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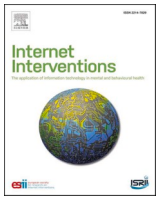

Feasibility and acceptability of using smartphone-based EMA to assess patterns of prescription opioid and medical cannabis use among individuals with chronic pain

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ABSTRACT

Background: Intensive longitudinal studies are needed to examine the co-use of prescription opioid medication and medical cannabis and their effects on chronic pain. The current study sought to investigate the feasibility and participant compliance with a smartphone-based Ecological Momentary Assessment (EMA) data collection protocol among individuals who use multiple substances and suffer from chronic pain.

Methods: A total of 46 participants (mean age = 44.8 years; 78% female; 85% Non-Hispanic White) were recruited online and completed a 30-day EMA phase where they responded to prompted surveys (four random past-hour surveys and one daily diary per day) about opioid medication use, medical cannabis use, and pain symptoms. Qualitative follow-up interviews were conducted with a subset of 10 participants. Linear and logistic regression models were used to examine baseline participant characteristics in relation to EMA compliance. Qualitative indicators of participant study experience were extracted from interviews.

Results: Participants responded to an average of 70% of past-hour surveys and 92% of daily diaries. Female participants were more likely to complete all daily diaries and at least one past-hour survey per day on all 30 days, respectively (OR = 5.60, 95% CI: 1.02–30.77, $p < .05$; OR = 7.08, 95% CI: 1.28–39.16, $p < .05$). Female participants were also more likely to complete at least 75% of their prompted past-hour surveys (OR = 4.67, 95% CI: 1.00–21.69, $p < .05$). Interview participants reported a positive study experience overall, although some mentioned problems related to smartphone notifications, redundant questions, or being prompted when they were not feeling well. Participants also mentioned problems with reporting the amount of medical cannabis used (e.g., milliliters of vaping liquid).

Conclusions: Study results demonstrate both feasibility and acceptability of using EMA methodology to examine use patterns of medical cannabis and prescription opioid medication among individuals with chronic pain.

1. Introduction

Chronic pain affects over 50 million Americans (Centers for Disease Control and Prevention, 2018), and frequently, opioids are prescribed to aid patients in managing such pain. A recent estimate suggests that as many as 25% of patients with chronic pain misuse prescription opioids, and 10% may meet criteria for opioid use disorder (Vowles et al., 2015), compared to 0.2% of the general population (Degenhardt et al., 2014). While the current surge in opioid overdose rates is mainly driven by synthetic opioids, the misuse of prescription opioids remains a major risk factor for later heroin use (Jones, 2013). In light of the risks associated with prescription opioid misuse, clinical practice guidelines stress the importance of non-opioid treatments for chronic pain (Dowell et al., 2016). As such, cannabis and cannabinoid products have been increasingly recommended to patients by their providers for chronic pain management (Boehnke et al., 2019). Recent evidence suggests that these systematic recommendations may result in co-use patterns among patients whereby they either substitute some portion of their opioid

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medication with cannabis or replace the opioid medication completely (Boehnke et al., 2016; Corroon et al., 2017; May et al., 2018).

Intensive longitudinal studies are needed to examine co-use of these two substances, opioid medication and medical cannabis, and their effects on pain (Nugent et al., 2018). Existing cross-sectional studies have not had the level of sensitivity needed to evaluate patterns of co-use, including product switching and substitution, and associations with pain symptoms. Moreover, cross-sectional surveys do not elucidate the time-course of opioid medication and medical cannabis use on a day-by-day level, or the trajectories from opioid use to co-use of both substances.

Ecological Momentary Assessment (EMA) is a data collection method that repeatedly captures brief self-reported behavioral, cognitive, affective, and functional states in close-to-real-time. EMA is ideally suited for collecting fine-grained data on medication use frequency and pain-related symptoms, as it has low recall bias and high ecological, or real-world, validity (Shiffman, 2009; Shiffman et al., 2008). By capturing routine behaviors, emotions, and cognitions in close-to-real-time, EMA overcomes the influences of memory degradation and heuristic biases that commonly confound retrospective surveys (Coughlin, 1990; Shiffman, 2009; Stone and Broderick, 2007). Findings from an EMA study focusing on patterns of co-use would strengthen existing results by providing naturalistic evidence for or against the potential opioid-sparing effect of cannabis on a daily basis. Such a study could also help determine sociodemographic characteristics and co-use trajectories that are associated with likelihood of transitioning from opioid medication to medical cannabis.

EMA studies typically involve participants receiving multiple short surveys per day, generating the potential for high participant burden and resulting non-response and dropout, and it is important to understand study compliance in detail (Stone and Shiffman, 2002). An EMA study's compliance, or survey completion rates, indicates the study's ability to capture representative information from participants (Sokolovsky et al., 2014; Wen et al., 2017). Previous reviews and meta-analyses have shown completion rates of 85–86% for chronic pain-focused EMA studies (May et al., 2018; Ono et al., 2019). The effect of pain intensity on compliance is unclear, given that higher pain may cause individuals to be distracted and miss prompts or could motivate participation in support of pain research (Ono et al., 2019). Compliance in reporting on substance use behaviors in EMA studies has been more variable (Shiffman, 2009), with a recent meta-analysis demonstrating a lower compliance of 75% (Jones et al., 2019). Poly-use of recreational substances may also be associated with low compliance, reflecting heightened impairment causing individuals to miss or disregard survey prompts (Messiah et al., 2011). To our knowledge, compliance with an EMA methodology that is focused on opioid medication and medical cannabis co-use, and in the context of persons who have chronic pain, has not been examined.

To address this open question in the existing literature, the current study examines the feasibility and acceptability of conducting an intensive longitudinal study using a 30-day smartphone-based EMA approach to investigate the relationship between prescription opioid medication use, medical cannabis use, and chronic pain.

2. Methods

2.1. Study overview

The current study included online surveys, smartphone-based EMA data collection, and qualitative interviews to investigate prescription opioid medication and medical cannabis use in relation to chronic pain.

2.2. Participants

Study investigators recruited participants from December 2019 to June 2020 from 11 states (Alaska, California, Colorado, Illinois, Maine, Massachusetts, Michigan, Nevada, Oregon, Vermont, and Washington) and Washington D.C., which all had legalized recreational cannabis use at the time of recruitment. Recruitment occurred through targeted Facebook and Instagram ads and through the Colorado-based Realm of Caring Foundation focused on medical cannabis, who shared recruitment information on social media. Ads contained a link that directed interested individuals to more information about the study, the eligibility questionnaire, and the online informed consent form. Individuals were deemed eligible based on the following self-reported criteria: were at least 18 years of age, had a prescription for opioid medication for pain symptoms, used opioid medication in the past 30 days, received a recommendation for or started using medical cannabis in the past 30 days, had a pain disorder, reported pain as at least a 3 on a scale of 0 to 10 on at least 10 days of each month for the past 3 months or longer, had an iPhone or Android smartphone, and currently lived in a state with legalized recreational cannabis use. Individuals who reported having a severe mental illness such as schizophrenia, psychosis, or dementia were excluded from the study.

2.3. Procedures

After screening into the study and consenting to participate, eligible participants were required to send study staff a picture of a valid identification (e.g., driver's license) to validate their age, identity, and place of residence. Enrolled participants completed a baseline survey hosted by Qualtrics to report demographic characteristics, substance use history and current behavior, and pain. Participants were also asked to identify any long-acting and/or short-acting oral and non-oral opioid medication(s) they had used in the past 30 days. They were similarly asked to select from a list all medical cannabis products (flowers, oil, concentrates, edibles, topicals, prescription medications) that they used in the past 30 days.

After completing the baseline survey, participants moved to the EMA phase of the study, which was conducted using the PiLR EMA study app, developed by MEI Research Ltd., on their personal smartphones. Before they began responding to surveys, participants engaged in a three-day demo period during which they received training from study staff on how to use the app and then had multiple days to practice using the app by answering sample questions. Participants received an email containing written instructions on how to install and use the study app and information on survey timing, frequency, and incentives. During the demo period, study staff conducted follow-up telephone calls to answer questions and confirm that participants understood how to use the app. Sample questions for the demo period were replicas of the questions asked on the actual past-hour surveys.

After the demo period, participants began the 30-day EMA phase where they responded to prompted surveys about opioid use, cannabis use, and pain symptoms. On each of the 30 days, participants were prompted to complete five surveys, four of which were prompted at random times between 8 am and 11 pm of their device's local time, pertained to the past hour, and had a 1-h time window to complete. The 1-h time interval for the randomly prompted surveys was selected to maximize the probability of observing situations in which opioid medications and cannabis products were used by participants, while limiting the recall window for time-coverage in a way that would minimize participant recall bias. In absence of gold standards for time coverage in EMA studies, the 1-h time interval for coverage was selected after deliberation among research team members and should be treated as an ad-hoc decision for this particular study. The fifth survey was a daily diary that was prompted between 10 am and 11 am, pertained to the entire previous day, and had a 12-h time window for completion.

For each individual participant, EMA surveys were pre-populated with the prescription opioid medication(s) and medical cannabis product(s) the participant had reported currently using in the baseline survey. The number of survey items in each survey ranged based on the number of prescription opioid medication(s) and medical cannabis

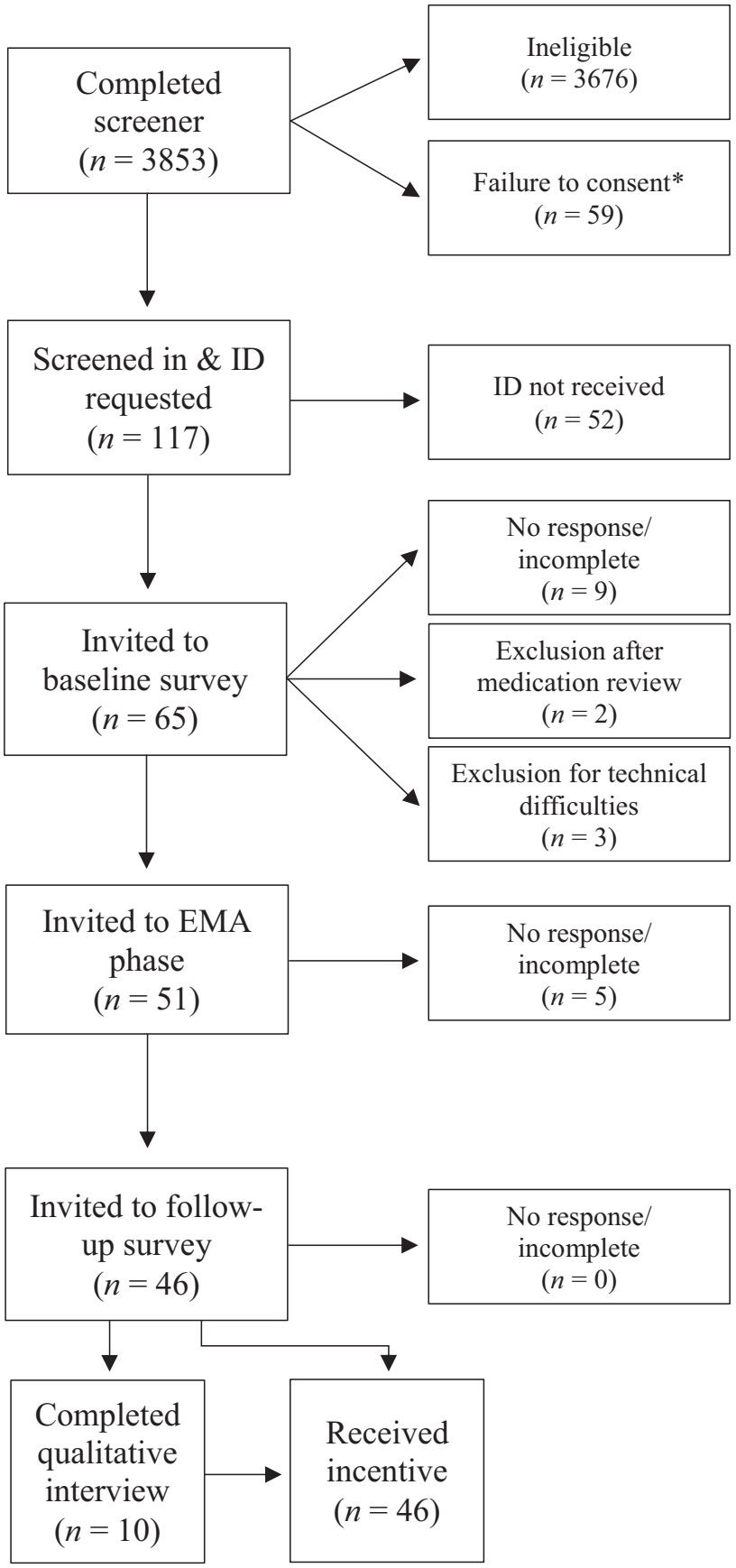

Fig. 1. Participant flow through phases of study using smartphone-based EMA
*Includes individuals who declined consent ($n = 1$) and who did not answer consent questions correctly after three attempts ($n = 58$).

product(s) reported at baseline and was affected by skip patterns (e.g., questions about quantity and pain relief were only asked if the participant reported using any medication or cannabis product). The total range was 11 to 29 items in the daily diary survey and 19 to 30 items in the past-hour survey. Each EMA survey took a maximum of two minutes to complete, for an expected maximum time commitment of no more than 10 min per day to complete all five prompted surveys.

During the EMA phase, study staff sent participants SMS text message check-ins about their current compliance rate at Days 3, 4, 14, and 21 and communicated via email and text message if participants had questions or comments. The study team monitored participant EMA survey activity and conducted regular check-ins to understand and troubleshoot issues and work with the survey app programming team to address technical problems on the backend.

After completing the EMA phase, participants completed a follow-up Qualtrics survey about past 30-day substance use, pain, quality of life ("The World Health Organization Quality of Life Assessment (WHO-QOL): development and general psychometric properties", 1998), sleep (Bastien et al., 2001), and functioning (Feragne et al., 1983; Rodriguez et al., 2012). Finally, qualitative telephone interviews were conducted with a subset of participants ($n = 10$) to explore experiences with the study. The subset of participants included individuals who marked "yes" on the screening form for being willing to participate in the follow-up telephone interview and finished the full EMA data collection period. Topics covered in the interviews included overall experience in the study; experiences with tracking and reporting prescription opioid use, medical cannabis use, and pain levels; and experiences interfacing with the smartphone app and surveys. Participants each received $2 for each day they completed at least one survey, for a maximum possible $60, and an additional $60 was given if they completed multiple surveys per day and reached a completion rate of at least 75%. Participation in the qualitative interview was incentivized with an additional $25. Incentives were provided in the form of electronic gift cards, which were emailed to participants at the end of their participation in the study.

2.4. Measures

Outcomes were related to study feasibility and acceptability. *Overall study feasibility* was measured by examining the prevalence of the study sample moving through subsequent study phases. For feasibility related specifically to the EMA surveys, participation and compliance were assessed. *Participation* was characterized by the number of past-hour surveys and daily diary surveys completed, and the number of days on which surveys were completed. *Compliance* was characterized by survey response rates and early dropout prior to the end of the 30 days. In particular, compliance outcomes included the proportion of surveys completed, response to all 30 days of surveys (no = 0, yes = 1), and completion thresholds (90% for daily diaries and 75% for hourly surveys; no = 0, yes = 1), all assessed at the participant level. Dropout was operationalized as non-response to all prompted surveys on a given day and no subsequent response thereafter through Day 30. *Acceptability* of the study design was also examined from the participants' perspective according to their responses from the qualitative telephone interviews at follow-up. Responses of interest focused on lessons learned about methodology, implementation, and participant experience.

Participant characteristics were measured at baseline and included: sex (male = 0, female = 1); age (younger than 40 years = 0, 40 years or older = 1); race (Non-Hispanic White = 0, Other = 1); education (less than college degree = 0, college degree or higher = 1); any past three-month illicit drug use at baseline (no = 0, yes = 1); maximum frequency of past three-month illicit drug use at baseline (daily or almost daily vs not daily); any alcohol use in a typical week (no = 0, yes = 1); number of days of opioid medication use in the past 30 days; number of days of medical cannabis use in the past 30 days; average, least, and worst pain in the past 30 days (rated 0 to 10); and Graded Chronic Pain Scale category (Grade I: low disability-low intensity, II: low disability-high intensity, III: high disability-moderately limiting, IV: high disability-severely limiting) (Von Korff et al., 1992).

Study process-related characteristics included what type of smartphone operating system (OS) the participant used to complete the EMA surveys (Android = 0, iPhone = 1) and whether the participant experienced a problem with receiving notifications for prompted surveys at any point during the EMA phase (no = 0, yes = 1).

2.5. Statistical analysis

Analyses were both quantitative and qualitative. Study investigators examined descriptive characteristics of the study sample, overall feasibility, and EMA participation and compliance. Univariate linear and logistic regression models were also used to examine whether baseline participant characteristics and study process-related characteristics were related to EMA compliance. Study investigators also extracted themed responses from the qualitative interviews to understand participants' acceptability of the study design and overall experience with the study. In this process, one member of the study team read the interview transcripts in their entirety and extracted and coded emerging themes in Dedoose, with a second member of the team then reviewing and revising all transcripts and codes for completeness. Codes addressed pre-determined themes based on sets of interview questions and included the following: overall participant experience in the study; experiences with tracking and reporting prescription opioid use, medical cannabis use, and pain levels; and participant experiences of using the smartphone app and completing surveys.

3. Results

The study sample consisted of 46 participants who were majority female (78%; $n = 36$). On average, they were 45 years of age ($m = 44.8$; SD = 12.9), and most were non-Hispanic White (85%; $n = 39$). Slightly more than half had a two- or four-year college degree or beyond (59%; $n = 27$). For past three-month illicit drug use at baseline, two participants reported any use, with both reporting use of sedatives daily or almost daily. Given this low prevalence, illicit drug use was not examined in relation to the outcomes. Approximately one-fifth of participants (22%; $n = 10$) reported drinking any alcohol during a typical week. Participants used opioid medications an average of 19.6 days (SD = 11.1) in the past 30 days, with 48% ($n = 22$) reporting use on all 30 days, and used medical cannabis an average of 23.1 days (SD = 9.4), with 57% ($n = 26$) reporting use on all 30 days. Average pain score in the past 30 days was 6.0 (SD = 1.2) on a scale of 0 to 10, with the average score for worst pain being 8.6 (SD = 1.3) and average score for least pain being 3.6 (SD = 1.8). Over half of participants (57%; $n = 26$) reported pain that was Grade IV (high disability-severely limiting), with 30% ($n = 14$) reporting Grade III pain and 13% ($n = 6$) reporting Grade I or II pain. Grades I through III were combined in the analyses to examine the association between the most severe pain and the outcomes.

For smartphone type, 52% ($n = 24$) of participants used an iPhone to complete their EMA surveys, and 48% ($n = 22$) used an Android. Nineteen participants (41%) reported experiencing some level of notification issues during their EMA phase. Notification problems were associated with either participants not having notifications turned on for the EMA app or temporary issues with backend programming of the survey app and notifications.

3.1. Overall study feasibility

The participant flow through the study phases is shown in Fig. 1. A total of 115 participants were eligible for the study, and of those, 55% ($n = 63$) submitted their identification and were then verified for study enrollment. Over three-quarters (83%; $n = 52$) of enrolled participants completed the baseline survey. Approximately 88% ($n = 46$) of those who completed the baseline survey participated in the entire 30-day

Table 1
Summary of EMA reporting and compliance ($N = 5142$ surveys).

Daily diaries (n = 1268)	
Completed daily diaries / Expected total diaries	1268/1380 (91.9%)
Total daily diaries per participant (m +/− SD; range)	27.6 +/− 3.9; 11–30
Participants completing 100% of prompted daily diaries	23/46 (50.0%)
Participants completing at least 90% of prompted daily diaries	33/46 (71.7%)
Past-hour surveys (n = 3874)	
Completed past-hour surveys / Total sent random prompts	3874/5520 (70.2%)
Total past-hour surveys per participant (m +/− SD; range)	84.2 +/− 28.7; 13–116
Participants reporting 1+ past-hour survey on each of the 30 days	25/46 (54.3%)
Participants completing at least 75% of prompted past-hour surveys	27/46 (58.7%)
Observations per participant day (days w/ 1+ completed survey) (m +/− SD)	3.1 +/ 1.0

SD = standard deviation.

EMA phase. Two of the 46 EMA phase participants dropped out of the study early (their last days were Day 22 and Day 26, respectively). All participants who completed the EMA phase also completed the follow-up survey. A subset of participants who had completed the EMA phase ($n = 11$) were approached by research staff to complete a qualitative follow-up interview. Participants were contacted via email or text with a maximum of two attempts. The qualitative follow-up interview was completed by 10 participants.

3.2. EMA assessments

Overall, 5142 observations were reported, of which 1268 were daily diaries and 3874 were past-hour surveys (Table 1). The mean number of past-hour completed surveys per person was 84.2 (SD = 28.7; range: 13–116), out of a maximum possible 120 prompted surveys (70% overall compliance). Approximately half of participants (54%; $n = 25$) completed at least one past-hour survey on each of the 30 days, and on days when there was at least one survey completed, approximately three surveys were completed ($m = 3.1$; SD = 1.0), out of a maximum of four. The mean number of daily diaries was 27.6 (SD = 3.9; range: 11–30) out of a maximum possible 30 (92% overall compliance), and 50% ($n = 23$) of participants completed daily diaries on all 30 days. Over 70% (72%; $n = 33$) of participants completed at least 90% of their prompted daily diaries, and over half (59%; $n = 27$) of participants completed at least 75% of their prompted hourly surveys.

3.3. Associations with compliance

Associations between participant and study characteristics and compliance outcomes are included in Table 2. Participants who had higher average pain for the past 30 days at baseline completed marginally fewer daily diary surveys ($b = -0.03$, SE = 0.02, $p < .10$). Female participants were more likely to complete all daily diaries and at least one past-hour survey on all 30 days, respectively (OR = 5.60, 95% CI: 1.02–30.77, $p < .05$; OR = 7.08, 95% CI: 1.28–39.16, $p < .05$), and compared to participants with lower grade pain, those with Grade IV pain were marginally more likely to complete all 30 days of daily diaries (OR = 2.97, 95% CI: 0.87–10.12, $p < .10$). Female participants were also more likely to complete at least 75% of their prompted hourly surveys (OR = 4.67, 95% CI: 1.00–21.69, $p < .05$), as were those with a college degree or higher (OR = 3.27, 95% CI: 0.94–11.32, $p < .10$). Neither of the study process-related characteristics was significantly associated with any of the outcomes for either the daily diaries or the past-hour surveys.

3.4. Interviews with participants after study completion

After study completion, 10 participants completed interview with study staff on the phone. Participants who completed the interviews were not significantly different from the remaining participants on most key metrics except average pain, where interviewees reported lower average pain compared to those who were not interviewed. There were no differences in least or worst reported pain. Additionally, interviewees were more likely to be male. Interviews explored participant experience with the study app, EMA procedures, study measures, and topics related to medical cannabis, prescription opioid medications, and chronic pain. Themes included the following: issues with survey notifications, confusion with how to answer certain questions, overall positive experience, ease of use, and the study app serving as a tracking aid. Problems with study procedures mentioned by participants included the following: issues with not receiving notifications, too many notifications, notifications that came too early in the morning or too late in the evening, having to respond to redundant questions, or being prompted to respond to surveys when they were not feeling well. Several participants mentioned the subjectivity of pain ratings, and a few also reported problems with reporting the amount of cannabis used (e.g., milliliters of vaping liquid).

However, participants reported a positive study experience overall, mentioning that the study app was simple and easy to use and noting the convenience of being able to participate in a research study on their smartphone. Multiple participants also reported that tracking their pain and substance use over the course of the study gave them new insights into their pain symptoms and substance use behaviors. Participants also appreciated that smartphone surveys were pre-populated with their individual opioid medications and cannabis products, which added to the ease of reporting.

Though the interview guide did not prompt for a discussion of this topic, several participants mentioned the perceived importance of conducting a study on medical cannabis and opioid medication use for chronic pain and were pleased to contribute to this area of research.

4. Discussion

The purpose of the current study was to examine feasibility and acceptability of using EMA methods to assess patterns of medical cannabis and prescription opioid medication use among individuals with chronic pain. Specifically, for the EMA surveys, compliance rates observed in our study are comparable to those in previous work. A 2018 review of EMA studies for chronic pain found that for the nine existing smartphone studies, compliance rates ranged from 69.8% to 89.7% (May et al., 2018). Our study's completion rates are comparable, with 70% compliance for randomly-prompted surveys and even higher for daily diaries (over 90%). The compliance rates of our current study are particularly notable given that the 30-day duration was longer, and thus potentially more burdensome to participants, than all but one of the smartphone studies in the 2018 review (May et al., 2018).

Additionally, on average, if a participant responded to one past-hour EMA survey during a given day, he or she responded to multiple surveys that day. This point reinforces the need for and importance of regular check-ins by study staff to remind participants of their response rates and encourage continued participation. Compliance with daily diaries was higher than with past-hour surveys, so more frequent follow-up is needed to boost participation with past-hour surveys.

Finally, for overall study feasibility, just over half of those who screened into the study submitted their identification for enrollment; however, few participants who made it past the identity verification stage dropped out of the study in the subsequent survey phases. Once participants made it past the identity verification stage, they were likely to stay enrolled until the end of the study.

The current results suggested that participant characteristics under study may not be related to compliance. Exceptions were female

Table 2
Univariate associations of participants and study characteristics with survey compliance.

	Daily diaries			Past-hour surveys		
	Proportion of surveys b (SE)	Responded to all 30 days OR (95% CI)	Responded to 90% of surveys OR (95% CI)	Proportion of surveys b (SE)	Responded to all 30 days OR (95% CI)	Responded to 75% of surveys OR (95% CI)
Baseline characteristics						
Gender						
Male	Ref	Ref	Ref	Ref	Ref	Ref
Female	0.02 (0.05)	5.60 (1.02–30.77)*	2.00 (0.45–8.87)	0.11 (0.08)	7.08 (1.28–39.16)*	4.67 (1.00–21.69)*
Age						
Younger than 40 years	Ref	Ref	Ref	Ref	Ref	Ref
40 years or older	0.04 (0.05)	1.85 (0.38–9.03)	1.22 (0.21–7.15)	0.13 (0.09)	3.00 (0.53–17.11)	6.30 (0.69–57.67)
Race						
Non-Hisp White	Ref	Ref	Ref	Ref	Ref	Ref
Other	0.06 (0.05)	2.92 (0.49–17.22)	2.67 (0.28–25.25)	0.12 (0.10)	6.32 (0.68–58.89)	5.14 (0.55–47.97)
Education						
Less than college degree	Ref	Ref	Ref	Ref	Ref	Ref
College degree or higher	−0.02 (0.04)	2.49 (0.74–8.45)	0.85 (0.22–3.20)	0.04 (0.07)	2.34 (0.69–7.86)	3.27 (0.94–11.32)+
Any alcohol use in a typical week						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	0.04 (0.05)	1.68 (0.40–7.08)	1.76 (0.31–9.86)	0.05 (0.09)	1.34 (0.32–5.67)	0.38 (0.09–1.61)
Number of opioid medication use days[a]	0.000 (0.002)	1.04 (0.99–1.10)	1.01 (0.95–1.07)	0.002 (0.003)	1.03 (0.98–1.09)	1.04 (0.99–1.10)
Number of cannabis use days[a]	0.001 (0.002)	1.03 (0.96–1.10)	1.05 (0.98–1.12)	−0.001 (0.004)	1.03 (0.96–1.10)	0.97 (0.91–1.04)
Average pain[a]	−0.03 (0.02)+	1.30 (0.79–2.16)	0.68 (0.38–1.22)	−0.05 (0.03)	0.88 (0.53–1.47)	0.71 (0.41–1.24)
Least pain[a]	−0.002 (0.01)	1.14 (0.83–1.57)	0.88 (0.64–1.20)	−0.01 (0.02)	0.93 (0.66–1.31)	1.03 (0.75–1.44)
Worst pain[a]	−0.02 (0.02)	1.13 (0.70–1.84)	0.82 (0.51–1.31)	−0.04 (0.03)	0.95 (0.59–1.52)	0.74 (0.45–1.20)
Graded Chronic Pain Scale						
Grade I - III	Ref	Ref	Ref	Ref	Ref	Ref
Grade IV	0.001 (0.04)	2.97 (0.87–10.12)+	1.16 (0.32–4.29)	−0.02 (0.07)	1.36 (0.42–4.46)	1.89 (0.57–6.30)
Study process-related characteristics						
Smartphone type						
Android	Ref	Ref	Ref	Ref	Ref	Ref
iPhone	−0.04 (0.04)	1.00 (0.31–3.22)	0.91 (0.25–3.34)	−0.03 (0.07)	0.48 (0.15–1.60)	0.97 (0.30–3.18)
Notification issues						
No	Ref	Ref	Ref	Ref	Ref	Ref
Yes	0.02 (0.04)	0.84 (0.25–2.74)	1.18 (0.31–4.45)	−0.001 (0.07)	0.89 (0.27–2.92)	0.95 (0.28–3.15)

SE = standard error; OR = odds ratio; CI = confidence interval.
+ $p < .10$.
* $p < .05$.
[a] Past 30 days.

participants, who comprised the majority of the study sample, were more likely to have higher compliance with both types of EMA surveys, and those with at least a college degree were marginally more likely to have high compliance with past-hour surveys. Although such analyses conducted within a larger sample size would help confirm the current findings, non-significant relationships between participant demographic and pain-related characteristics and EMA survey completion have also been reflected in a recent meta-analysis on factors that affect EMA completion rates in chronic pain studies (Ono et al., 2019). In the current study, participant characteristics of interest, namely substance use, including prescription opioid medication, medical cannabis, illicit substances, and alcohol were all observed to be unrelated with compliance outcomes. Frequencies of medical cannabis use and prescription opioid medication use in the past 30 days at baseline were also unrelated to compliance. When examining effects of pain on compliance, we found that baseline severity of chronic pain and related disability was also unrelated to compliance, despite the fact that a large proportion of the sample indicated that they had high pain intensity that was severely limiting. Taken together, these points help build confidence that detailed EMA data can be successfully collected from a population that is potentially severely disabled by chronic pain and regularly using multiple substances.

The acceptability of this EMA methodology among individuals with chronic pain was indicated by themes in the qualitative interviews. Overall, participants reported ease of use of the study app and with answering the questions in the individual surveys. Reflecting the quantitative results, the interviews did not uncover any themes that participants found it difficult to respond to surveys or keep up with compliance based on substance use or pain. Many participants also reported perceived value in the study to help monitor their medical cannabis and opioid medication use, even though the study was not purposely meant to help with this aspect. It is possible that as a result of the pain, and especially more intense and more limiting pain, individuals are more invested in the process of trying to find a remedy and used the study as a cue to action (Rosenstock, 1974) to track and manage their pain and treatment regimen.

Interview feedback also uncovered opportunities for improvement for future EMA studies focused on individuals with chronic pain. Future work might focus on the timing of EMA survey prompts since participants might find it difficult to respond when surveys are prompted outside of their normal waking hours. Participants expressed the need for maintaining sleep schedules when possible, especially since pain frequently interfered with sleep quality. Participants also spoke about their difficulty rating subjective pain, especially if there were multiple bodily areas with differing pain levels. Although patients were extensively trained on the use of the EMA software application, we did not provide targeted training on how to make pain ratings, a practice that has been shown to enhance the precision of pain assessment (Gewandter et al., 2020; Treister et al., 2018). Future studies should incorporate specific training on how to make pain ratings repeatedly in the context of an EMA assessment schedule. Finally, interviews uncovered participants' problems with reporting types and amounts of cannabis used. Given the evolving landscape of the cannabis product market (Luc et al., 2020; Spindle et al., 2019) and evidenced by feedback that some

participants had added or removed products based on what worked best for their specific pain, future work should include questions that are flexible in allowing reporting on changing cannabis regimens.

A substantial subset of 41% of participants reported experiencing some level of notification issues during their EMA phase in the current study. Since our study relied on participants' own phones ("bring your own device" or "BYOD"), this design decision could have impacted these notification issues and consequently compliance with EMA surveys. While our analyses controlled for OS type and notification issues, and found that these predictors were not significant, EMA researchers nonetheless should be aware that relying on BYOD designs could increase technical difficulties compared to studies in which participants receive dedicated study phones. On the other hand, potential advantages of BYOD studies include that researchers do not have to purchase devices and the fact that participants are already familiar with their own device and do not need to manage an additional device (e.g., keeping it charged and carrying on them) for the duration of the study. Pros and cons of either approach should be carefully weighed by EMA researchers before committing to a study design.

One key limitation of the results is they are derived from a small sample, which may have limited power. Future work will be needed to replicate findings in a larger sample to confirm the absence of associations between key participant characteristics and compliance outcomes. Future work may also explore the associations between within-person parameters, such as changes in pain, and likelihood of survey response. Moreover, our sample was predominantly female and Non-Hispanic White, and future efforts to increase diversity among study participants are needed. An additional limitation was the self-report nature of inclusion criteria for the study, which could have been susceptible to participants being untruthful about their substance use and/or chronic pain diagnosis. A substantial number of participants did not confirm their identity in order to be included in the study. This may have been due to potentially fraudulent responses of individuals trying to enroll in the study for the monetary incentives but could also highlight discomfort with disclosing identity information in the context of a study on substance use and chronic health conditions. Balancing participant confidentiality and data quality safeguards are an ongoing challenge for online studies. Finally, the potential impact of participant training on EMA compliance was not systematically investigated in the current study and future research is needed to explore this research question.

EMA methodology allowed us to conduct this pilot study completely remotely, facilitating access to participants on a nationwide scale. Our results demonstrate both feasibility and acceptability of using such methodology to examine use patterns of medical cannabis and prescription opioid medication among individuals with chronic pain. Results from this work pave the way for larger-scale epidemiologic studies, opportunities to conduct intervention work, and expansion of assessments to capture increasing geographic representation by participants as recreational and medical cannabis laws continue to evolve.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: PHF is on the advisory board for Ninnion Therapeutics.

RV has received consulting fees and honoraria for service on the scientific advisory board for the following companies within the past 12 months: Canopy Growth Corporation, MyMD Pharmaceuticals Inc., Syqe Medical Ltd.

KED has no conflicts of interest related to this project. In the past 3 years, she has been paid as a consultant for Grünenthal, Inc. and MindMed; received honoraria for advisory board work for Canopy Corporation and Beckley-Canopy; served as a paid expert witness for the Baltimore District Attorney; served as an unpaid advisor to Peabody Pharmaceuticals; and received research and salary support from the National Institutes on Drug Abuse and the Ashley Addiction Treatment Center.

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