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Reducing Risk for Adolescent Substance Misuse with Text-Delivered Counseling to Adolescents and Parents

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ABSTRACT

Background: Text-delivered prevention programs provide unique opportunities to deliver substance use prevention interventions to at-risk populations. *Methods:* A pilot randomized controlled trial was conducted to test the feasibility, acceptability, and preliminary efficacy of a 4-week, automated personalized text-messaging prevention program, designed to reduce risk factors and increase protective factors associated with adolescent substance use and misuse. Sixty-nine adolescents were recruited from a Federally Qualified Health Care clinic and randomized to a text-delivered intervention, or a wait-list control condition. Simultaneously, fifty-two parents of adolescent participants were enrolled into a parenting skills text-delivered intervention. Participants completed a baseline assessment and three follow-up surveys over three-months. Adolescent saliva specimens for drug testing were collected. *Results:* All intervention-allocated adolescents implemented at least one of the text-based counseling recommendations and 79% indicated that they found the texts helpful. Significant intervention effects were found on risk and protective factors for substance misuse. Adolescents in the intervention group reported reduced depression symptoms ($d = −.63$) and anxiety symptoms $(d = −.57)$. Relative to controls, adolescents in the intervention group maintained a higher quality of parental relationship ($d = .41$) and parenting skills ($d = .51$), suggesting a prophylactic effect. Marginal decrease in the odds of positive drug tests were found for youth in intervention group (77.1% decrease, $p=0.07$) but not with controls (54.3% decrease, $p=0.42$,). *Conclusions:* Results provide preliminary evidence in the feasibility, acceptability, and efficacy of targeting risk and protective factors that are implicated in substance use *via* text-delivered interventions for high-risk populations.

Trends in substance use for adolescents and adults vary substantially over time and by specific substance (Lipari & Van Horn, 2017; Monitoring the Future, 2019). Since the late 1990s the United States has been addressing an epidemic of illicit and prescription opioid misuse (POM), overdose and deaths (Dayer et al., 2019). Because of the high rates of mortality due to POM, it has become a focus of many national, state and substance use treatment and prevention efforts. Although adults comprise the majority of POM users, adolescent and young adult POM has also increased during the epidemic (Jones et al., 2019). Because POM is now the leading cause of unintentional injury and death among adolescents and young adults (Hudgins et al., 2019) and early POM use predicts a wide range of other substance use problems, reducing POM among these age groups is also a public health imperative to curb current and future problems (Jones et al., 2019).

Developmentally, youth do not typically initiate substance use with opioids (Mietch, 2015). Results from a recent scoping review on POM among adolescents and young adults revealed that a variety of demographic, individual, and social factors place individuals at an elevated risk for POM (Bonar et al., 2020) including: being female (Fink et al., 2015), lower SES (Vaughn et al., 2016), rural residence (Monnat & Rigg, 2016), peer and parental attitudes (Donaldson et al., 2015), peer use (Nicholson et al., 2016), parenting (Donaldson et al., 2015; Vaughn et al., 2016), substance use generally (Ford & Rigg, 2015), smoking cigarettes or marijuana (Miech et al., 2015), alcohol use and binge drinking (McCabe et al., 2017), and use of sedatives or stimulants (Biggar et al., 2017). Because adolescent or young adult POM is generally preceded by a variety of factors including use of other substances, some have called for programs that target malleable risk and protective factors to reduce substance use generally as an important approach for preventing POM (e.g. Compton et al., 2019). Moreover, scientists recommend that universal approaches, which engage participants regardless of level of risk, demonstrate effects on substance use generally and POM specifically (Crowley et al., 2014).

Preventing substance use and POM are important developmentally because youth who engage in POM tend to have poorer long-term outcomes. In a longitudinal national study, 52.6% of adolescents who engaged in POM as little as three to nine times in their lifetime, reported substance use disorder symptoms (symptoms of alcohol, cannabis, opioid, or other substance use disorder) at age 35 (McCabe et al., 2019). Preventive efforts are warranted when occasional adolescent POM significantly predicts substance use disorder symptoms two decades later. Preventing youth POM is thus critical to stemming substance use disorders in the US and precluding further cost to society.

Malleable risk & protective factors implicated for adolescent substance use and POM

Adolescent substance use and POM has been linked with numerous risk and protective factors. Two key domains of influence include parenting skills and adolescent depression and anxiety symptoms. Each domain exerts direct, indirect, and interactive prospective influences on youth substance use. Parenting skills can be organized into behavioral practices such as involvement with the adolescent, monitoring the adolescent's whereabouts, and communication with the adolescent in general, and specifically about the risk and consequences of substance use. For example, parents who are involved with their adolescent's activities such as homework, as well as providing limits on evening activities outside of the home, reduce the likelihood of adolescent substance use and POM (Vaughn et al., 2012). Parental monitoring, the active process of parents gathering information about where and with whom their youths are spending time, might directly influence substance use (Dishion & McMahon, 1998) or indirectly influence it by affecting the attitudes their adolescents' hold about substances and the peers with whom they spend time (Donaldson et al., 2015). Clear and consistent parental disapproval of POM has been directly linked with less adolescent POM (Egan et al., 2019). The overall quality of the adolescent-parent relationship, such as warmth and closeness, can also reduce risk for POM (Donaldson et al., 2015).

Anxiety and depression among adolescents is implicated in adolescent opioid misuse (U.S. Department of Health & Human Services, 2019). Specifically, feelings of sadness, hopelessness, and depression (Ali et al., 2015; Barnett et al., 2019; Griesler et al., 2019; Osborne et al., 2020) as well as anxiety (Osborne et al., 2020; Welsh et al., 2017) have been associated with POM among adolescents. There is also evidence that adolescent anxiety and depression are associated with family processes of conflict and hostility (Fosco & Lydon-Staley, 2020; Sheeber et al., 2001). Taken together, this research suggests that the adolescent-parent relationship, parenting skills, and anxiety and depression act as important risk and protective factors that influence POM similarly to adolescents' misuse of other substances.

A large number of intervention studies have illustrated that key family factors can be modified for families of adolescents by participating in preventive interventions (Leslie et al., 2016; Van Ryzin et al., 2016). Changing these underlying family risk factors leads to reductions in the likelihood of adolescent substance use and misuse (Kumpfer et al., 2003). There are also effective programs to reduce youth anxiety (Lochman & Wells, 2003) and depression (Gladstone & Beardslee, 2009). Most of the evidence illustrating these effects come from programs that provide person-to-person therapy, counseling, or prevention activities. The potential of these programs have not been fully realized due to lack of integration into systems such as primary health care settings where universal prevention programs can reach large numbers of families (Leslie et al., 2016). Another strategy to increase the reach of effective family programming is through Mobile Health (mHealth) applications. However, less is known whether risk factors and adolescent substance use, including POM, can be reduced with mHealth.

Delivering substance use prevention more efficiently with mobile health (mHealth)

As mobile phone ownership has rapidly increased among Americans in the past decade, mHealth technology approaches are now being incorporated into technology-delivered interventions. Most often, mHealth strategies include the use of mobile phones to deliver intervention or assessment *via* smartphone app or text-messaging. Stand-alone interventions delivered *via* text message appear effective in preventing or reducing youth alcohol and tobacco use, though limited evidence exists for younger adolescents as compared to older adolescents and young adults (Mason et al., 2015). To our knowledge, there are no published text-delivered POM targeting adolescents and parents simultaneously, thus underscoring the need for this research.

Current study

The current study was designed as a small-scale randomized universal prevention trial to evaluate the feasibility, acceptability, and preliminary efficacy of a text-delivered POM prevention intervention in partnership with a Federally Qualified Health Center (FQHC). Feasibility was tested by examining whether this University-Community partnership could successfully integrate new procedures to screen and evaluate eligibility of patients for the research study and successfully recruit a sample to conduct a small randomized controlled trial. We also evaluated the acceptability of the intervention for those patients who participated. Based on our prior studies (Mason et al., 2018a) we set specific benchmarks for acceptability and hypothesized that high rates of participants would access the intervention activities (> 85%) and would report that they liked the intervention (> 70%) and find the activities helpful (> 70%). Finally, we developed and tested a parenting skills intervention to accompany our evidence-based adolescent intervention, Peer Network Counseling-text (Mason et al., 2014, 2016, 2018a, 2018b) as part of the services these adolescents received through our FQHC partner. We are aware of no studies that have tested

a text message-delivered intervention designed specifically to target adolescent POM risk. Based on this review and our past research, we hypothesized that adolescents receiving the texting intervention would show decreased risk factors for POM in the individual domain (depressive and anxiety symptoms) and increased protective factors against POM in the family domain (adolescent-parent relationship, parents improved parenting skills. We also hypothesized that adolescents in the intervention group would reduce substance use including POM compared to the control group. Although there is limited research suggesting that female youth are at elevated risk for POM (Fink et al., 2015) use, even less is known about text-delivered treatment response by biological sex among adolescents. As such, we conducted exploratory analyses testing if sex as a biological variable would moderate the effects of the intervention on risk and protective factors and on substance use or POM.

Methods

Recruitment and setting

All procedures were approved by the Institutional Review Board at the first author's university, and a Certificate of Confidentiality was obtained from the National Institutes of Health. Sixty-nine adolescents were recruited from our community partner settings, either of two Federally Qualified Health Care (FQHC) clinics near the first author's university, and randomized to a text-delivered intervention, or a wait-list control condition. Simultaneously, fifty-two parents of adolescent participants were enrolled into a parenting skills text-delivered intervention. Eligibility requirements for adolescent participants were: 1) age 13 to 18; 2) spoke fluent English, 3) had access to a text-capable phone, 4) did not have a medical condition that would prevent them from participating, and 5) were patients at the FQHC where recruitment took place. Additionally, a parent or legal guardian for each adolescent was offered the opportunity to participate in the study (receive a text-delivered parenting intervention) at the same time as his or her adolescent child. For adolescents who were under 18 years old, a parent or legal guardian provided informed consent for their participation in the study and assent was obtained from the adolescent.

FQHC's operate under the mission of providing primary and behavioral health care services to in underserved areas and to underserved populations regardless of their ability to pay. Clients of FQHCs tend to be those with higher numbers of social risk factors (e.g. low socioeconomic status, disadvantaged neighbor hoods) increasing the likelihood they will experience poor health outcomes such as substance use (National Academies of Sciences et al., 2016). The FQHC partner for this study integrates primary care and behavioral care and treats 71,500 patients annually, with a payer mix of 42% Medicaid, 17% Medicare, 25% self-pay, and 16% commercial insurance. The race/ethnicity makeup is 63.3% Caucasian/White, 16.3% African-American/Black, 15.6% Hispanic/Latino, while 18.2% either did not report or refused to report their ethnicity/race. Recruitment proceeded

between January 2019 and May 2019 and all data collection was completed by August 2019. Recruitment and screening procedures were integrated into the standard clinic processes for families and adolescents by following clinic directors' suggestions for when, where, and how to approach patients. Professional signage and handouts were used that were easily seen and available for staff and patients to inform patients about the study. Research staff were sensitive not to interrupt clinic procedures and utilized private spaces to discuss the study with interested families.

Procedures

Eligibility screening was conducted during recruitment. Once adolescents expressed interest in the study and it was confirmed they were within the age range, a research assistant accompanied the adolescent and his or her parent to a private office within the clinic. After consent/assent was obtained, parents were led back to a waiting area, and then adolescents completed a screening survey on a study laptop to confirm they met all eligibility criteria. Upon eligibility confirmation, a web address to the baseline survey was sent to the adolescent's phone *via* text message. Parents of enrolled adolescents were also invited to participate. For parents who chose to enroll, a link to the parent version of the baseline survey was also sent to the parent's device to complete while in the waiting area. Participation in the study was voluntary for both parents and adolescents.

Upon completion of the baseline survey, adolescent participants were randomized to either an intervention group or a waitlist control group. The intervention group received a text-messaging intervention that began the day after enrollment and lasted four weeks. Each parent participant was assigned to the same condition as his or her adolescent child. Parents who were assigned to the intervention group received a separate text-messaging intervention designed for parents which followed the same schedule as the one for the adolescent participants. Both adolescent and parent participants from both conditions were asked to complete three monthly follow-up surveys. Figure 1 is a CONSORT diagram providing recruitment and treatment details.

As a component of the baseline survey, adolescents provided a saliva drug screen and were instructed on how to upload photos of the results to the survey with their own devices. Adolescents were given a packet that included a saliva drug screen to be completed during the third and final follow-up survey. Participants were asked to upload photos of the drug screen results during the follow-up survey and to mail the completed drug screen back to the study's staff using a stamped self-addressed envelope given to them at enrollment.

Texting interventions

Adolescent intervention

The intervention implemented with adolescents in this study was a modified version of Peer Network Counseling-txt.
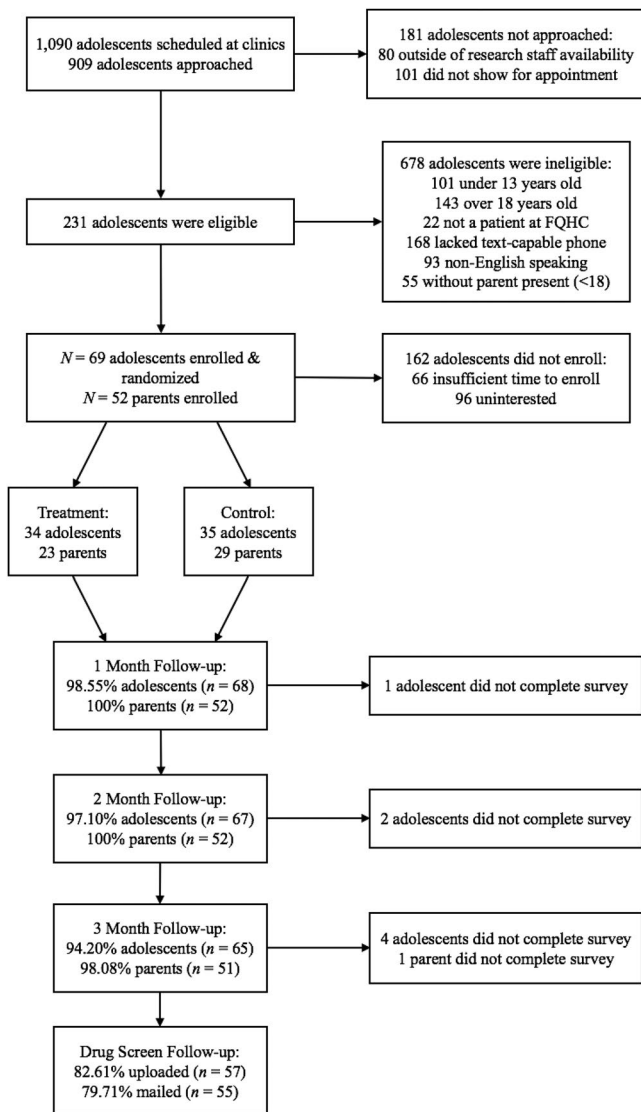
Figure 1. CONSORT diagram of study participants.

PNC-txt is a brief, text-delivered, substance use intervention that uniquely focuses on peer relations as the primary mechanism for behavioral change. PNC-txt has been used successfully as an indicated prevention intervention and as a treatment intervention. PNC-txt has shown efficacy in reducing tobacco use among adolescents (Mason et al., 2016), cannabis use among young adults (Mason et al., 2018a, 2018b), and increasing readiness to reduce hazardous alcohol use among young adults (Mason et al., 2014). PNC-txt applies Motivational Interviewing (Miller & Rollnick, 2013) clinical principles, as well as Social Cognitive Theory factors that operate as regulators and motivators of cognitive, social, and behavioral skills within environmental contexts (Bandura, 1997). PNC-txt activates reflection on their close peers' prosocial and risk-enhancing behaviors and the accompanying places where these behaviors occur, in order to reduce risk and increase protective factors.

Adolescents received personalized, automated, risk reduction and health promotion text-messages every other day during a four-week period following enrollment. The intervention produced 16 days of two-way "conversations,"

Table 1. Adolescent intervention example messages.

Text 1	Hi **Subject Name**! Before we start, please rate your stress right now (0 = no stress − 10 = extreme stress). Text any number from 0 to 10
Text 2	Thanks. Reactions to negative life events can have a big impact on us. Let's review some unsafe or unhealthy ways to handle stress. Text OK
Text 3	Examples of unhealthy ways to deal with stress include using drugs or alcohol, hurting yourself, letting someone hurt you, and acting on impulse.
Text 4	Do you think you use any unsafe or unhealthy ways to deal when you get stressed? 1 = never, 2 = sometimes, 3 = often, or 4 = always. Text the number
Text 5	Thanks! Think about a really stressful week that you've had recently. Now let's think of healthy ways to handle stress. Text OK when ready to continue
Text 6	Now, let's look at some ways to deal with stress again. Pick one to try the next time you feel upset or stressed out. Which skill did you pick? Text 1–10
Text 7	Good! See if you can use **_COPING SKILL_** over the next couple of days to help you manage times when you are upset or in a tough situation.
Text 8	This is about helping you be ready to handle stress when it comes your way. You can text HOW2DEAL at any time, if you want to learn more. Text OK
Text 9	Thanks **SUBJECT NAME**! That ends today's texts. Need more support? Text: BOOST. This is not being read immediately, if this is a crisis call 911

Note. Bolded text indicates tailored content that is imported from participants' baseline survey data. Bolded and italicized text indicates tailored content based on choices made within the text conversations. If the response to Text 1 is an 8 or higher, the participant receives a random supportive message, such as: *"Everyone has tough days, but you are not alone. We hope these texts can help you learn to deal with days like these"* and is reminded to contact 911 for emergencies, before being returned to the intervention. Text 6 is accompanied by an image with a list of coping strategies. Text 7 is accompanied by an animated GIF that represents the coping skill selected in Text 6.

averaging just over 6 per day for a total of 101 intervention texts. Examples include texts about handling stress related to school, peers, and family, self-care, asking for help, and practicing healthy coping skills (e.g. staying active, healthy routines, relaxation skills). Baseline survey data are used to auto-populate and tailor the PNC-txt intervention. Individualized text content was determined based on responses to several measures (substance use, parent relations, peers, stress, coping) from the baseline survey. Participants were instructed to text the word "boost" to receive extra automated supportive messages at any time. Table 1 shows an example of one day within the adolescent intervention. The intervention targets broad risk factors associated with substance use in general. However, the intervention engages adolescents in reflecting on the current opioid epidemic, the associated risks, and how stress may be linked to this risk behavior.

Parenting intervention

Enrolled parents received the Parenting Practice-text (PP-txt) intervention, a four-week texting program created for this study, which mirrored the timing, duration, and format of PNC-txt, but focused on supportive parenting practices to prevent and reduce adolescent substance use. A behavioral-skill developmental framework organized the parenting intervention (Dishion et al., 2016; Patterson et al., 1982). The texts were derived from the extant literature and targeted four evidenced-based parenting practice skills: parent-child

Table 2. Parent intervention example messages.

Text 1	Hi **SUBJECT NAME**. Have you communicated or reinforced your rules recently? Text Yes or NO
Text 2	Now we are going to talk about checking up and communication. Checking up means that you check in to see if your teen is where they are supposed to be.
Text 3	You can text, call, or even stop by. How do you usually check up on your teen? Text back your answer
Text 4	Idea for you: try to think about how you ask questions so your teen feels like talking.
Text 5	Instead of asking "why are you hanging out with Jack?" try "seems like you and Jack are hanging out a lot these days. What do you guys usually do?" Text OK
Text 6	This will help your teen to not feel judged and will tell you more. Show real interest in them and their friends, and try not to show disapproval.
Text 7	We know this is hard! This will help your teen feel more open with you. Text OK
Text 8	Great **SUBJECT NAME**! This ends today's texts. Want more support? Text boost

communication (Stattin & Kerr, 2000), parental monitoring (Cottrell et al., 2007), parental disapproval of substance use (Miller-Day & Kam, 2010), and parental involvement (Furman & Buhrmester, 2009). Table 2 illustrates a single day of text messages within the PP-txt parenting intervention.

Measures

Demographics
Adolescent participants reported their age, sex, and race as part of the initial enrollment survey.

Feasibility and acceptability
We assessed the feasibility of the text-delivered intervention by the frequency of responses to intervention messages and completion of the program, including follow-up surveys. We assessed acceptability by participants' reports of program satisfaction, helpfulness, use of the skills (e.g. relaxation skills, or parenting skills), and privacy of texts.

Anxiety and depression
The Patient Health Questionnaire 4 (PHQ-4) was used to assess past 2-week psychiatric symptomatology among adolescent participants. The PHQ-4 is comprised of four items, two of which represent anxiety symptoms and two that represent symptoms of depression (Khubchandani et al., 2016; Kroenke et al., 2009). Responses range from $0 = not\ at\ all$ to $3 = nearly\ every\ day$, with a total score range of 0 to 12. Higher total scores indicate increased psychiatric symptomatology, with 9 or more being indicative of severe distress. In our study the reliability coefficient value of α =.83 indicated good internal consistency for total scores from the PHQ-4.

Adolescent-parent relationship quality
Relationship quality was assessed with the Parent Relations (Adolescent Report) subscale from the Behavior Assessment System for Children, 2nd Edition, Self-Report of Personality (BASC-2, SRP-A; Reynolds & Kamphaus, 2004). The subscale

is comprised of ten items, with a single true/false item ("I get along well with my parents"), and nine Likert-type items with responses ranging from $0 = never$ to $3 = always$. Items are summed, with lower scores denoting a continuum of mild to moderate disturbed relations with parents, to severe family problems and alienation. Higher scores indicate a positive status of the adolescent-parent relationship including trust, concern, importance, and positive adjustment. Possible scores range from 4 to 28. In our study, the reliability coefficient value of α =.90 indicated very good internal consistency for this scale.

Parenting skills
Parenting skills were assessed with the Parenting Practices Scale (PPS), a 12-item measure created for this study (Mason et al., 2020). We created parent and adolescent versions of the PPS. The PPS was derived from the extant literature and assesses four skills: a) *parent-child communication* (Stattin & Kerr, 2000), parental support and encouragement, asking about things the adolescent likes; b) *parental monitoring* (Cottrell et al., 2007), parent asks about the adolescent's activities, free-time and friends; c) *parental disapproval of substance use* (Miller-Day & Kam, 2010), parental warning about using drugs, discusses rules and consequences of using drugs; d) *parental involvement* (Furman & Buhrmester, 2009), parent attending adolescent's activity, doing things with the adolescent that he/she enjoyed. The PPS parent report significantly correlates with the PPS adolescent report (r = .442, p = 0.01) and the adolescent PPS report significantly correlates with the BASC-Parent Relations-adolescent report (r = .671, p = 0.01). The reliability coefficient value of α =.83 for the parent-report and α =.86 for the adolescent report indicate good internal consistency for total scores. For each measure (adolescent and parent versions) items are summed separately for a total score, with higher scores indicating greater frequency of use of parenting skills.

Adolescent drug use
Adolescent drug use was biochemically assessed with a 10-panel Precision DX Saliva Drug Test swab device. Mouth swabs were administered at enrollment with staff training the adolescent on the procedures. Adolescents self-administered the mouth swabs at the 3-month follow-up survey. Test results provided positive or negative indicators for marijuana, cocaine, amphetamine, opiates, methamphetamine, phencyclidine, barbiturate, benzodiazepine, oxycodone, and buprenorphine. Detection time for these substances using saliva ranges from 12 h (marijuana) to 1 to 3 days (opiates) (Precision OralScan – 10 Panel Saliva, n.d.).

Statistical analyses
PNC-txt intervention effects were tested using linear growth models using SAS PROC MIXED. Baseline levels (intercepts) and monthly rates of change (slopes) in outcomes were estimated as random, differing between each individual, and were allowed to covary. Differences in growth model parameters

(intercept, slope) were estimated by PNC-txt (versus control). To increase the precision of estimated treatment effects, baseline covariates sex, race (white versus non-white), age, and parent enrollment status were included as predictors of outcome intercepts (through main effects of covariates) and slopes (through covariate by month interactions). All covariates were grand-mean centered so that estimated intercepts and slopes represented estimates for the "average" participant. Models were conducted for each "outcome," separate for adolescents and parents. PNC-txt effects on the intercept are interpreted as baseline group differences, and effects on the slope are interpreted as intervention effects on the rate of change over time. Cohen's *d* effect sizes for PNC-txt were calculated from model parameters; these represented the model-estimated difference between PNC-txt and control groups at three months post-intervention, scaled using standard deviation units of the outcome at baseline (Feingold, 2009). Separate analyses were conducted on adolescent and parent measures.

Results

Sample demographics

The sample of 69 adolescents was 67% female with a mean age of 15.2 (SD 1.4). The sample was primarily white 76.8%, 8.7% Hispanic/Latino, 7.2% Black/African American, 5.8% more than one race, and 1.4% other. The sample of 52 parents was 90.4% female with a mean age of 45.6 (SD 8.6). The parent sample was 84.6% white, 11.5% Black/African American, and 3.8% more than one race. Parents education level was 23.1% with a bachelor's degree and 36.5% had private health insurance.

Feasibility and acceptability of texting interventions

The feasibility of implementing this text-based intervention into a community clinic is promising. These implementation procedures allowed for the successful approach and screen of 83% of adolescents who had clinic appointments during the five months of recruitment. Of those not approached for screening, 44% were missed because our research team was not able to staff the clinics and the remaining were missed because they did not show up for their appointments.

Participant responses indicated a high degree of acceptability for the PNC-txt intervention. Adolescents completed 94% of all PNC-txt intervention messages (responded to all messages delivered), and parents completed 98% of all PP-txt messages. All of the adolescents (100%) and 91% of parents reported that they tried the suggestions from the texts in their real-life. They also showed high rates of responsivity to the research procedures including completing the 3-month survey (91% adolescent, 93% parent follow-up rate). Eighty-two percent of adolescents and 96% of parents reported being satisfied with the number of texts delivered, and 79% of the adolescents and 78% of parents indicated that the text conversations were helpful. The most frequently endorsed coping skill by adolescents was stress management (relaxation or exercise), with 79% stating that they learned new ways to deal with stress. Parents reported most frequently trying the 'active listening to their adolescents' parenting skill and 91% reported that the intervention made them think about their relationship with their child. Finally, 91% of adolescents felt that the texts they received were private, compared to 61% of parents.

Intervention effects on Adolescent-Parent relationship, parenting skills, and anxiety and depression

Adolescent outcomes

Table 3 shows growth model results for adolescent reported parent relations, parenting skills, depressive symptoms, and anxiety symptoms. Significant intervention by time effects for each of these four outcomes suggest significant intervention effects on outcome slopes. Figure 2 shows model-estimated trajectories and depicts the findings. First, Panel A shows that adolescents' perceptions of the quality of the parent relationship decreased over time for control group ($p = 0.02$) but not for the interventions group ($p = 0.42$) and Panel B shows a similar trajectory with adolescents' perceptions of their parents' parenting skills, which decreased over time for controls ($p = 0.01$) but not for the intervention group ($p = 0.57$), where this slope slightly increased. Second, Panels C and D show that adolescent depression symptoms increased over time for controls ($p = 0.039$) as did adolescent anxiety symptoms ($p = 0.051$) whereas depression symptoms decreased ($p = 0.06$) as did anxiety symptoms ($p = 0.04$) for the intervention group. Small-to-medium Cohen's *d* effect sizes were observed for the adolescent reported outcomes: parent relations $d = .41$, parenting skills $d = .51$, depression $d = -.63$, and anxiety $d = -.57$.

We tested whether baseline differences and effects over time differed by sex through condition by sex interactions predicting the intercept and condition by time by sex interactions predicting the slope. Although the three-way interactions were not significant, the differences of effect sizes by sex suggests that females appear to be more responsive to the parenting and depression outcomes. Whereas for males, the intervention effect was most strongly associated with a reduction in anxiety symptoms as an outcome. Table 4 shows effect sizes for each of the three outcomes by sex.

Parent outcomes

Parents reported only on parent-adolescent relationship and their positive parenting practices. Analyses indicated that parent-adolescent relations increased in both the intervention and control groups, but neither increase was statistically significant (control: Estimate = 0.07, SE = 0.24, $p = 0.78$; intervention: Estimate = 0.34, SE = 0.27, $p = 0.21$). The rate of increase did not differ between the two groups ($F (1, 150) = 0.57$, $p = 0.45$). Parenting practices also increased in both the parent intervention and control groups, but not significantly (control: Estimate = 0.39, SE = 0.33, $p = 0.24$; intervention: Estimate = 0.51, SE = 0.37, $p = 0.16$). The rate of increase did not differ between the two groups ($F (1, 150) = 0.06$ $p = 0.81$).

Table 3. Growth model results: PNC-txt+P effects on adolescent report of parent relations, parenting skills, depression, and anxiety.

	Parent Relations			Parenting Skills			Depression			Anxiety		
Fixed effects												
Baseline Level	Est	SE	p	Est	SE	p	Est	SE	p	Est	SE	p
Intercept	18.66	1.07	<.0001	24.64	1.21	<.0001	1.67	0.29	<.0001	2.35	0.31	<.0001
PNC-txt+P	−0.70	1.54	0.652	−1.97	1.73	0.260	1.23	0.41	0.004	0.86	0.45	0.059
Female	−1.35	1.63	0.411	−2.90	1.84	0.120	0.25	0.44	0.576	0.48	0.47	0.320
Nonwhite	3.09	1.82	0.095	1.42	2.06	0.494	−0.38	0.49	0.444	−0.05	0.53	0.930
Age	−0.24	0.54	0.655	−0.85	0.61	0.169	0.05	0.14	0.753	0.12	0.16	0.446
Parent Enrolled	2.47	1.89	0.196	3.84	2.14	0.078	0.42	0.51	0.409	0.38	0.55	0.497
Monthly Rate of Change	Est	SE	p	Est	SE	p	Est	SE	p	Est	SE	p
Month	−0.63	0.28	0.027	−1.06	0.43	0.015	0.19	0.09	0.039	0.18	0.09	0.051
PNC-txt+P X Month	0.87	0.41	0.036	1.31	0.63	0.039	−0.37	0.13	0.006	−0.37	0.13	0.006
Female X Month	0.08	0.44	0.851	−0.43	0.68	0.53	0.07	0.14	0.642	−0.19	0.14	0.186
Nonwhite X Month	−1.07	0.50	0.035	0.52	0.77	0.50	−0.03	0.16	0.869	−0.20	0.16	0.227
Age X Month	−0.09	0.15	0.541	0.21	0.23	0.35	0.06	0.05	0.250	0.05	0.05	0.276
Parent Enrolled X Month	−0.58	0.53	0.277	0.14	0.81	0.86	0.03	0.17	0.851	−0.19	0.17	0.269
Random Effects	Est	SE	p	Est	SE	p	Est	SE	p	Est	SE	p
Intercept Variance	34.73	7.08	<.0001	35.93	9.13	<.0001	2.09	0.51	<.0001	2.34	0.49	<.0001
Slope Variance†	1.40	0.52	0.004	2.27	1.26	0.035	0.08	0.06	0.097	--	--	--
Intercept-Slope Covariance†	−0.29	1.45	0.840	2.62	2.48	0.291	0.05	0.13	0.698	--	--	--
Residual Variance	6.67	0.82	<.0001	20.26	2.48	<.0001	1.03	0.13	<.0001	1.41	0.14	<.0001

Note: *Month* refers to the conditional rate of change for participants in the control group, with covariates held at their grand means.
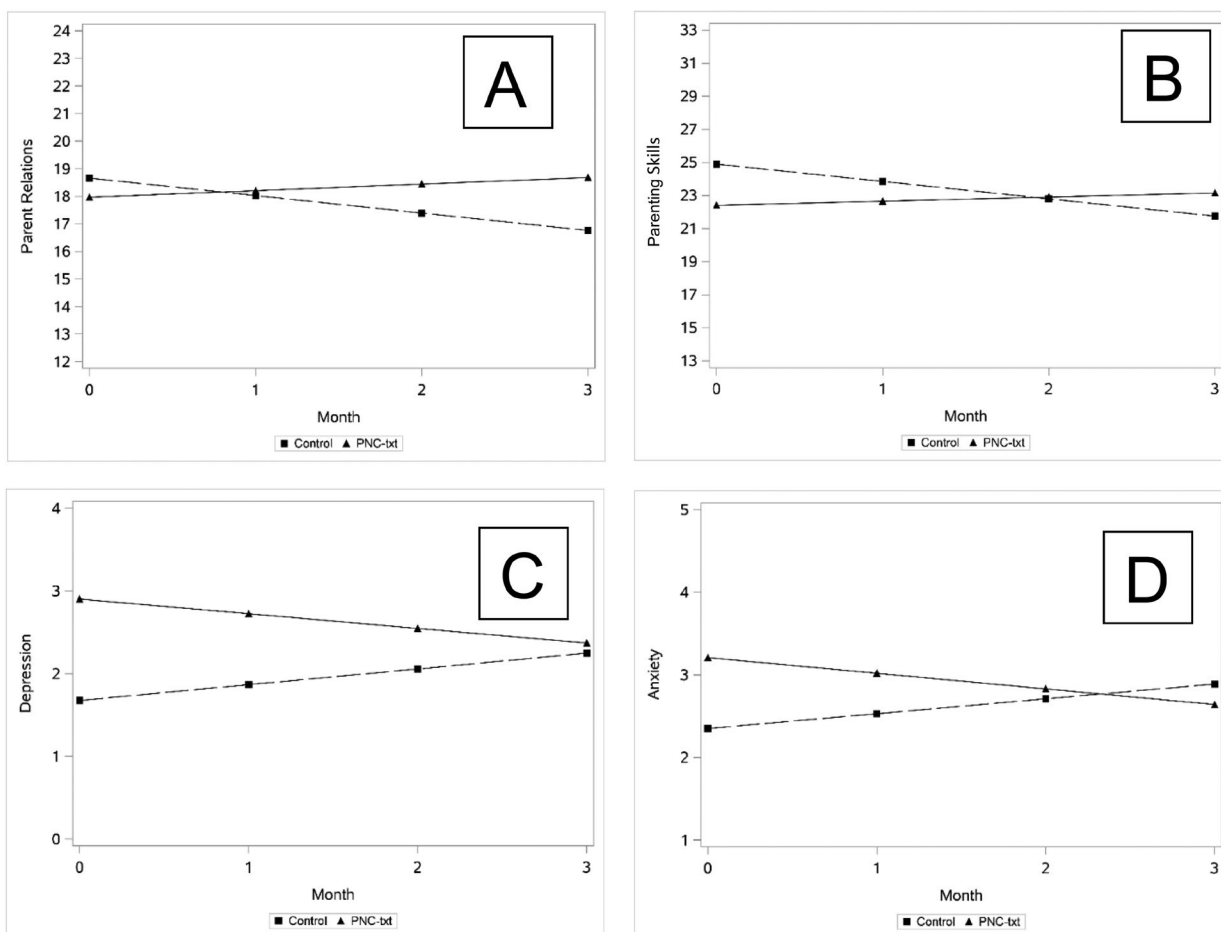†Slope variance and intercept-slope covariance could not be estimated for models with anxiety as the outcome.

Figure 2. Growth model results of adolescent report on Parent Relations, Parenting Skills, Depressive symptoms and Anxiety symptoms over three months by treatment condition.

Texting intervention effects on adolescent drug tests

We explored whether the intervention reduced the occurrence of positive adolescent drug tests across the three-month follow-up period relative to controls. Table 5 provides the results of the saliva drug tests for 10 substances by experimental condition. Examination of means suggested that the probability of a positive drug test decreased more strongly for those in the intervention group (baseline percentage =

Table 4. PNC-txt + P Cohen's d effect sizes by sex.

	Parent Relations	Parenting Skills	Depression	Anxiety
Females	.61	.68	-.84	-.36
Males	-.02	.20	-.17	−1.12

Table 5. Adolescent substance use saliva test results by experimental condition ($n = 69$).

	Baseline		3-Months	
	Control	Treatment	Control	Treatment
Positive Drug Test (any drug)	11.4%	20.6%	5.7%	5.9%
Marijuana	5.7%	11.8%	5.7%	2.9%
Cocaine	0%	2.9%	0%	0%
Amphetamine	8.6%	13.5%	0%	5.9%
Opiate	0%	2.9%	0%	0%
Methamphetamine	0%	2.9%	0%	0%
PCP	0%	2.9%	0%	0%
Barbituates	0%	2.9%	0%	0%
Benzodiazepines	0%	2.9%	0%	0%
Oxycodone	0%	2.9%	0%	0%
Buprenorphine	0%	2.9%	0%	0%

20.6%; 3-month follow-up percentage = 5.9%) versus the control group (baseline = 11.4%; 3-month = 5.7%). Given that only two waves of drug test data were present (baseline and 3 months), we could not estimate random growth models to test whether the percent decrease in the positive drug test rate differed over time between intervention and control groups. Instead, we estimated a logistic regression model with clustered standard errors (accounting for the nesting of baseline and 3-month observations within individuals) testing main effects of month (3-months versus baseline) and intervention (versus control), along with a month by intervention interaction. These models adjusted for main effects of sex, race/ethnicity, parent enrollment, and age (all mean-centered). Percent decrease was calculated as (1 – odds ratio)*100%. Although we found no significant difference in the decrease of substance use between intervention and control youth (intervention by month interaction b = −0.69, $p = 0.58$), we did find that the decrease in the odds of a positive drug test was marginally significant for youth in the intervention group (OR = 0.23, 95% CI: 0.05, 1.13, $p = 0.07$, 77.1% decrease) but not in the control group (OR = 0.46, 95% CI: 0.07, 3.10, $p = 0.42$, 54.3% decrease).

Discussion

The purpose of the current pilot investigation was to test an adolescent substance use and POM risk reduction text-delivered intervention that was comprised of an adolescent and a parenting component. Findings from this pilot study provide guarded encouragement about the potential to reduce risk factors, increase protective factors for adolescent POM, and reduce substance use. These results support previous research supporting integrating family-based interventions within primary healthcare settings (Leslie et al., 2016). Given the small sample size and the low rates of substance use, the marginally statistically significant reduction in the odds of having a positive drug test for the intervention group is encouraging. A strength of this pilot investigation was the use of biochemical verification of drug use versus typical self-report. Because of this, confidence in these results is increased, where these marginally significant reductions of drug use could be interpreted as potentially clinically meaningful when coupled with the other significant findings.

The finding that the intervention reduced anxiety and depression symptoms is also promising as these have been implicated in adolescent substance use in general and opioid misuse specifically. The 4-week texting intervention appears to have produced a medium effect on reducing depression and anxiety symptoms. The intervention program does not explicitly address depression or anxiety; however, the focus on stress reduction, self-care, asking for help, and coping skills (e.g. staying active, healthy routines, relaxation skills) may be associated with the reduction of psychiatric symptoms. The successful reduction of known risk factors for substance use and POM is encouraging given the relative cost compared to traditional counseling and the inherent scalability of text-delivered interventions for at risk adolescents and their parents. While caution is warranted due to the small sample size of this trial, the medium effect sizes on mental health outcomes ($d = .51$ depression, $d = .63$ anxiety) are double the size of internet delivered treatments for youth depression and anxiety $d = .25 - .28$ (Calear & Christensen, 2010). The effect size produced targeting the adolescent-parent relationship quality ($d = .41$) is nearly 3 times the size of internet delivered parenting interventions ($d = .14$) (Spencer et al., 2020). Thus, these comparisons provide encouragement for our text-delivered intervention.

Intervention effects on parenting were mixed, with positive effects on measures from the adolescent perspective, but not on measures from the parents' perspectives. It is not unusual for adolescents and their parents to perceive parenting behaviors differently and to see these perceptions change differently following interventions (Coatsworth et al., 2015). It is also not remarkable that adolescent reports of parenting and parent-adolescent relationship quality decline over time, as the patterns showed in our data (Barber et al., 2005). Our results indicated a protective effect, such that adolescents in the intervention condition reported that their parents' parenting maintained a higher level, while reports among the control condition indicated a decline. Adolescents in the intervention group perceived their parents as engaging in more positive parenting skills such as monitoring, involvement, communication, and substance use disapproval. The strength of this finding is notable, given that we conducted intent-to-treat analyses, meaning adolescents were included in these analyses whether their parents participated in the intervention or not. This is the recommended strategy even though it may *decrease* the likelihood of finding an intervention effect due to individuals in the intervention group not receiving the parent-focused intervention activities.

It may be that the adolescent texting intervention improved the adolescent's perceptions of their parents' positive parenting strategies and their relationship with their parents, which then reduced depression and anxiety symptoms. A large literature exists that supports family relationships and adolescent depression and anxiety (Papini &

Roggman, 1992; Rueter et al.,1999; Sheeber et al., 2001). Taken further, it is plausible that reducing anxiety and depression and improving, even slightly, parent relationship quality, could have reduced substance use, including POM. However, this pathway was not empirically supported with these data, although theoretically, this interpretation is reasonable.

Our second hypothesis that sex as a biological variable would moderate the effects of the intervention was partially supported. While the three-way interaction of time X condition X sex was not statistically significant, the texting program appears to decrease depression symptoms and improve the adolescent-parent relationship quality and parenting skills among females, and reduce anxiety symptoms among males. A test of baseline mean differences among these variables by sex revealed no significant differences. It is unknown from these data why or how the intervention might operate differentially by sex. These findings of potential differences should be examined in a larger, longer trial to understand the possibility of the moderating effects of sex.

Finally, engagement with the intervention was very high for adolescents and for the parents, indicating that the content was acceptable and appropriate. Coupled with this finding was that all of the adolescents tried at least some of the text-delivered health-promoting suggestions, and 91% of the parents tried some of the parenting practice exercises, demonstrating strong engagement with the intervention. Close to 80% either agreed or strongly agreed that the text conversations were helpful, providing confidence in the perceived value of the intervention program. Interestingly, only 61% of parents perceived the texts as private, compared to 91% of the adolescents. This is not entirely unexpected as adolescents are more comfortable and trusting with digital interaction and content relative to older adults. Yet, when asked if they would rather talk to a person versus the texting program, only 30% of parents reported that they would, compared to 26% of the adolescents, suggesting both groups have about the same preference for text-delivered interventions. Taken together, these data indicate that the modality, timing, and content of the intervention is acceptable and appropriate for this sample.

The interpretation of these results should be considered in light of this pilot study's limitations. First, the sample size limits the power to detect findings and could also skew the results. The marginally significant drug test may have been significant with a larger sample. While the use of saliva drug test is a strength of this current study, the time-limits on ability to capture results weakened our ability to capture drug use more broadly. For example, marijuana could only be detected up to 12 h. Second, although participants were randomized into conditions, the baseline difference in biologically measured substance use in the experimental condition was almost twice the control condition. Although these baseline differences were accounted for in our analyses, other variables such as whether youth were receiving other forms of treatment in addition to PNC-txt, or were on medications were not measured in this study. Collecting and accounting for those kinds of variables would help inform future studies and add confidence that the effects were due exclusively to PNC-txt. Given that one of the study weaknesses is small sample size and that this limitation was likely responsible for the random unequal distribution of positive drug tests between conditions at baseline, conclusions regarding treatment effect differences must proceed cautiously. One explanation for the marginal drug test result differences between conditions is a regression to the mean for the treatment condition, whose positive test results were about twice the percentage of the control condition at baseline. Thus, the more frequent positive tests within the treatment condition may have been driven by a few outlier cases which subsequently regressed to the mean at three months post baseline. Third, there was an imbalance in the adolescent-parent groups, where 17 adolescents enrolled into the study without a participating parent. As this was a pilot study, we included all adolescents (parent enrollment was optional), as part of the goal of this project was to test the feasibility of enrolling parents into the study. It is unknown if this difference produced variability in the outcomes as the sample is too small for subgroup analyses. Fourth, the design followed participants for just three months, limiting the ability to assess longer-term variation of outcomes. Fifth, the measure used to assess anxiety and depression was a four-item screening tool and therefore provided limited insight into participant symptomatology for depression and anxiety. However, the PHQ-4 is a well-regarded screening measure, providing confidence within the parameters of its purpose. These limitations are common features of pilot investigations, and as such, do not negate these results. Larger samples, longer follow-ups, and more comprehensive measures will provide more confidence in future results generated from this type of research.

These encouraging results provide preliminary confidence in the feasibility, acceptability, and initial effectiveness of targeting risk and protective factors that implicate opioid misuse *via* a text-delivered intervention. To our knowledge, this is the first text-delivered intervention targeting high-risk youth and parents to reduce adolescent POM. The strong engagement with the intervention, coupled with these promising findings, suggest that text-delivered interventions could be an important component in the development of innovative, multi-prong strategies to prevent POM.

Declaration of interest

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