these measures. However, EMA provided the additional benefit of documenting the instability of these processes over time.

4.1. Limitations

Because this was a pilot study, our statistical power was limited for subgroup analyses due to the small sample size ($N = 32$) of the study and was also limited at the within-subject level by the sparseness of our substance use outcomes. Because of this, our analyses were conducted at the daily level to maximize statistical power, and additional work is needed to examine the lagged and bidirectional associations among these study constructs (e.g., morning PTSD symptoms predicting later prenatal bonding or substance use). Demographics of participants were consistent with the lower socioeconomic population in this region and, thus, represented the general patient population of the clinic. However, African Americans, Asians, and Pacific Islanders are underrepresented in this region, and therefore our results may not generalize to these populations. We had a high attrition rate between screening and baseline visits, and, although those who participated did not differ significantly as a group on tracking variables from patients who did not participate or from those who screened out, they may have differed from participants on unknown variables. We also could not conduct baseline assessments at the clinic or offer taxi service to participants for appointments (which could have affected the number of participants who screened in but did not make it to a baseline appointment before falling outside the gestation eligibility window). Additionally, we do not know how the 12 women who declined to be screened, or the nine women who were unable to be screened differed from the 77 screened women. Consequently, our sample is susceptible to some selection bias. We did not have biological confirmation of self-reported substance use and therefore may have missed some episodes of use.

4.2. Conclusions

In a sample of treatment-engaged pregnant women with SUD and trauma, we found evidence that suggests PTSD symptom severity may be a temporally proximal risk factor for prenatal substance use and that facets of prenatal bonding may be temporally proximal protective factors for alcohol use at a day-to-day level. Given the known emotional fluctuations associated with pregnancy (Newham and Martin, 2013) and consequences of prenatal substance use to mothers and children (Quesada et al., 2012), it is critical to determine proximal antecedents to substance use in this at-risk population. Additional work is needed with EMA to disentangle within-subject and between-subject effects of these factors on prenatal substance use and to determine the best interventions targeting such fluctuating potential proximal risk/protective factors. We demonstrated that EMA research can be conducted with high-risk, disadvantaged, pregnant women with SUD. We had excellent retention, were able to collect EMA data at rates similar to studies with lower-risk populations, and participants reported substantial substance use via EMA.

Role of the funding source

Funding for this study was provided by The National Institutes of Health (grant numbers R25DA035163, K23AA025094, and K01AA023233). Funding sources have had no involvement in study design; in the collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the paper for publication.

Contributors

Author Sanjuan designed the study; wrote the protocol; managed

the study; collected, analyzed, and interpreted data; and wrote substantial portions of the manuscript. Author Pearson assisted in the design and set-up of the study, analyzed and interpreted data, and also wrote substantial portions of the manuscript. Author Poremba informed the design and set-up of the study, collected data, and drafted and edited portions of the manuscript. Author Amaro informed the design and conduct of the study and edited the manuscript. Author Leeman informed the design and conduct of the study and edited the manuscript. All authors contributed to and have approved the final manuscript.

Conflict of interest

All authors declare they have no conflict of interest.

Acknowledgements

We kindly thank the medical staff at the clinic, especially Mandy Hatley and Mija Serrano, who accommodated our staff and welcomed us into their space.

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