

## Research Paper

## Fentanyl test strips as an opioid overdose prevention strategy: Findings from a syringe services program in the Southeastern United States

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## ABSTRACT

**Background:** In 2016, the number of overdose deaths involving illicitly-manufactured fentanyl (IMF) surpassed heroin and prescription opioid deaths in the United States for the first time, with IMF-involved overdose deaths increasing more than 500% across 10 states from 2013 to 2016. IMF is an extremely potent synthetic opioid that is regularly mixed with heroin and often sold to unwitting consumers. Community-based organizations have started to distribute fentanyl test strips (FTS) as a strategy to identify IMF in street purchased products. We investigated the association between FTS use and changes in drug use behavior and perceived overdose safety among a community-based sample of people who inject drugs (PWID) in the United States.

**Methods:** Between September–October 2017, a total of 125 PWID completed an online survey about their most recent FTS use in Greensboro, North Carolina. Our first outcome of interest included whether PWID engaged in any of the following changes in drug use behavior after using FTS: used less than usual, administered tester shot, pushed syringe plunger slower than usual, and snorted instead of injected. Our second outcome of interest was whether PWID felt that FTS use made them feel better able to protect themselves from overdose. We conducted bivariate and multivariate analyses to determine the association between FTS use and these two outcomes.

**Results:** Overall, 63% of the sample reported a positive FTS test result and 81% reported using FTS prior to consuming their drugs. For the outcomes, 43% reported a change in drug use behavior and 77% indicated increased perceived overdose safety by using FTS. In multivariable models adjusting for demographic and FTS correlates, PWID with a positive FTS test result had five times the odds of reporting changes in drug use behavior compared to those with a negative result. PWID who used the FTS after drug consumption were 70% less likely to report behavioral changes at subsequent drug consumption compared to those who used it before consumption. PWID who were not existing clients of the syringe services program had four times higher odds than existing clients to report increased overdose safety from using FTS.

**Conclusions:** We found that using FTS and receiving a positive test result was associated with changes in drug use behavior and perceptions of overdose safety. FTS may represent an effective addition to current overdose prevention efforts when included with other evidence-based strategies to prevent opioid overdose and related harm.

## Introduction

The opioid overdose crisis in the United States continues to generate unprecedented levels of mortality. Over 63,000 people died from a drug overdose in 2016, with more than 60% of deaths involving an opioid (Hedegaard et al., 2017). In 2016, the number of overdose deaths involving illicitly-manufactured fentanyl (IMF) surpassed the number of heroin-involved deaths and prescription opioid-involved deaths for the first time, with IMF-involved overdose deaths increasing more than

500% across 10 states from 2013 to 2016 (O'Donnell, Halpin, Mattson, Goldberger, & Gladden, 2017). A recent report published by the Centers for Disease Control and Prevention (CDC) detected IMF in 56% of opioid overdose deaths (O'Donnell, Halpin, et al., 2017), with the highest burden in the Northeast and Midwest regions of the country and rising trends identified in the South and West (Peterson et al., 2016; Tomassoni et al., 2017). Postmortem toxicological reports from opioid overdose decedents have identified new polydrug combinations (e.g., alprazolam + gabapentin + IMF) that suggest the emergence of high-

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risk consumption patterns and complex clinical presentations (Dragovic et al., 2016; Marinetti & Ehlers, 2014).

Fentanyl is a synthetic opioid 50 times more potent by weight than heroin, with a rapid onset of action and relatively short duration of effect. The vast majority of fentanyl overdose deaths since 2013 involve IMF, not diverted prescription fentanyl. Manufactured in clandestine labs outside of the U.S., IMF typically enters the country alongside heroin and other illicit drugs through illicit channels before being sold by itself or used to adulterate heroin (Drug Enforcement Administration, 2017a). IMF includes fentanyl analogs (e.g., carfentanil) that may be purchased on the internet and shipped through international postal services before being distributed throughout regional drug markets in the U.S. (Frank & Pollack, 2017). IMF has also been pressed into counterfeit prescription drugs, with fake versions of Oxy-Contin, Percodan, and Xanax linked to overdose outbreaks in several states (Green & Gilbert, 2016). In addition, IMF has been found on illustrated blotter paper commonly associated with paper tablets of lysergic acid diethylamide (LSD; Drug Enforcement Administration, 2015).

National estimates from the Drug Enforcement Administration show law enforcement seizures of IMF have increased substantially, from 4,697 reports in 2014 to 14,400 in 2015 (O'Donnell, Gladden, & Seth, 2017). This rapid growth in supply has led to increased saturation of IMF in existing and emerging heroin markets while exacerbating the opioid overdose risk environment by introducing a new level of difficulty for consumers as they try to parse out different “heroin” types and discern IMF from heroin (Somerville et al., 2017; Marshall et al., 2017). Due to a heightened risk environment and the urgent need to prevent and treat opioid overdose, several public health strategies established by harm reduction organizations have been implemented in high-burden communities throughout the U.S., including overdose education and naloxone distribution (OEND) programs and Good Samaritan Laws (Lambdin et al., 2018; McClellan et al., 2018; Strang et al., 2012; Walley et al., 2013).

Most recently, fentanyl test strip (FTS) technology has emerged as a drug checking strategy to address the fentanyl crisis. FTS was originally developed as a field immunoassay to screen for the presence of fentanyl in urine, but harm reduction organizations discovered that FTS can also detect fentanyl in illicit drug solutions. This realization has led many harm reduction organizations to distribute FTS to people who consume street opioids as an off-label approach to test street drugs for fentanyl (Harm Reduction Coalition, 2018). One type of FTS technology commonly distributed by harm reductions organizations is manufactured by BTNX, Inc., a Canadian biotechnology company that specializes in drug testing research and development.

A recent report compared BTNX's FTS technology with both Raman Spectroscopy (TruNarc machine) and Fourier-transform infrared spectroscopy (Bruker Alpha machine) to determine FTS's effectiveness for detecting fentanyl's presence (sensitivity) and absence (specificity) in street drug products (Johns Hopkins University, 2018). Among the three technologies, BTNX's FTS performed the best with the lowest detection limit (0.13 mcg/ml) and highest sensitivity (96% and 100%) and specificity (90% and 98%) for fentanyl, in addition to detecting 4-out-of-4 fentanyl analogs (two cases involving acetyl fentanyl and two cases involving furanyl fentanyl). These findings suggest that BTNX's FTS technology is effective and can be used off-label to detect the presence of fentanyl and several fentanyl analogs in street drug products.

Numerous international studies have demonstrated the utility of drug checking services for consumers of illicit drugs (Butterfield et al., 2016; Decorte, 2001; Giné et al., 2017; Harper et al., 2017; Hungerbuehler et al., 2011), especially MDMA testing among club and rave culture (Barratt et al., 2018; Mounteney et al., 2016; Saleemi et al., 2017). A recent study in Rhode Island among young (aged 18–35 years) people who use drugs showed high levels (> 90%) of willingness to use FTS (Krieger et al., 2018). Comparably less is known about whether FTS

use can help facilitate safer drug use behavior and protect against overdose for this population (Prekupec et al., 2017).

The current study investigated behavioral outcomes associated with the off-label use of FTS among a community-based sample of people who inject drugs (PWID). The study was conducted at a harm reduction organization in the southeastern United States that recently started distributing FTS as part of their overdose prevention efforts. Our primary objective was to determine the influence of FTS results on drug use behavior and perceptions of overdose safety. Based on existing literature and our collective fieldwork experience, we hypothesized that PWID who received a positive FTS result would be more likely to change their drug use behavior than those who received a negative result.

## Methods

### Study sample

We administered anonymous online surveys to PWID in Greensboro, North Carolina to examine the association among self-reported FTS results and behaviors and attitudes. The study was conducted in September and October 2017 in collaboration with the Urban Survivors Union (USU), a community-based organization that provides syringe services and OEND programs to PWID. Study recruitment began on International Overdose Awareness Day (August 31, 2017) to publicize the study and maximize enrollment. Initial recruitment involved direct intercept with people receiving services at USU. Informational flyers were also posted at USU and made available for people to disseminate amongst their social networks. PWID interested in study participation visited USU's fixed site where they were referred to study staff for instructions on determining eligibility for the study. Eligibility criteria included being aged 18 years or older, having injected illicit opioids within the past 24 hours, and reporting having ever used FTS to test street drugs.

In the Spring of 2017, USU began distributing BTNX Inc.'s Rapid Response Fentanyl Test Strips as part of their overdose prevention strategy. BTNX FTS is a lateral flow chromatographic immunoassay that qualitatively detects the presence or absence of fentanyl and fentanyl analogs in urine but does not assess concentration levels. Positive and negative results are signified by single and double red lines, respectively (Fig. 1). USU offered FTS to program participants in combination with naloxone and overdose education literature, which included directions for how to use the FTS and a directive to use the strips prior to drug consumption (Asher, 2018; Harm Reduction Coalition, 2018).

Data collection occurred on computers made available at USU's SSP in Greensboro using a secured online data collection platform (SurveyGizmo, Boulder, Colorado). To ensure both anonymity and prevent duplicate responses, we implemented a quality control mechanism that used existing program participants' anonymous program identifiers as their study identification (ID). Study participants who were not already enrolled at USU were assigned a randomly-generated, unique identifier as their study ID. After respondents confirmed their eligibility and provided informed consent, they proceeded to a 20-minute online survey that asked about their most recent FTS use. Upon survey completion and verification by study staff, respondents were provided a \$20 Visa gift card as remuneration. The study protocol was approved through a full review by the institutional review board at RTI International.

### Survey measures

Data were collected using an online survey instrument pertaining to social and demographic characteristics, including age, gender, race/ethnicity, education, marital status, living situation, health insurance status, employment status, and quality of life. In addition, access to transportation was added based upon its identification as one of six key

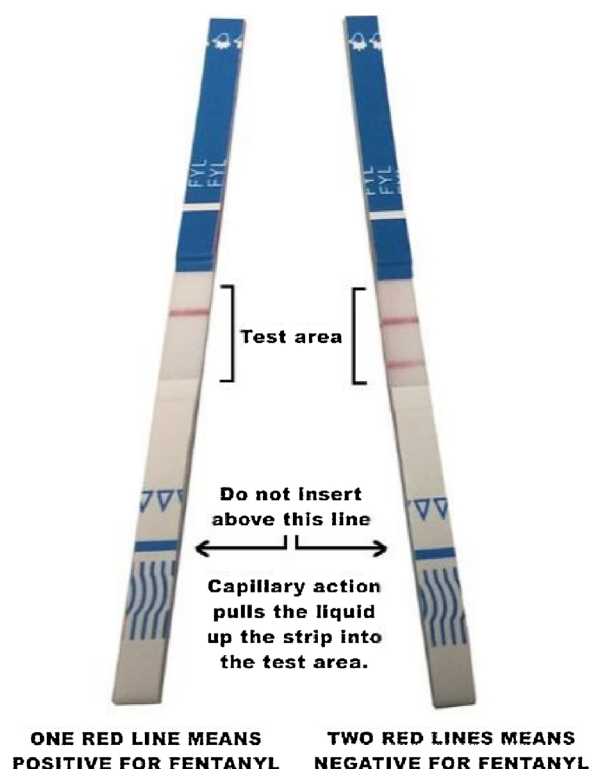


Fig. 1. Rapid Response™ Fentanyl Test Strip (BTNX, Inc.).

variables for rural program access in a recent vulnerability assessment published by the CDC (Van Handel et al., 2016). FTS correlates included ever experiencing an opioid overdose, previous experience with naloxone (e.g., ever administered naloxone during overdose, received naloxone training), SSP utilization, purposively seeking fentanyl, FTS usage before or after drug consumption, and the FTS result from last test.

Participants were instructed to report on their behavior and perception as it related to the most recent FTS use. Several a priori measures of safer drug use behavior were identified by extensive community-based field work with PWID and further confirmed by discussions with key harm reduction stakeholders. Four safer drug use behaviors were combined to make a generalized drug use behavior variable (any behavior vs none): used less drug than usual; pushed syringe plunger slower than usual; administered tester shot; and snorted instead of injected. Of note, two other safer drug use behaviors—threw away the drugs ( $n = 0$ , 0%) and staggered drug use with injection partner ( $n = 1$ , 1.6%)—were included on the survey, but due to sparseness, were not included in the generalized drug use behavior variable. Perceived overdose safety was assessed by asking participants, “Does using FTS make you feel better able to protect yourself from overdose?” (yes/no).

### Statistical analysis

Descriptive statistics were calculated for demographics, FTS correlates, and the study outcomes. We employed a stepwise process to arrive at a parsimonious set of covariates for the final multivariable models (Hosmer & Lemeshow, 2000). First, we conducted bivariate analyses to determine significant associations between demographics and FTS correlates with changes in drug use behavior and perceived overdose safety using the  $\chi^2$  statistic, or Fisher’s exact test in instances of small cell sizes. Variables that were significant at the  $P < 0.20$  level in the bivariate analyses were then included in multivariable logistic regression models. We used a backward selection process to retain covariates that were significantly associated with drug use behavior and perceived overdose safety at the  $P < 0.05$  level. Firth’s penalized

**Table 1**  
Characteristics of Survey Respondents: Greensboro, NC, United States, September–October 2017.

Characteristics		Overall (N = 125)	
		n (%)	
Gender	Female	55	(44.0)
	Male	70	(56.0)
Age	20–29	28	(22.4)
	30–39	59	(47.2)
	40+	38	(30.4)
Race	NH White	97	(77.6)
	NH Black	15	(12.0)
	Other <sup>a</sup>	13	(10.4)
Marital Status	Single	41	(32.8)
	Married/Partnership	45	(36.0)
	Separated/Divorced	39	(31.2)
Education	< College	55	(44.0)
	Some College	40	(32.0)
	Tech/College Graduate	30	(24.0)
Living Situation	Home/Apartment	87	(69.6)
	Shelter/Halfway House	13	(10.4)
	Park/Public Place	10	(8.0)
	Friends/Family	15	(12.0)
Employment Status	FT/PT	52	(41.6)
	Unemployed	61	(48.8)
	Retired/Disabled	12	(9.6)
Health Insurance Status	No	71	(56.8)
	Yes	54	(43.2)
Car Available to Drive	No	52	(41.6)
	Yes	73	(58.4)
Quality of Life	Poor/Fair	39	(31.2)
	Good/Excellent	86	(68.8)
Lifetime Overdose	No	65	(52.0)
	Yes	60	(48.0)
Naloxone Experience <sup>b</sup>	No	22	(30.2)
	Yes	103	(82.4)
SSP Client	No	68	(54.4)
	Yes	57	(45.6)
Wanted Fentanyl	No	86	(68.8)
	Yes	39	(31.2)
FTS Usage	Before	101	(80.8)
	After	24	(19.2)
FTS Result	Negative	46	(36.8)
	Positive	79	(63.2)

Abbreviations: NH, non-Hispanic; HS/GED, high school/general equivalency degree; Tech, technical school; FT/PT, full-time/part-time; SSP, syringe services program.

<sup>a</sup> Other races include Hispanic, Asian American, Pacific Islander, Native American, Alaska Native, and Multiracial.

<sup>b</sup> Naloxone experience includes “ever having administered naloxone to another person” or “ever having received training to administer naloxone”.

likelihood method was used to estimate the final models to address issues of separation and bias of the parameter estimates due to small sample sizes (Greenland & Mansournia, 2015). This computed adjusted odds ratios (aOR) and 95% confidence intervals (CI) for the demographics and FTS correlates associated with the outcomes. To test the robustness of our findings, we conducted a sensitivity analysis that

modeled associations between demographics and FTS correlates with changes in drug use behavior and perceived overdose safety only among those PWID who reported using FTS prior to drug consumption ( $n = 101$ ). Stata version 15.1 was used to execute all analyses.

## Results

A total of 129 PWID completed the online survey. Respondents who reported an uncertain FTS result ( $n = 4$ ) were excluded from analyses. Of the remaining 125 respondents, 56% were male, 70% were 20–39 years old, 78% were white, 24% were college or technical school graduates, 70% lived in a home/house, and 49% were unemployed (Table 1). Nearly half of the sample (48%) reported having experienced an overdose in their lifetime, while 82% reported previous experience with naloxone. More than three quarters of the sample (81%) reported using FTS before drug consumption and nearly one-third (31%) reported seeking fentanyl when performing the FTS test. Approximately two-thirds (63%) of the FTS results at last use were positive.

For the study outcomes overall, 43% of the sample reported changes in drug use behavior and 77% indicated that FTS increased their perceived overdose safety. Using less drug than usual was the most commonly reported change in drug use behavior (32%) followed by performing a tester shot (17%), snorting instead of injecting (10%), and pushing the plunger more slowly (9%). Based on the bivariate analyses, marital status, education, employment status, health insurance, naloxone experience, FTS usage, and FTS result were retained for further analysis with changes in drug use behavior, while age, race, employment status, and SSP client status were retained for perceived overdose safety.

In the final multivariable models (Table 2), unemployed PWID had lower odds of reporting changes in drug use behavior compared to employed PWID ( $aOR = 0.29$ , 95% CI = 0.13–0.66) and PWID who used FTS after drug consumption also had lower odds of changing drug use behavior compared to PWID who used FTS before consumption ( $aOR = 0.33$ , 95% CI = 0.11–0.95). PWID reporting a positive FTS result had higher odds than those with a negative result to report changes in drug use behavior ( $aOR = 5.08$ , 95% CI = 2.12–12.17). PWID aged 40 years and older had higher odds than people aged 20–29 years to report perceived overdose safety ( $aOR = 3.98$ , 95% CI = 1.18–13.40). Non-SSP clients had higher odds than existing clients to report increased perceived overdose safety ( $aOR = 4.06$ , 95% CI = 1.63–10.13).

The sensitivity analysis of PWID who used FTS before drug consumption ( $N = 101$ ) yielded highly comparable results to the analysis of the full sample ( $N = 125$ ). Among the subsample of 101 PWID, respondents who reported a positive FTS result had increased odds of changing their drug use behavior compared to respondents with negative FTS results ( $aOR = 4.88$ , 95% CI = 1.91–12.46); unemployed PWID had lower odds of reporting changes in drug use behavior compared to employed PWID ( $aOR = 0.21$ , 95% CI = 0.09–0.55); PWID aged > 40 years had higher odds than those aged 20–29 years reporting increased overdose safety ( $aOR = 4.03$ , 95% CI = 1.08–15.02); and non-SSP clients had higher odds than existing clients to report increased overdose safety ( $aOR = 4.51$ , 95% CI = 1.58–12.88).

## Discussion

This study examined the off-label use of FTS technology by PWID and its effect on changes in drug use behavior and perceptions of overdose risk. Of 125 PWID, nearly two-thirds (63%) reported a positive FTS result from their most recent use. PWID who reported positive FTS results had five times higher odds of changing their drug use behavior compared to those with negative results. Although we found no statistically significant association between FTS results and perceptions of overdose risk, a high percentage of respondents (77%) indicated that FTS made them feel more able to protect themselves from overdose.

In contrast to reports claiming that “opioid addicts” lack impulse

control and are unable to make healthy decisions (Grant et al., 2000; Jones et al., 2012; Volkow & Fowler, 2000), PWID’s capacity to make safer drug use decisions when confronted with test results has been well documented (Bandura, 1990; Celentano et al., 2002; Weinstein, 1989). One example consistent with our findings comes from the hepatitis C (HCV) literature and involves injection equipment serosorting: a disease prevention strategy whereby PWID choose injection partners based on disease status (e.g., HCV+) to reduce infectious disease transmission (Smith et al., 2013; van den Boom et al., 2014). In a national study of 9,690 PWID, Smith et al. (2013) found that PWID who received HCV antibody test results and knew their anti-HCV status were more likely than those with an unknown HCV status to engage in safer injection behaviors (e.g., sharing injection equipment only with partners of concordant disease status).

Our study employs the logic of serosorting to situate “drug checking” with FTS as a test that can influence PWID’s decision to practice safer drug use behaviors based on the result. In the current analysis, PWID who reported a positive test result at last use were significantly more likely to change drug use behavior compared to those with a negative test result ( $aOR = 5.1$ , 95% CI = 2.1–12.2). Like serosorting, this finding provides additional evidence that PWID, when receiving test results indicating potential harm, can change how they inject drugs to prevent adverse health outcomes.

Another notable finding is that over three-quarters of our sample (81%) reported using FTS to test their drugs prior to consuming them. This contrasts with a recent Canadian study that found only 38% of PWID used FTS before consumption (Lysyshyn et al., 2017). As our study found that respondents who used FTS after consumption had lower odds of reporting changes in drug use behavior, it is possible that discrepancies between studies emerged due to the Canadian study recruiting PWID from a supervised consumption site (SCS). SCSs are staffed by health professionals and PWID may be less motivated to use FTS before consuming street-purchased opioids because they are using them in a safe environment (Kennedy et al., 2018; Kerr et al., 2017; Kral & Davidson, 2017). In the absence of SCSs, the high percentage of FTS use before consumption in the current study suggests that PWID are willing to use FTS as an added strategy to protect against fentanyl overdose and preempt the need for emergency interventions (e.g., naloxone, EMS, acute hospitalization).

The impact of FTS distribution on service utilization is also noteworthy. Slightly over half of our sample (54%) were non-SSP participants, and this group had four times higher odds than existing SSP clients to report FTS increased overdose safety. Studies in the U.S. show that SSPs provide direct harm reduction services to only a small proportion of PWID in a given community or locality (Lorvick et al., 2006; Riley et al., 2010). Results from this study provide evidence that FTS distribution may represent a cost-effective strategy to increase program participation among PWID not currently utilizing harm reduction services in their community.

Nearly one-third (31%) of our study sample reported wanting fentanyl when testing their most recently purchased street drugs. This finding is consistent with another study that found 26% of respondents ( $N = 256$ ) reported their preference for fentanyl (Johns Hopkins University, 2018). Ethnographic research suggests that recent shifts in illicit opioid preferences may be a function of the specific psychoactive effects associated with fentanyl (Ciccarone et al., 2017), such as a stronger “rush” compared to heroin (Armenian et al., 2018). Increased preference for fentanyl may also reflect IMF’s growing saturation in illicit drug markets and associated increases in (witting and unwitting) fentanyl exposure that can result in exacerbated physical dependence and greater tolerance among PWID (Cicero, Ellis, & Kasper, 2017; Helander, Backberg, Signell, & Beck, 2017; Marshall et al., 2017; Somerville et al., 2017). Together, these findings may represent a growing proportion of PWID who prefer IMF and IMF-adulterated heroin over heroin alone.

Further complicating fatal overdose risk are recent reviews



**Table 2**  
Multivariable Logistic Regression Models of Associations with Changed Drug Use Behavior and Perceived Overdose Safety.

Correlates		Changed Drug Use Behavior			Perceived Overdose Safety		
		Prevalence		Adjusted <sup>a</sup>	Prevalence		Adjusted <sup>a</sup>
		n (%)		aOR (95% CI)	n (%)		aOR (95% CI)
Gender							
	Female	27	(49.1)	—	42	(76.4)	—
	Male	27	(38.6)	—	54	(77.1)	—
Age							
	20–29	12	(42.9)	—	18	(64.3)	1.00
	30–39	23	(39.0)	—	46	(78.0)	2.42
	40 +	19	(50.0)	—	32	(84.2)	3.98
Race <sup>b</sup>							(0.86–6.83)
	NH White	41	(42.3)	—	75	(77.3)	—
	NH Black	8	(53.3)	—	14	(93.3)	—
	Other	5	(38.5)	—	7	(53.8)	—
Marital Status							
	Single	12	(29.3)	—	30	(73.2)	—
	Married/Partnership	22	(48.9)	—	38	(84.4)	—
	Separated/Divorced	20	(51.3)	—	28	(71.8)	—
Education							
	< College	22	(40.0)	—	43	(78.2)	—
	Some College	14	(35.0)	—	31	(77.5)	—
	Tech/College Graduate	18	(60.0)	—	22	(73.3)	—
Living Situation							
	Home/Apartment	40	(46.0)	—	64	(73.6)	—
	Shelter/Halfway House	5	(38.5)	—	11	(84.6)	—
	Park/Public Place	2	(20.0)	—	9	(90.0)	—
	Friends/Family	7	(46.7)	—	12	(80.0)	—
Employment Status							
	FT/PT	31	(59.6)	1.00	36	(69.2)	—
	Unemployed	18	(29.5)	0.29	48	(78.7)	—
	Retired/Disabled	5	(41.7)	0.63	12	(100.0)	—
Health Insurance Status							
	No	27	(38.0)	—	57	(80.3)	—
	Yes	27	(50.0)	—	39	(72.2)	—
Car Available to Drive							
	No	21	(40.4)	—	39	(75.0)	—
	Yes	33	(45.2)	—	57	(78.1)	—
Quality of Life							
	Poor/Fair	17	(43.6)	—	28	(71.8)	—
	Good/Excellent	37	(43.0)	—	68	(79.1)	—
Lifetime Overdose							
	No	31	(47.7)	—	47	(72.3)	—
	Yes	23	(38.3)	—	49	(81.7)	—
Naloxone Experience <sup>c</sup>							
	No	5	(22.7)	—	18	(81.8)	—
	Yes	49	(47.6)	—	78	(75.7)	—
SSP Client							
	No	27	(39.7)	—	59	(86.8)	4.06
	Yes	27	(47.4)	—	37	(64.9)	1.00
Wanted Fentanyl							(1.63–10.13)
	No	35	(40.7)	—	67	(77.9)	—
	Yes	19	(48.7)	—	29	(74.4)	—
FTS Usage							
	Before Drug Consumption	48	(47.5)	1.00	76	(75.2)	—
	After Drug Consumption	6	(25.0)	0.33	20	(83.3)	—
FTS Result							
	Negative	10	(21.7)	1.00	36	(78.3)	—
	Positive	44	(55.7)	5.08	60	(76.0)	—

Abbreviations: NH, non-Hispanic; HS/GED, high school/general equivalency degree; Tech; technical school; FT/PT, full-time/part-time; SSP, syringe services program.

<sup>a</sup> The adjusted models retained covariates that achieved significance at the  $P < 0.05$  level using a backward stepwise procedure.

<sup>b</sup> Other races included Hispanic, Asian American, Pacific Islander, Native American, Alaska Native, and Multiracial.

<sup>c</sup> Naloxone experience includes “ever having administered naloxone to another person” or “ever having received training on how to administer naloxone.”

identifying strong links between economic instability and “deaths of despair” (i.e., deaths from drug overdose, alcohol-related disease, and suicide) in states hard hit by the opioid epidemic (Case & Deaton, 2017; Diez Roux, 2017; Rudd et al., 2016; Zibbell et al., 2017). Our study found that unemployed PWID had lower odds of reporting changes in drug use behavior compared with employed PWID. This finding highlights the impact economic instability exerts on drug use behavior and

overdose risk, especially among PWID who experience homelessness, unemployment, incarceration, eviction, and residential transience (Galea & Vlahov, 2002). These “root” causes of the ongoing opioid crisis need further exploration (Dasgupta et al., 2018). Targeted outreach efforts, tailored interventions, and referral to specialty services are necessary to provide supplemental support for economically disadvantaged PWID.

The use of FTS as a primary overdose prevention strategy is gaining traction and rapidly becoming a component of harm reduction programs in the U.S. At present, however, there is a paucity of evidence on their safety and efficacy, and numerous questions remain as to whether their use can indeed reduce overdose risk. Qualitative research (Marshall et al., 2017; Somerville et al., 2017), including rapid assessment ethnography (Ciccarone, 2017), can serve as key supports of implementation science when examining drug checking technologies (Barratt et al., 2018). Further studies that investigate attitudes and risk-reduction behaviors associated with FTS use, including barriers to behavioral change, would also benefit from direct observation in real world settings. For example, field research can aid in studying the correlation between consumer perceptions and discernment of fentanyl with FTS detection alongside gold standard gas/liquid chromatography coupled with mass spectrometry. With reports of fentanyl increasingly being detected in non-opioid drugs like cocaine and methamphetamine (Marinetti & Ehlers, 2014; Seth et al., 2018), clinical and toxicological studies are needed to address the issue of fentanyl testing in different drug classes or different source-forms of heroin (e.g., black tar).

### Limitations

These results should be considered in light of several potential limitations. The generalizability of this study is limited, given that data were from just one community in the southeastern U.S. According to the Drug Enforcement Administration, IMF is more prevalent in Greensboro, NC and other states east of the Mississippi River, regions where heroin powder is dominant and can be more easily mixed with IMF (also a powder), compared to western states like California, New Mexico and Texas where black tar heroin is dominant and more difficult to adulterate with IMF (Drug Enforcement Administration, 2017b). The small sample size limited our ability to derive more precise estimates in the multivariable analyses, although stepwise and sample size penalization procedures improved model parsimony. Limited sample size also precluded a more thorough examination of FTS use with the four changes in drug use behaviors. Because the survey was taken anonymously, it is possible that some respondents could have participated twice and double counted in the sample, particularly persons not already enrolled at USU and unfamiliar to SSP staff. We suspect subject duplication was minimal, however, given the short time frame of the study (two months) and its rigorous, in-person enrollment procedures. In addition, a small proportion of the total sample (3%) reported an uncertain FTS result, a finding comparable to other recent FTS studies (Harm Reduction Coalition, 2018; Health Canada, 2017; Johns Hopkins University, 2018). Our study suggests, however, that the effects of FTS use on drug use behavior outweigh the very small likelihood of an uncertain result. As the general population is still encouraged to use other common types of health protections (e.g., condoms, over-the-counter pregnancy tests) despite being subject to diagnostic error or improper use, the public health message that PWID not use FTS and assume that all street drugs are tainted with IMF may be counter-productive regarding informed decision-making and maintaining an internal locus of control (Celentano et al., 2002; Mitchell et al., 2017). Larger prospective studies are now needed to further evaluate patterns of FTS use and the types of changes in drug use behavior that can lead to reductions in opioid overdose, including the need to develop strategies in situations of product uncertainty.

The current study suggests that FTS use has the potential to facilitate changes in drug use behavior among PWID, but the question as to whether FTS can lead to reductions in overdose was beyond the study's scope and requires further investigation. Nevertheless, the need for more evidence should not prevent community-based organizations and public health agencies from distributing FTS as part of a comprehensive overdose prevention strategy. When seen in this light, FTS can follow the path of syringe exchange and lay naloxone distribution, interventions initially developed by harm reduction activists and organizations

before adequate evidence was available and prior to being endorsed by state and federal public health agencies. A recent commentary recommends a similar approach for FTS, echoing the importance of additional research and the need to provide FTS within a package of evidence-based harm reduction services (McGowan, Harris, Platt, Hope, & Rhodes, 2018). In addition to FTS, there remains a need to evaluate other types of drug checking technologies, including portable chromatography and spectroscopy devices that can be utilized onsite at SSPs and SCSs, or through community-based drop-off laboratories and mail order tests that provide more comprehensive drug panels. Given an increasingly lethal fentanyl risk environment, FTS technology represents a low-cost and timely strategy that can inform evidence-based overdose prevention and provide the foundation for developing safer drug use practices for PWID.

### Contributors

Jon. E. Zibbell, Nicholas C. Peiper, Dan Ciccarone, and Louise B. Vincent originated the idea and design for this article. Nicholas C. Peiper, Sarah Duhart Clarke, and Alex H. Kral analyzed the data. Nicholas C. Peiper and Sarah Duhart Clarke created the figures and tables. Nicholas C. Peiper, Jon E. Zibbell, Sarah Duhart Clarke, and Dan Ciccarone conducted literature searches and wrote the article. This manuscript has been approved by all authors and is not being reviewed or considered for publication at another journal.

### Conflict of interest

The authors declare no conflicts of interest.

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