International Journal of Interdisciplinary Research in Medical and Health Sciences
ISSN: 2837-9969| Impact Factor : 8.08
Volume. 12, Number 3; July-September, 2025;
Published By: Scientific and Academic Development Institute (SADI)
8933 Willis Ave Los Angeles, California
https://sadijournals.org/index.php/IJIRMHS|editorial@sadijournals.org

MOBILE HEALTH APPLICATIONS FOR RECOVERY FROM OPIOID ADDICTION IN CALIFORNIA

Benjamin Adejumo
Western Covenant University, 3333 Wilshire Blvd #700, Los Angeles, CA, United States
Email: benjamin@wcuniversity.edu
DOI: https://doi.org/10.5281/zenodo.15849157

Abstract: This study examined the creation and assessment of mobile health (mHealth) applications aimed at facilitating opioid addiction recovery in California, emphasizing evidence-based interventions. A total of 196 people with opioid use disorder (OUD) were enrolled and randomized into intervention (n = 98) and control (n = 98) groups, with stratified randomization being used to confirm balanced baseline characteristics. Over 24 weeks, the intervention group, which used a specialized mHealth application, demonstrated considerably higher decreases in opioid usage than the control group. The number of days of opioid use decreased from 8.9 to 2.7 in the intervention group, compared to a reduction from 9.1 to 5.8 in the control group (IRR = 0.46, 95% CI = 0.30–0.70, p < .001). Treatment retention was significantly greater among app users, with 83% continuing on MOUD at week 24, in contrast to 66% in the control group (OR = 2.67, 95% CI = 1.37–5.19, p = .004). Increased application involvement is associated with significantly enhanced retention advantages (OR = 3.55, 95% CI = 1.63–7.72). Secondary outcomes indicated enhanced mental health, evidenced by more significant reductions in PHQ-9 and GAD-7 scores among application users, as well as increased EQ-5D quality-of-life improvements (p = .016). Three engagement trajectories were identified by latent growth modeling, with "high-stable" users attaining the most advantageous outcomes. Thematic analysis of 37 interviews corroborated these findings, emphasizing the motivational impact of real-time feedback, the cultural significance of multilingual communication, privacy safeguards, and the necessity of connectivity for rural participants. The findings indicate that customized, interactive mHealth applications can improve OUD treatment outcomes and mitigate structural obstacles to recovery among various communities in California.

Keywords: Mobile Health Applications, Opioid Addiction Recovery, Evidence-Based Interventions. Latent Growth Modeling, Thematic Analysis

1. Introduction

Mobile health applications have emerged as a promising way to promote opioid addiction recovery by enhancing standard medication-based therapies and enabling scaled, accessible interventions. The opioid epidemic continues unabated in the United States, with overdose fatalities reaching 84,000 in 2022, and preliminary statistics suggesting a negligible drop in 2023 (Williamson et al., 2025). The compelling need to broaden

treatment reach and improve retention in care has led to a surge in research examining digital therapies for opioid use disorder (OUD), notably smartphone-based applications (Lyzwinski et al. 2024).

Medications for opioid use disorder (MOUD)—such as methadone, buprenorphine, and naltrexone—constitute the benchmark in OUD treatment. While effective at reducing morbidity and death, gaps persist in patient adherence, retention, and addressing co-occurring mental health disorders. For example, preliminary trials have indicated that MOUD complementing with app-based contingency management (CM) dramatically reduces the number of opioid use days and increases retention among underserved groups (Marino et al., 2024; Lee, 2024). A retrospective cohort study of 600 persons found that patients utilizing a CM app alongside MOUD had almost 35% fewer days of opioid usage at treatment conclusion and remained in care for nearly 19% longer than those on MOUD alone (Lee, 2024).

In parallel, randomized controlled trials have assessed mood-focused digital tools within MOUD groups. A randomized controlled trial with 63 individuals utilized the "Mood Triggers" app, a cognitive-behavioral therapy intervention, to alleviate depression and anxiety symptoms, revealing moderate to substantial effect sizes (Heinz et al., 2024). This experiment found secondary effects, including lower self-reported OUD severity and greater social engagement, demonstrating the value of integrated mental health support via digital platforms (Heinz et al., 2024). Elevated acceptability scores further emphasize patient readiness to embrace these techniques.

A number of feasibility and acceptability trials have established the framework for more ambitious efficacy research. For instance, the HOPE app—designed to support MOUD—integrated daily self-monitoring, goal-setting, community forums, and secure provider communications. In a pilot cohort of 16 patients, HOPE demonstrated good usability, increased self-efficacy, and sustained engagement after six months (Hodges et al. 2022). Similarly, early-phase digital treatments combining behavioral modules with buprenorphine treatment produced promising adherence and abstinence increases over 12 weeks (Monico et al. 2024).

Recent systematic and comprehensive reviews emphasize the rising panorama of OUD-related apps and user opinions on mHealth techniques. Laundry-reviewed opioid apps in the Apple and Google Play stores found over 160 customized for OUD recovery, with prominent features in motivation, responsibility, linkage to care, desire management, and informational assistance (Williamson et al. 2025). Accessibility and cost obstacles exist, with paywalls or invitation-only models limiting reach. A systematic review by Kiburi et al. (2023) investigated 20 randomized digital intervention trials globally and concluded that although outcomes (abstinence, retention) indicate variable but occasionally considerable gains, methodological heterogeneity complicates conclusions. Across interventions, user satisfaction and acceptability are consistently rated high (Kiburi et al. 2023).

Qualitative research, such as Lyzwinski et al. (2024), underlines that individual with OUD feel great benefit in mHealth interventions—especially when personalized, privacy-conscious, and integrated with provider assistance. Users say that personalization, multimedia content, and social support elements boost engagement. Wearable sensors, SMS messaging, and app-based alerts are regarded as beneficial adjuncts for regulating cravings, reducing overdose, and ensuring treatment adherence (Lyzwinski et al. 2024).

Despite expanding evidence, a significant scarcity of strong randomized trials exists, particularly in geographically focused investigations. Oesterle et al. (2024) noted the lack of RCT-level support for OUD treatment applications, while others advocate for contextually relevant research, including state-level deployment in regions such as California (Oesterle et al., 2024). Moreover, the California opioid crisis presents distinct

demographic, geographic, and healthcare system factors—ranging from rural access issues to various linguistic and cultural needs—that necessitate specific digital solutions.

In summary, available evidence strongly supports that app-based therapies, such as contingency management tools, mood and anxiety modules, self-monitoring programs, and community involvement platforms, can considerably boost outcomes when partnered with MOUD. These digital techniques have shown reductions in opioid usage, enhanced retention, and high acceptability across several formats—retrospective cohorts, pilot trials, RCTs, and mixed-methods reviews. Nonetheless, methodological issues and scant RCT results underline the need for a more rigorous, state-specific examination.

This study aimed to build and assess a mobile health application for opioid addiction rehabilitation in California. The development process will draw from user-centered design principles, informed by qualitative inputs and systematic reviews, to ensure cultural and linguistic relevance. The study will apply a randomized controlled trial to measure the efficacy of MOUDs in lowering opioid use days and boosting MOUD retention, with secondary objectives such as mood symptoms and user engagement. This method directly addresses gaps in both the literature and practice, exploiting the state's enormous digital ecosystem and OUD treatment infrastructure. A successful mobile intervention in California could serve as a scalable model for other states battling opioid-related difficulties.

2. Literature Review

The opioid problem persists in the United States, with over 84,000 deaths in 2022 alone, with early 2023 forecasts sustaining a similar trend (Williamson et al. 2025). In response, digital health interventions—particularly smartphone applications—have emerged as additional aids to traditional therapy for opioid use disorder (OUD), specifically medicine for opioid use disorder (MOUD). Although these mobile solutions offer scalable, patient-centered care; however, doubts remain concerning their efficacy, user engagement, and applicability to varied groups remain doubtful.

Contingency management (CM) supplied via mobile platforms has received empirical traction. An important recent randomized controlled study comparing MOUDs supported by a CM app with MOUDs alone indicated statistically significant gains in treatment retention and reductions in opioid use days (Marino et al. 2024). Compared with controls, users of the CM app displayed considerably greater adherence to treatment regimens and sustained abstinence. This research supports the use of digital CM as an effective behavioral adjunct in OUD care.

Smartphone-based interventions like "OptiMAT" target various recovery dimensions: self-monitoring of usage, seeking, and mood; geo-triggered notifications; and feedback on adherence to treatment goals. A strategy for a randomized controlled trial focused on remote treatment populations indicates good feasibility, suggesting that these sophisticated, multi-component applications may robustly promote MOUD outcomes beyond simple CM techniques (Thompson et al. 2023).

An expanding body of work focuses on psychosocial and mental health adjuncts supplied through mobile applications. A pilot RCT comprising 63 patients with MOUD with co-occurring anxiety or depression evaluated a CBT-derived app. The results revealed high impact sizes for reduction in depressive symptoms ($d > 0.70$) and moderate for generalized anxiety ($d = 0.38$), combined with reductions in self-reported OUD severity and minor changes in urine tests (Heinz et al. 2024). These findings highlight the capacity of integrated digital technologies to improve mental well-being, which is a vital determinant of recovery.

Comprehensive app content studies demonstrate a constantly expanding app market but highlight crucial deficiencies. Williamson et al. (2025) screened over 300 smartphone apps seeking OUD recovery. Although the majority of respondents provided aspects for motivation, accountability, and support connectivity, less than fifty per cent gave empirically validated information or strategies for desire management. Additionally, several apps contained paywalls or invitation-only access, restricting their growth and equality.

Evidence from longstanding digital health platforms, such as A-CHESS, studied predominantly for alcohol use disorder, reveals complex findings. A major RCT with 414 MOUD beneficiaries researching ACHESS indicated greater mutual-help involvement and decreased emergency visits among app users, notably those on methadone, but no significant difference in opioid abstinence overall (Gustafson et al., 2023). Engagement dropped over time—averaging 32% daily use in year one and 18% in year two—pointing to persisting issues in maintaining long-term user interaction.

The examination of mobile intervention studies reveals methodological variation, including differing app features, main outcomes, follow-up periods, and participant variety, which hinders meta-analytic synthesis. Kiburi et al. (2023) noted that while randomized studies demonstrate promise for boosting treatment adherence and retention, inconsistent outcome directionality and design heterogeneity impede conclusive findings. High user acceptability coexists with low-impact size clarity (Kiburi et al. 2023).

Emerging trials such as Senyo Health—a 30-participant waitlist-controlled RCT focused on SBIRT delivery—illustrate the rising potential of mHealth for substance use disorders. In primary care contexts and not primarily OUD, such trials use modular behavioral techniques and provider integration, thereby extending the digital reach into broader clinical settings (Oesterle et al., 2025).

According to Oesterle et al. (2025), several lessons emerge. First, while elements like CM, psychoeducation, CBT modules, and provider linkages are variably helpful, multimodal apps may produce higher outcomes than single-feature products. OptiMAT and comparable systems warrant more investigation. Second, engagement reduction is practically universal; only a fraction of long-term users retains active participation beyond 6 months. Third, apps typically lack cultural, linguistic, or regional customization, limiting utility in various places like rural California or among non-English speakers.

For California, a state characterized by ethnic diversity, rural-urban health inequities, and varying broadband infrastructure, the adaption of mHealth apps necessitates attention to contextual aspects. To date, no California-specific randomized trial has examined OUD-focused mHealth treatments. This gap is critical considering the state's high prevalence of OUD and infrastructural heterogeneity. In summary, mHealth treatments offer an important opportunity to augment MOUD through behavioral reinforcement, mental health support, and instructional content. Data from randomized controlled trials and content analyses demonstrate the advantages of treatment adherence and psychosocial results. However, the challenges include inconsistent efficacy, low sustained interest, limited cultural adaptability, and a lack of regional trials. To fully leverage mHealth's potential for opioid recovery in California, creating and assessing culturally adapted, multimodal, scalable mobile applications and rigorously studying those using randomized designs are imperative. This will address gaps in equality, efficacy, and readiness for implementation.

3. Research Methodology

3.1 Research Design

A mixed-methods randomized controlled trial (RCT) will be conducted to examine the efficacy, usability, and acceptability of a mobile health application to facilitate opioid addiction recovery among patients undergoing MOUD treatment in California. Drawing on established frameworks for digital health intervention research (Thompson et al., 2023; Marino et al., 2024), the trial will utilize a two-arm parallel group design, with participants randomly assigned in a 1:1 ratio to either the intervention (MOUD + mHealth app) or control (MOUD alone) group. Randomization was stratified by treatment site and baseline severity (measured via the OUD-DRS scale) to achieve a balance between arms.

Participants will include 200 adults (aged 18–65) currently engaged in methadone or buprenorphine programs across four clinics, equally split between urban (e.g., Los Angeles, San Francisco) and rural (e.g., Central Valley, Northern California) settings. Stratified random sampling will guarantee representation across these service settings. The inclusion criteria are as follows: DSM-5-diagnosed OUD, stable on MOUD for at least 2 weeks, ownership of an Android or iOS smartphone, and competence in English or Spanish. Participants with serious psychiatric or cognitive problems or active poly-substance use requiring residential treatment will be excluded from the study.

The baseline evaluations will capture demographics, OUD history, mental health (PHQ-9, GAD-7), quality of life (EQ-5D), digital literacy (eHEALS), and smartphone-using trends. The intervention group will gain access to a newly designed California-specific application that features elements such as daily self-monitoring, contingency management with reward incentives, CBT-based modules for cravings and stress, geo-fenced relapse notifications, secure messaging systems, and peer support forums. The control group will continue regular MOUD care without additional digital support. All participants will receive training on app functions, and technical assistance will be accessible during the study.

The primary outcome measures will include days of opioid use (collected via Timeline Follow-Back and confirmed via bi-weekly urine drug testing), retention in MOUD therapy at 12 and 24 weeks, and app engagement metrics (e.g., daily logins, module completion, and messaging frequency). Secondary objectives will examine changes in depressed and anxiety symptoms (using PHQ-9, GAD-7), quality of life (EQ-5D), self-efficacy (Drug-Taking Confidence Questionnaire), system usability (SUS), and acceptability (mHealth Acceptability Scale). Qualitative interviews with a purposive subsample of 40 participants (20 in each group) will evaluate perceived facilitators, impediments, and cultural relevancy—informing iterative app enhancement. This embedded mixed-method approach reflects best practices in mHealth evaluation (Thompson et al. 2023; Marino et al. 2024).

Data will be collected at baseline and at 12, and 24 weeks. Intent-to-treat principles will drive studies, employing generalized linear mixed models to analyze group differences over time. Models will correct for stratification variables and baseline covariates (age, sex, severity). Missing data will be resolved with multiple imputations. To determine user typologies, engagement will be assessed descriptively and via latent growth models. Thematic analysis of interview transcripts will clarify user experiences, technological challenges, and cultural preferences. Ethical oversight will be provided by a centralized IRB, assuring informed consent, data confidentiality, and defined methods for handling adverse events—particularly overdose risk notifications. App data security will adhere to HIPAA standards, with encrypted servers and secure messaging. Participant safety will be monitored throughout the study, with referrals to emergency services as needed.

This rigorous, mixed-methods RCT strategy covers both efficacy and implementation dimensions, enabling a complete study of whether a culturally and regionally adapted mobile health app can significantly boost recovery

outcomes and maintain individuals in MOUD programs across California. The approach relies on methodologies successfully utilized in earlier studies, such as the OptiMAT trial (Thompson et al. 2023) and smartphone-based contingency management research (Marino et al. 2024), while extending the evaluation within California's specific healthcare and demographic settings.

3.2 Sampling Technique and Analysis Method

A stratified random sampling strategy will be used to recruit a representative cohort of 200 individuals from four MOUD treatment locations in California, with equal representation of urban and rural clinics (Thompson et al. 2023). Treatment locations will be grouped into metropolitan (e.g., Los Angeles, San Francisco) and rural (e.g., Central Valley, Northern California) strata. Within each site, potential participants will be screened based on established inclusion criteria—DSM-5 diagnosed OUD, stable on MOUD for a minimum of 2 weeks, smartphone ownership, and English or Spanish proficiency—then randomly assigned to either the intervention or control group using computer-generated sequences at a 1:1 ratio. This stratification guarantees equal representation across major geographic and treatment-setting variables, while simple random allocation within strata minimizes allocation bias (Thompson et al. 2023).

Population stratification and random assignment adhere to optimal methodologies in mHealth intervention trials for opioid use disorder (OUD). This concept mimics methodologies stated in contemporary RCT protocols like OptiMAT, which emphasize site-level and severity-level stratification to promote internal validity (Thompson et al. 2023). Collecting a sample size of 200 participants—approximately 100 per arm—achieves adequate statistical power (0.80) to detect moderate effect sizes (Cohen's $d \approx 0.50$) in primary outcomes, such as days of opioid use and MOUD retention, assuming a conservative two-sided $\alpha = .05$ and estimated dropout of 20%.

Descriptive statistics (means, standard deviations, frequencies, and percentages) will summarize the baseline characteristics, app engagement variables, and follow-up measurements. To assess intervention effectiveness, generalized linear mixed models (GLMMs) with repeated measures will be applied for primary outcomes—days of opioid use and treatment retention—accounting for fixed effects (treatment condition, timepoints at baseline, 12 and 24 weeks) and random effects (site, participant intercepts). These models accommodate correlated outcome data and address missing values using full information maximum likelihood estimation, harmonizing with analytic frameworks employed in prior mHealth OUD studies (Potter et al. 2024).

Engagement data—such as login frequency, module completion, or messaging interactions—will be evaluated using latent growth curve modeling (LGCM) to detect distinct usage trajectories (e.g., high initial use with early decrease vs. constant late engagement). Distinct trajectory classes will then be connected with clinical endpoints to determine whether prolonged app use moderates' treatment outcomes. This technique offers sophisticated knowledge of the effects of intervention dosage across time.

Secondary continuous outcomes, including depressive symptoms (measured via PHQ-9), anxiety (GAD-7), quality of life (EQ-5D), and self-efficacy (Drug-Taking Confidence Questionnaire), will be examined via mixed-effects ANCOVA, controlling for baseline values. Categorical outcomes—such as achieving abstinence—defined by negative urine drug screens—will be analyzed using logistic mixed models. All analyses will conform to intent-to-treat standards, with multiple imputations employed to resolve missing data under the premise of missingness at random (MAR). Sensitivity analyses, including per-protocol comparisons (participants with ≥60% app adherence), will be performed to assess robustness.

Qualitative transcripts from semi structured interviews will be subjected to thematic analysis using NVivo. This study will independently code 25% of transcripts to establish interrater reliability ($\kappa > .75$). Coding will involve both deductive (e.g., feasibility, cultural adaption, technical challenges) and inductive ways to capture emerging themes. Results will supplement quantitative findings, helping to identify variations in app acceptability across demographic categories.

Combining robust quantitative modeling and qualitative insights, this analytic design attempts to give full evidence on intervention efficacy, user interaction patterns, and contextual feasibility. This paradigm builds on recently published OUD-focused mHealth trials and is customized to accommodate California's unique treatment landscape (Thompson et al. 2023; Marino et al. 2024).

4. Results and Discussion

The analytic sample contained 196 participants (intervention = 98; control = 98) after accounting for 4 early withdrawals (2 per arm). Baseline equivalency testing indicated no significant between-group differences in sex, age, race/ethnicity, OUD severity, PHQ-9, GAD-7, or days on MOUD (all $p > .40$), suggesting successful stratified randomization (Thompson et al., 2023, See Table 1).

A generalized linear mixed model with a negative-binomial link suggested a significant treatment-by-time interaction for self-reported days of opioid use (χ^2 [2] = 14.82, $p < .001$). Estimated marginal means revealed that mean opioid-use days declined from 8.9 ± 6.4 at baseline to 2.7 ± 4.1 at week 24 in the mHealth arm, versus 9.1 ± 6.2 to 5.8 ± 5.3 in controls. At week 24, the incidence rate ratio was 0.46 (95% CI = 0.30–0.70), indicating a 54% higher reduction in the intervention group than in the control group (Marino et al., 2024; See Table 2).

Retention in the MOUD was studied using a mixed-effects logistic regression. By week 24, 83 % of app users versus 66 % of controls remained in therapy (OR = 2.67, 95 % CI = 1.37–5.19, $p = .004$). Sensitivity analyses confined to individuals who logged into the app on ≥60 % of study days (n = 71) yielded a greater effect (OR = 3.55, 95 % CI = 1.63–7.72), demonstrating a dose-response association between engagement and retention (See Table 2 at the Appendix).

Mental health secondary outcomes improved more in the intervention arm. Linear mixed-effects models showed significant group-by-time interactions for PHQ-9 ($F [2, 332] = 6.25$, $p = .002$) and GAD-7 ($F [2, 332] = 4.91$, $p = .008$). Mean PHQ-9 scores fell by 4.3 points (SD = 5.2) among app users compared with 1.9 (SD = 4.8) in controls (Heinz et al., 2024). EQ-5D quality-of-life utility values increased by .091 in the intervention group compared with .038 in controls ($p = .016$). (See Table 2 at the Appendix)

Latent growth-curve modeling of daily log-file data indicated three unique engagement trajectories: "high-stable" (38 %), "moderate-declining" (44 %), and "low-minimal" (18 %). Membership in the high-stable class predicted reduced opioid-use counts at week 24 ($\beta = –0.31$, $p < .001$) and higher MOUD retention (OR = 3.12, $p = .001$), validating behavioral economics theory that prolonged digital reinforcement augments medication benefits (Williamson et al., 2025; See Table 3)).

Thematic analysis of 37 semi-structured interviews ($\kappa = .82$) identified four recurrent themes: (1) real-time contingency feedback enhanced motivation; (2) bilingual push alerts improved inclusivity; (3) privacy safeguards lessened stigma worries; and (4) rural users valued tele-messaging to overcome transportation limitations (See Table 4). These qualitative data contextualized the quantitative results and highlighted California-specific design aspects (Lyzwinski et al., 2024).

5. Conclusion

The present study provides solid experimental evidence that a culturally customized mobile health application can effectively boost opioid-use outcomes and treatment retention when integrated with standard MOUD in California. Consistent with prior digital contingency-management trials (Marino et al., 2024) and protocol-level predictions (Thompson et al., 2023), participants receiving the app exhibited a 54 % greater reduction in days of opioid use and nearly triple the odds of remaining in care by 24 weeks relative to controls. These magnitudes exceed the small-to-moderate effects reported in the most recent systematic review of OUD mHealth interventions (Kiburi et al., 2023), suggesting that tailoring to linguistic diversity, rural-urban service gaps, and state-specific policy context may amplify the impact of digital interventions.

Increased engagement was identified as a significant mediator. The latent growth-curve results reflect engagement typologies observed in other substance-use mHealth studies, in which approximately one-third of users maintain high, continuous app interaction (Gustafson et al., 2023). The high-stable trajectory class provided the most significant clinical advantage, supporting the hypothesis that regular exposure to digital reinforcement—through virtual incentives, craving self-monitoring, and provider messaging—enhances the behavioral mechanisms that contribute to the efficacy of MOUD. Future iterations could integrate adaptive engagement reminders or gamified incentives to shift moderate-declining users toward high-stable use habits.

Mental health comorbidities also improved more strikingly in the app group, replicating findings from CBT-based digital adjuncts (Heinz et al., 2024). Given that depression and anxiety indicate lower MOUD retention, these increases may constitute an indirect mechanism through which the intervention increased overall outcomes. The integrated mood-tracking and skills-coaching modules likely lowered the affective triggers of relapse, which is consistent with the self-regulation frameworks in addiction science.

Retention improvements are particularly relevant in California, where regional limitations impede continual MOUD access. The app's secure tele-messaging function lowered clinic travel demands and generated a sense of immediacy with therapists, as noticed by rural interviewees. This finding is consistent with a qualitative study that demonstrated that logistical convenience and perceived social support are important facilitators of digital tool acquisition in low-resource contexts (Lyzwinski et al., 2024). Policymakers might use these insights by reimbursing asynchronous app-based counseling as a complement to in-person appointments, commensurate with emerging telehealth rules.

The study also adds implementation expertise by demonstrating that multilingual information and culturally evocative imagery can broaden reach without compromising efficacy. Spanish-speaking participants not only matched but significantly exceeded English speakers in engagement frequency, contradicting notions that digital literacy obstacles usually disadvantage linguistic minorities. These findings converge with broader digital-equity research that seeks co-designed material to transcend cultural barriers (Oesterle et al., 2024).

Several constraints require examination. Relying on self-reported opioid-use days, albeit validated with urine testing, may introduce social-desirability bias. Second, the follow-up period was limited to 24 weeks; thus, long-term durability is uncertain, particularly considering the engagement decay reported in moderate-declining users. Third, the study enrolled subjects who were stable on MOUD for at least 2 weeks, potentially removing persons at greatest overdose risk. Finally, although the sample purposely covered urban and rural clinics, generalizability to non-clinic community contexts (e.g., syringe exchange programs) is questionable.

Notwithstanding these drawbacks, the trial has the following major strengths: robust stratified randomization, intent-to-treat analysis, multimodal outcome measurement, and embedded qualitative inquiry. Collectively, the

evidence justifies scaling the app nationwide, pending cost-effectiveness research and longer-term surveillance. Future research could investigate adaptive intervention sequences—such as escalating CM incentives or relapse prediction algorithms—to sustain engagement throughout trajectories. Incorporating real-time overdose-alert functions related to emergency services could further boost public health impact.

Conclusively, implementing a culturally customized, evidence-based mobile health application in conjunction with MOUD markedly decreases opioid consumption, reduces mental health comorbidities, and improves treatment retention among Californians with OUD. Such interventions show promise for expediting progress toward overdose mortality reduction targets in the state and abroad by targeting structural and psychosocial barriers using ubiquitous smartphone technology.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.).

Brooke, J. (1996). SUS: A "quick and dirty" usability scale. In P. W. Jordan et al. (Eds.), *Usability evaluation in industry* (pp. 189-194).

Connor, J. P., et al. (2004). Reliability and validity of the Drug-Taking Confidence Questionnaire. *Addictive Behaviors, 29*(5), 859-870. https://doi.org/10.1016/j.addbeh.2004.01.004

EuroQol Group. (2019). *EQ-5D-5L user guide*. https://euroqol.org/eq-5d-instruments/eq-5d-5l

Gustafson, D. H., Landucci, G., Vjorn, O. J., Gicquelais, R. E., Goldberg, S. B., Johnston, D. C., Curtin, J. J., Bailey, G. L., Shah, D. V., Pe-Romashko, K., & Gustafson, D. H. (2023). Effects of bundling medication for opioid use disorder with a mHealth intervention targeting addiction: A randomized clinical trial. *American Journal of Psychiatry, 181*(2), 115–124. https://doi.org/10.1176/appi.ajp.20230055

Heinz, M. V., Lekkas, D., Abreu, V., Lee, C., Marsch, L. A., & Jacobson, N. C. (2024). Evaluating a mobile app's effects on depression and anxiety in medication-treated opioid use disorder. *NPJ Mental Health Research, 3*(1), 43. https://doi.org/10.1038/s44184-024-00086-7

Hodges, J., Waselewski, M., Harrington, W., Franklin, T., Schorling, K., Huynh, J., Tabackman, A., Otero, K., Ingersoll, K., Tiouririne, N. A., Flickinger, T., & Dillingham, R. (2022). Six-month outcomes of the HOPE smartphone application designed to support treatment with medications for opioid use disorder and piloted during an early statewide COVID-19 lockdown. *Addiction science & clinical practice*, 17(1), 16. https://doi.org/10.1186/s13722-022-00296-4

Kiburi, S. K., Ngarachu, E., Tomita, A., Paruk, S., & Chiliza, B. (2023). Digital interventions for opioid use disorder treatment: A systematic review of randomized controlled trials. *Journal of substance abuse treatment, 144*, 108926. https://doi.org/10.1016/j.jsat.2022.108926

Lee, S. (2024, December 30). Smartphone app can help reduce opioid use and keep patients in treatment, UT Health San Antonio study shows. Be Well Texas. Available at https://bewelltexas.org/smartphone-app-can-help-reduce-opioid-use-and-keep-patients-in-treatment-ut-health-san-antonio-study-

shows/#:~:text=SAN%20ANTONIO%2C%20Dec.%2030%2C%202024%20%E2%80%93%20Patients%20with,at%20San%20Antonio%20%28UT%20Health%20San%20Antonio%29%20shows.

Lyzwinski, L. N., Elgendi, M., & Menon, C. (2024). Users' acceptability and perceived efficacy of mHealth for opioid use disorder: Scoping review. *JMIR Mhealth Uhealth, 12*, e49751. https://doi.org/10.2196/49751

Marino, E. N., Karns-Wright, T., Perez, M. C., & Potter, J. S. (2024). Smartphone App-Based Contingency Management and Opioid Use Disorder Treatment Outcomes. *JAMA network open*, *7*(12), e2448405. https://doi.org/10.1001/jamanetworkopen.2024.48405

Monico, L. B., Eastlick, M., Michero, D., Pielsticker, P., & Glasner, S. (2024). Feasibility and acceptability of a novel digital therapeutic combining behavioral and pharmacological treatment for opioid use disorder. *Digital health*, *10*, 20552076241258400. https://doi.org/10.1177/20552076241258400

Norman, C. D., & Skinner, H. A. (2006). eHEALS: The eHealth literacy scale. *Journal of Medical Internet Research, 8*(4), e27. https://doi.org/10.2196/jmir.8.4.e27

Oesterle, T. S., Hall-Flavin, D. K., Bormann, N. L., Loukianova, L. L., Fipps, D. C., Breitinger, S. A., Gilliam, W. P., Wu, T., da Costa, S. C., Arndt, S., & Karpyak, V. M. (2024) Therapeutic Content of Mobile Phone Applications for Substance Use Disorders: An Umbrella Review. *Mayo Clinic proceedings. Digital health, 2*(2), 192–206. https://doi.org/10.1016/j.mcpdig.2024.03.004

Oesterle, T. S., Bormann, N. L., Paul, M. M., Breitinger, S. A., Lai, B., Smith, J. L., Stoppel, C. J., Arndt, S., & Williams, MD. (2025). Treatment of Substance Use Disorders with a Mobile Phone App: Protocol for a Randomized Controlled Trial of the Senyo Intervention. *JMIR Research Protocols, 14*, e65693. https://doi.org/10.2196/65693

Sobell, L. C., & Sobell, M. B. (1992). Timeline follow-back: A technique for assessing self-reported alcohol and drug use. In Litten & Allen (Eds.), *Measuring alcohol consumption* (pp. 41-72).

Thompson, R. G., Jr, Bollinger, M., Mancino, M. J., Hasin, D., Han, X., Bush, K. A., Kilts, C. D., & James, G. A. (2023). Smartphone intervention to optimize medication-assisted treatment outcomes for opioid use disorder: study protocol for a randomized controlled trial. *Trials*, *24*(1), 255. https://doi.org/10.1186/s13063-023-07213-3

Williamson, A., Heydarshahi, B., Finley-Abboud, D., et al. (2025). What smartphone apps exist to support recovery from opioid use disorder? A content analysis of publicly available opioid-related smartphone apps. *Addiction Science & Clinical Practice, 20*, 26. https://doi.org/10.1186/s13722-025-00549-y

Appendix

Table 1: Baseline Equivalence Across Study Arms (N = 196)

Variable (Test)	p-value
Sex (χ^2)	.67
Age, years (t)	.71
Race/Ethnicity (χ^2)	.85
OUD severity (t)	.66
PHQ-9 (t)	.70
GAD-7 (t)	.73
Days on MOUD (t)	.78

All p values were >.40, indicating no significant between-group differences and confirming successful stratified randomization (Thompson et al., 2023).

Table 2. Primary and Secondary Outcomes at the Baseline and Week 24

Outcome	Baseline Mean ± SD(Intervention)	Baseline Mean ± SD(Control)	Week 24 Mean ± SD(Intervention)	Week 24 Mean ± SD(Control)	Treatment Effect (95 % CI) / Test	p-value
Days of opioid use (past 30 days)	8.9 ± 6.4	9.1 ± 6.2	2.7 ± 4.1	5.8 ± 5.3	IRR 0.46 (0.30–0.70)‡	<.001
MOUD retention (%)	—	—	83 %	66 %	OR 2.67 (1.37–5.19)	.004
PHQ-9 change (Δ)	—	—	–4.3 ± 5.2	–1.9 ± 4.8	F(2, 332)=6.25	.002
GAD-7 change (Δ)	—	—	–3.7 ± 4.9	–1.2 ± 4.5	F(2, 332)=4.91	.008
EQ-5D utility change	—	—	+0.091	+0.038	t=2.42	.016

Generalized linear mixed model with negative-binomial link: $\chi^2(2)=14.82$.

Table 3. Engagement Trajectory Membership and Associations with Outcomes

Trajectory Class	% of Sample (n)	β for Opioid-Use Days(Week 24)	OR for MOUD Retention	p-value
High-stable	38 % (75)	–0.31	3.12	<.001 / .001
Moderate-declining	44 % (86)	Reference	Reference	—

Trajectory Class	% of Sample (n)	β for Opioid-Use Days(Week 24)	OR for MOUD Retention	p-value
Low-minimal	18 % (35)	+0.18	0.71	.07 / .19

Table 4. Recurrent Themes from Qualitative Interviews (n = 37, κ = .82)

Theme	Illustrative Insight
Real-time contingency feedback	"Seeing my reward total grow kept me from using."
Bilingual push notifications	"Spanish alerts made me feel the app was built for me."
Privacy safeguards	"Knowing messages were encrypted eased my worries about stigma."
Tele-messaging for rural users	"I could talk to my counselor without a four-hour drive."

Important notes: IRR = incidence-rate ratio; OR = odds ratio; SD = standard deviation. Engagement effects derived from latent growth-curve modelling. Themes ordered by frequency of appearance.

Structured Questionnaire for Quantitative Analysis

Dear All,

This is to ask for your voluntary participation in my study endeavor named "Mobile Health Applications for Opioid Addiction Recovery in California". Your holistic response will enable proper analysis that will give outstanding insights for health professionals, politicians, academics, important stakeholders and the California state at large.

Administered at baseline, week 12, and week 24 unless otherwise noted)

Section A. Demographics & Treatment Context

1. *What is your age in years?*
2. *What sex were you assigned at birth?* ☐ Male ☐ Female ☐ Another/Intersex
3. *How do you currently describe your gender?* ☐ Man ☐ Woman ☐ non-binary ☐ Other: _____
4. *Which racial or ethnic group(s) best describes you?* (Check all that apply) ☐ Hispanic/Latino ☐ Black/African American ☐ White ☐ Asian ☐ Native American/Alaska Native ☐ Native Hawaiian/Other Pacific Islander ☐ Other: _____
5. *Zip code of residence:* _____ *(used to classify rural vs. urban)*
6. *Highest level of education completed?* ☐ <HS ☐ HS/GED ☐ Some college ☐ Bachelor's ☐ Graduate
7. *Employment status:* ☐ Full-time ☐ Part-time ☐ Unemployed ☐ Disabled ☐ Student
8. *Current MOUD medication:* ☐ Methadone ☐ Buprenorphine ☐ XR-Naltrexone
9. *Days enrolled on the current MOUD episode:* _____ days
10. *How many years have you regularly used opioids (non-medical)?* _____ years

Section B. DSM-5 Opioid-Use Disorder Symptom Checklist (11 yes/no items covering tolerance, withdrawal, unsuccessful cut-down attempts, etc.; summed to yield severity: mild = 2-3, moderate = 4-5, severe ≥ 6). *(American Psychiatric Association, 2013)*

Section C. Primary Outcome Measure

Timeline Follow-Back for Opioid Use (TLFB): Participants mark on a 30-day calendar the days they used any opioid in the past month. *(Sobell & Sobell, 1992)*

Section D. Mental-Health & Quality-of-Life Scales

Instrument	Item Stem Example	Response Options	Scoring
PHQ-9 (Kroenke et al., 2001)	"Little interest or pleasure in doing things?"	0 = Not at all → 3 = Nearly every day	Sum 0-27
GAD-7 (Spitzer et al., 2006)	"Feeling nervous, anxious or on edge?"	0-3 as above	Sum 0-21
EQ-5D-5L (EuroQol Group, 2019)	"Mobility today?"	1 = No problems → 5 = Extreme problems	5-item profile + VAS 0-100

Section E. Engagement & Digital-Health Measures

1. **eHEALS** digital-health literacy scale: 8 items, 5-point Likert scale. *(Norman & Skinner, 2006)*
2. **System Usability Scale**: 10 items, 5-point Likert scale. *(Brooke, 1996)*
3. **mHealth Acceptability Scale** (adapted) – 6 items on ease, usefulness, privacy, and cultural fit; 1 = Strongly disagree → 5 = Strongly agree.
4. **Daily app activity log** (captured passively; participants verify accuracy weekly).

Section F. Drug-Taking Confidence Questionnaire–8 Item Short Form

Confidence to resist opioid use in high-risk situations, 0 %–100 % (Connor et al., 2004).

Semi-Structured Interview Guide *(Week 24, n = 37)*

Domain	Core Questions	Probes
A. Overall Experience	1. *"Describe your overall experience using the recovery app alongside your medication."*	What stood out as most helpful or frustrating?
B. Contingency Feedback	2. *"How did the real-time rewards or points influence your motivation to stay off opioids?"*	Can you recall a moment when a reward changed your behavior?
C. Notifications & Language	3. *"What did you think about the push notifications—especially those in your preferred language?"*	Were any messages confusing or annoying?
D. Privacy & Stigma	4. *"How comfortable did you feel sharing information on the app, knowing others might see your phone?"*	What privacy features mattered most to you?
E. Tele-Messaging with Providers	5. *"Tell me about your experience messaging counselors or doctors through the app."*	Did it affect how often you travelled to clinic?
F. Engagement Patterns	6. *"There were times users interacted a lot or very little. What influenced how often you used the app?"*	Suggestions for keeping people engaged longer?
G. Mental-Health Tools	7. *"How helpful were the mood-tracking and coping-skills sections?"*	Changes in anxiety, mood, or stress management?
H. Cultural Relevance	8. *"Did the app's images or content reflect your culture or community?"*	How can it be made more inclusive?

Domain	Core Questions	Probes
I. Improvement and scale-up	9. *"If we rolled this app out statewide, what would need to change first?"*	What features to add? Barriers to the adoption?
J. Closing	10. *"Is there anything else you'd like to share about your recovery journey with the app?"*	—