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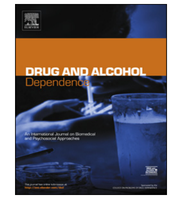

Full length article

A comparison of the utility of urine- and hair testing in detecting self-reported drug use among young adult opioid users

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A R T I C L E I N F O

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A B S T R A C T

Background: Biological testing can be used to validate or detect underreported drug use. Since hair testing is increasingly used in survey research, we examined how the utility of hair testing compares to a more common method—urine testing.
Methods: 532 adults (ages 18–29) reporting past-month heroin use and/or nonmedical prescription opioid use were surveyed about past-month use of various drugs. Participants were urine-tested and the majority (79.3%) provided a hair sample for analysis. We examined the utility of urine vs. hair-testing in detecting past-month use of various drugs.
Results: Compared to hair testing, urine testing was able to confirm higher proportions of self-reported use of heroin/opioids (85.5% vs. 80.9%), marijuana (73.9% vs. 22.9%), benzodiazepines (51.3% vs. 15.1%), and methadone (77.0% vs. 48.7%), while hair testing was more likely to detect reported cocaine use (66.3% vs. 48.0%) ($Ps < .01$). Compared to hair testing, urine testing was more likely to detect unreported use of marijuana (11.3% vs. 0.9%), and benzodiazepines (14.4% vs. 5.4%), and hair testing was more likely to detect unreported use of cocaine (27.0% vs. 5.8%) and oxycodone (19.7% vs. 1.4%) ($Ps < .001$). When added to urine testing, hair testing increased detection of reported and non-reported use of cocaine and oxycodone ranging from 14 to 22%.
Conclusions: While hair testing is efficacious in detecting drug use in wide window periods (e.g., past-year use), it is less efficacious than urine testing when testing for past-month use of select drugs among opiate/opioid users. However, hair testing is particularly efficacious in detecting unreported use of cocaine and/or oxycodone.

1. Introduction

Owing to practicality and cost-efficiency, self-report through survey methods has been the most common means of assessing drug use prevalence in epidemiological research. However, not all survey respondents provide accurate information regarding drug use, and numerous studies have shown that self-report often results in significant underreporting of use of various drugs compared to biologic tests (Colon et al., 2001; Delaney-Black et al., 2010; Fendrich et al., 1999, 2004b; Grekin et al., 2010; Gryczynski et al., 2014; Ledgerwood et al., 2008). Indeed, biological testing is among the most accurate means of measuring recent drug use, though epidemiologic survey researchers have generally not incorporated biological testing. Still, there may be potential value in employing biologic testings as adjuncts to such surveys. Aside from allowing us to "correct" drug use estimates based on self-report (Colón et al., 2010; Colon et al., 2001; Fendrich et al., 2008), data from adjunctive biologic drug testing can also provide greater insight into the nature of drug use underreporting, thereby facilitating potential improvements in survey design and implementation.

Hair testing and urine testing are two means of biologically testing bodily specimens for drug use. Urine tests are common in drug use studies because of accuracy, reliability, low implementation costs (e.g., using mass-produced drug panels such as dipsticks or point-of-care test cups), and widespread clinical use within healthcare settings (Moeller et al., 2008). However, most drugs (besides THC) only remain in urine for a few days, thereby limiting the ability of urine tests to detect use to a short window (Jufer et al., 2006; Smith-Kielland et al., 1999). Hair testing, increasingly used in survey research, is an advantageous alternative or addition because sample collection is typically painless, less invasive, and without need for extensive apparatuses. Moreover, many drugs can be detected in hair samples months or years after use, thereby enabling a long detection window (Gryczynski et al., 2014; Kintz et al.,

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2015). Further still, in household surveys of populations, refusal rates for hair-testing have been found to be lower than with urine testing (Fendrich et al., 2004a). Blood and saliva testing are two additional alternatives, but are similarly limited by a short detection window of hours to days (Vindenes et al., 2011).

As the incorporation of biological testing in survey-based research continues to grow, there is a need for continued research to determine the extent to which the utility of different drug tests may vary with drug class, as well as to clarify the nature of underreporting that may occur with self-report of different drugs. In this paper, we examine how the utility of hair testing compares to a more common method—urine testing—in a sample of current opiate/opioid users.

2. Methods

2.1. Study design

Data were collected from a cross-section of 532 young adults New York City in 2014–2016. Detailed information about study methodology has been published elsewhere (Mateu-Gelabert et al., 2017). Briefly, participants were recruited via Respondent-Driven Sampling (RDS), which is a form of chain-referral sampling designed to engage hard-to-reach populations and uses participants' social network connections to drive recruitment (Heckathorn, 2014). Twenty eligible individuals were recruited directly by research staff to initiate recruitment chains and the remainder of the sample was recruited via peer referrals from previous participants.

Individuals were eligible if they were 1) 18–29 years old, 2) lived in New York City, 3) spoke English, and 4) reported using heroin or prescription opioids nonmedically > 3 times in the past 30 days. In addition to self-report, recent opiate/opioid use was confirmed with a multimodal screening protocol that included urine testing for methadone, opiates (i.e., heroin, morphine, codeine), and oxycodone using a point-of-care device (described below), a visual prescription opioid pill identification quiz and, for those who reported recent drug injection, a visual check for injection marks. Individuals whose urine samples did not indicate recent opiate/opioid use (within approximately the past 1–4 days) could still be eligible if they reported using opioids > 3 times in the past 30 days and correctly identified at least 3 opioid pills in the visual quiz and/or had visible evidence of recent injection. After providing informed consent, participants completed structured, computer-assisted interviews. The study was approved by NDRI's Institutional Review Board.

2.2. Survey

The survey assessed demographic characteristics and past-month nonmedical use of various drugs including heroin, prescription opioids, methadone, marijuana, cocaine (including crack), benzodiazepines, and methamphetamine. Participants were also asked about use of “speedball”, which was defined as directly combining heroin and cocaine. It should be noted that eight participants reported speedball use, but did not self-report cocaine use; these eight participants were recoded as cocaine users (all participants who reported speedball use also reported heroin use). Participants were also asked whether they were currently in a methadone treatment program, and we coded a variable indicating self-reported use of “street” methadone or methadone obtained via treatment.

2.3. Urine and hair collection

Urine samples were collected at eligibility screening, which immediately preceded the interview and hair sample collection. Urine testing was conducted using a rapid point-of-care device—the 10-panel *i*Cup—manufactured by Alere Toxicology (Portsmouth, VA). Prospective participants were asked to provide a urine specimen in the integrated collection cup, and results were read by trained research staff approximately five minutes after collection.

Hair samples were collected by trained research staff who used scissors to cut a drinking straw-sized amount of hair (~200 strands) from the top of participants' heads, cutting as close to the scalp as possible. Participants who had hair less than ½” long were deemed to have an insufficient amount for collection (Fendrich et al., 2004b). The root end of each specimen was wrapped in aluminum foil, and the specimen was placed in a collection bag, labeled, sealed, and transported by courier to a local laboratory for analysis.

2.4. Urine and hair analysis

Urine specimens were tested using a qualitative immunoassay technique for the presence of the following drugs/metabolites (with values representing analytical cutoffs indicating a positive result): amphetamines (1000 ng/mL), barbiturates (300 ng/mL), benzodiazepines (oxazepam, 300 ng/mL), cocaine (benzoylecgonine, 300 ng/mL), methadone (300 ng/mL), methamphetamine (1000 ng/mL), opiates (morphine, 300 ng/mL), oxycodone (100 ng/mL), propoxyphene (300 ng/mL), and marijuana (11-nor-9-carboxy-Δ^9-tetrahydrocannabinol [THC-COOH], 50 ng/mL). Depending on the specific drug and amount used, urine testing is able to detect use within the past 1–7 days. Analysis was based on the presence or absence of an indicator line for each drug, as well as a control line for each drug to ensure proper functioning of the test. Results were immediately recorded.

The laboratory examined hair samples at the proximal segments (i.e., the portion closest to where the sample was cut) in order to determine drug use in the past 30 days (Kintz et al., 2015). Hair analysis comprised a two-step process consisting of initial qualitative screening via immunoassay, followed, as indicated, by quantitative confirmatory testing using liquid chromatography mass spectrometry (LCMS). Specimens were first screened for the presence of the following drugs or drug classes: amphetamines, barbiturates, benzodiazepines, cocaine, methadone, opiates/opioids, phencyclidine (PCP), propoxyphene, and cannabinoids. For any drugs/drug classes that were detected in qualitative screening, quantitative testing was then conducted (given there was enough hair) to confirm the result and, when applicable, to assess for the presence of specific drugs and/or metabolites within the class. We utilized qualitative hair test results to determine exposure to marijuana (THC-COOH, 1 pg/mg), cocaine (500 pg/mg), benzodiazepines (200 pg/mg), and methadone (200 pg/mg) (with values representing analytical cutoffs), as quantitative tests were not needed to detect drugs within these categories. We utilized quantitative hair test results to determine exposure to methamphetamine (100 pg/mg), opiates (6-MAM [100 pg/mg] and morphine [100 pg/mg]), and oxycodone (100 pg/mg) (with values representing analytical cutoffs), as such tests were necessary to determine the presence of these drugs when qualitative tests suggested exposure to amphetamines or opiates/opioids. Since the opiate urine test tested for the presence of heroin, morphine, and/or codeine, for consistency, we considered hair samples opiate-positive if quantitative analysis detected the presence of any of these three compounds.

Almost all participants (99.1%, $n = 527$) provided a urine sample for analysis, with exception of 5 (0.9%) who were unable to urinate. With regard to hair collection, 79.3% ($n = 422$) provided a sample. Of those who did not provide a sample (20.7%, $n = 110$), 96.4% ($n = 106$) did not have enough hair and 3.6% ($n = 4$) refused. With respect to those who provided a hair sample, 5.7% ($n = 24$) of samples were not able to be analyzed in full or in part, with 17.3% ($n = 73$) of samples unable to be examined for all or some quantitative analyses (after qualitative confirmation); 6.9% ($n = 29$) of samples were lost by or during shipping to the lab for analysis, and 0.2% ($n = 1$) had an ID labeling issue.

2.5. Statistical analysis

We first examined sample characteristics and computed prevalence of past-month self-reported nonmedical use of seven drugs or drug classes: opiates (i.e., heroin, codeine, morphine), marijuana, benzodiazepines, cocaine, oxycodone, methadone, and methamphetamine. We also examined prevalence of urine and hair samples testing positive for each drug examined. We then determined the percentage of self-reported drug use that was validated via urine- and hair-testing. We also determined the percentage of urine and hair tests that detected denied use of each drug (i.e. underreporting). We then examined whether there were differences in detection between the two testing methods, and McNemar tests were used to determine whether there were significant differences between proportions. We then computed sensitivity (the percentage correctly classified as positive given reported use), specificity (the percentage correctly classified as negative given non-reported use), positive predictive values (PPVs; the percentage correctly classified as reporting use given they tested positive), and negative predictive values (NPVs; the percentage correctly classified as reporting no use given they tested negative) for urine, hair, and both urine and hair, to determine the extent of correct classification of these measures with regard to self-reported use.

3. Results

As is shown in Table 1, most participants identified as white (69.6%) and male (67.9%); 61.4% had a high school diploma or less, and 44.7% were homeless. The mean age was 24.0 years (SD = 3.1). Table 2 presents self-reported past-month drug use and results of urine and hair tests for each drug. Heroin/opiate use was reported by 85.0% of the sample and use was detected in 80.2% of the sample. Urine tests yielded 40.4% and 25.0% higher prevalence of positive test results than hair for marijuana and benzodiazepines, respectively, and urine tests yielded 21.6% lower prevalence of positive test results than hair for cocaine use.

Table 1
Sample characteristics (n = 532).

	n	%
Age		
18–21	126	23.7
22–24	168	31.6
25–26	100	18.8
27–29	138	25.9
Gender		
Male	361	67.9
Female	167	31.4
Transgender (Male to Female)	3	0.6
Transgender (Female to Male)	1	0.2
Race		
White	367	69.4
Black or African American	42	7.9
Other/Mixed Race	62	11.7
Responded “Non-Applicable”	58	10.9
Ethnicity		
Non-Hispanic	379	71.5
Hispanic	151	28.5
Education		
Less than High School Diploma	106	20.0
High School Diploma or Equivalency	220	41.4
Some College or Associate’s Degree	179	33.7
College Graduate	26	4.9
Marital Status		
Never Married	469	88.2
Married or Co-Residing	36	7.7
Separated/Divorced/Widowed	21	4.1
Currently Homeless		
No	168	55.3
Yes	134	45.7

Note. Percentages represent valid percentages.

Table 3 compares percentages of each drug detected by urine and hair according to whether past-month use was self-reported. Compared to hair testing, urine testing confirmed higher proportions of self-reported use of opiates/heroin (85.5% in urine vs. 80.9%, $p = .010$), marijuana (73.9% in urine vs. 22.9%, $p < .001$), benzodiazepines (51.3% in urine vs. 15.1%, $p < .001$), and methadone (77.0% in urine vs. 48.7%, $p < .001$). Hair testing was more likely than urine testing to detect reported cocaine use (66.3% in hair vs. 48.0%, $p < .001$). Of note, urine testing detected 51% more reported use of marijuana, 36.2% more use of benzodiazepines, and 28.3% more use of methadone than hair testing. Hair testing in addition to urine testing only accounted for about a 1–2% increase in detection of reported use of marijuana, methadone, or benzodiazepines, but hair testing was able to add substantially to the detection power of urine testing with regard to reported use of cocaine (21.6%) and oxycodone (15.8%).

With regard to detecting drug use among those who reported not using (Table 3 continued), compared to hair testing, urine testing was more likely to detect use among those who did not report use of marijuana (11.3% in urine vs. 0.9%, $p = .001$), and benzodiazepines (14.4% in urine vs. 5.4%, $p = .001$), while hair testing was more likely to detect unreported use of cocaine (27.0% in hair vs. 5.8%, $p < .001$) and oxycodone (19.7% in hair vs. 1.4%, $p < .001$). Of note, urine testing detected 10.4% more non-reported use of marijuana than hair testing. However, hair testing detected 21.2% more non-reported cocaine and 18.3% more non-reported use of oxycodone than urine testing. Hair testing added to the detection power of urine regarding denied use of oxycodone (14.7%) and cocaine (13.8%). Fig. 1a and b compare the detection power of urine and hair between participants who reported use and who did not report use of each drug.

Table 4 presents results of diagnostic accuracy tests. Sensitivity of urine testing was typically higher than sensitivity of hair testing with notable differences with regard to marijuana (73.9% vs. 22.9%), benzodiazepines (51.4% vs. 15.1%), and methadone (77.0% vs. 48.7%). Sensitivity of hair testing for cocaine use, however, was higher than sensitivity of urine testing (66.3% vs. 48.0%). Sensitivity typically did not increase greatly through use of both urine and hair testing, although the combining of testing methods appeared to increase sensitivity most for methamphetamine and for oxycodone. The combination of urine and hair testing for opiates/heroin led to nearly perfect sensitivity (98.6%). Hair testing had nearly perfect specificity for marijuana (99.1%) and higher specificity for opiates/heroin (85.7%) and benzodiazepines (94.6%) compared to urine testing for each drug (88.7%, 77.2%, and 85.6%, respectively). However, urine testing had visibly higher specificity for cocaine (94.2%) and oxycodone (98.6%) compared to hair testing for each drug (73.0% and 80.3%, respectively). All methods had particularly high positive predictive values for marijuana use and heroin use, and negative predictive values were particularly high for methamphetamine and methadone.

4. Discussion

Biological testing can be used to validate drug use or detect unreported drug use based on self-report. Since testing hair samples for drug use is increasingly being used in survey research, we sought to examine how the utility of hair testing compares to a more common means of biological testing—urine testing.

Overall, we were able to validate the majority of self-reported past-month use of most drugs, especially opiates (primarily heroin), which was the most prevalent drug used in this sample. Together, urine and hair testing were able to validate nine out of ten reports of opiate/heroin use in the past month, while urine and hair tests were able to independently detect over four-fifths of reported use. Since use of heroin or other opiates/opioids > 3 times in the past month was an

Table 2
Self-Reported past-month drug use and urine and hair test results among the full sample.

	Past-Month Self-Reported Use, % (n)	Positive Urine Test, % (n)	Positive Hair Test, % (n)	Combined (Urine + Hair) % (n)	Difference (Urine - Hair) %	Difference (Total - Urine) %
Opiates/Heroin	85.0 (452)	76.1 (401)	74.4 (268)	80.2 (424)	1.7	4.1
Marijuana	71.4 (379)	55.8 (294)	15.4 (52)	56.5 (299)	40.4	0.7
Benzodiazepines	58.9 (313)	36.1 (190)	11.1 (41)	37.8 (200)	25.0	1.7
Cocaine	47.6 (253)	26.0 (137)	47.6 (175)	43.5 (230)	−21.6	17.5
Oxycodone	47.4 (252)	24.5 (129)	28.6 (103)	39.7 (210)	−4.1	15.2
Methadone	30.5 (162)	28.1 (148)	23.4 (86)	30.8 (163)	4.7	2.7
Methamphetamine	2.3 (12)	1.5 (8)	0.9 (3)	2.1 (11)	0.6	0.6

Note. Percentages for hair test results are based on those who provided hair and had an analyzable sample. Combined percentage is the total percentage of positive tests determined by either urine or hair; the difference between urine and hair demonstrates the percentage of positive detection hair adds to urine testing; the difference between urine and total percentage demonstrates the percentage of positive detection hair adds to the total, over and above urine testing. Opiates/Heroin refers to heroin use or nonmedical use of codeine or morphine (with 94.5% reporting heroin use). 80.3% (n = 427) of the full sample reported heroin use, 8.6% (n = 46) reported nonmedical codeine use, and 3.2% (n = 17) reported nonmedical morphine use.Cocaine contains those reporting crack use or “speedball” use which was defined as directly combining heroin and cocaine. Methadone included use of either “street” methadone or prescribed methadone.

Table 3
Comparisons of urine- and hair-testing in detecting self-reported and denied past-month drug use.

Drug	Drug Detection Results among Those Self-Reporting Past-Month Use					
	Urine % (n)	Hair % (n)	Combined (Urine + Hair) % (n)	Difference (Urine - Hair) %	Difference (Total - Urine) %	*P*
Opiates/Heroin (n = 452)	85.5 (383/448)	80.9 (263/325)	89.6 (403/450)	4.6	4.1	.010
Marijuana (n = 379)	73.9 (277/375)	22.9 (51/223)	75.0 (282/376)	51.0	1.1	< .001
Benzodiazepines (n = 313)	51.3 (159/310)	15.1 (33/218)	53.4 (166/311)	36.2	2.1	< .001
Cocaine (n = 253)	48.0 (121/252)	66.3 (128/193)	69.6 (176/253)	−18.3	21.6	< .001
Oxycodone (n = 252)	50.2 (125/249)	41.5 (61/147)	66.0 (165/250)	8.7	15.8	.909
Methadone (n = 162)	77.0 (124/161)	48.7 (57/117)	77.8 (126/162)	28.3	0.8	< .001
Methamphetamine (n = 12)	18.2 (2/11)	14.3 (1/7)	27.3 (3/11)	3.9	9.1	–
Drug	**Drug Detection Results among Those Denying Past-Month Use**					
	Urine % (n)	Hair % (n)	Combined (Urine + Hair) % (n)	Difference (Urine - Hair) %	Difference (Total - Urine) %	*P*
Opiates/Heroin (n = 80)	22.8 (18/79)	14.3 (5/35)	26.6 (21/79)	8.5	3.8	.727
Marijuana (n = 152)	11.3 (17/151)	0.9 (1/114)	11.2 (17/152)	10.4	−0.1	.001
Benzodiazepines (n = 218)	14.4 (31/216)	5.4 (8/149)	15.7 (34/217)	9.0	1.3	.001
Cocaine (n = 278)	5.8 (16/274)	27.0 (47/147)	19.6 (54/275)	−21.2	13.8	< .001
Oxycodone (n = 280)	1.4 (4/278)	19.7 (42/213)	16.1 (45/279)	−18.3	14.7	< .001
Methadone (n = 370)	6.6 (24/366)	11.6 (29/251)	10.1 (37/367)	−5.0	3.5	.087
Methamphetamine (n = 519)	1.2 (6/515)	0.6 (2/339)	1.5 (8/517)	0.6	0.3	.999

Note. Percentages for hair test results are based on those who provided hair and had an analyzable sample. Combined percentage is the total percentage of positive tests determined by either urine or hair; the difference between urine and hair demonstrates the percentage of positive detection hair adds to urine testing; the difference between urine and total percentage demonstrates the percentage of positive detection hair adds to the total, over and above urine testing; and *P* indicates whether the percentages testing positive for urine and for hair are statistically different as per McNemar test. Opiates/Heroin refers to heroin use or nonmedical use of codeine or morphine (with 94.5% reporting heroin use). Cocaine contains those reporting crack use or “speedball” use which was defined as directly combining heroin and cocaine. Methadone included use of either “street” methadone or prescribed methadone.

inclusion criterion for this study, it is possible that participants used opiates more frequently than other drugs, which may have increased the likelihood of detection using these test methods. Assuming past-month opiate use was not overreported, we were not able to confirm self-reported use in a tenth of the sample. We are unsure whether this is due to more or less recent use in the past month or to frequency of use, which was not analyzed.

The second most prevalent drug used, as well as the second most detected by our biological tests, was marijuana. Notably, urine testing was able to validate over 50% more instances of reported marijuana use than hair testing. Several other studies have also reported low sensitivity in detecting marijuana and/or lower concordance between hair test results and self-reported marijuana use (Gryczynski et al., 2014; Ledgerwood et al., 2008; Musshoff et al., 2006), though Sharma et al. (2016) reported 93% agreement between self-reported marijuana use and hair tests (utilizing 90-day window periods). One potential explanation is that infrequent marijuana use (e.g., weekly use or less) is more difficult to detect in hair (Taylor et al., 2017). Thus, respondents' past-month use of marijuana might have been sporadic or infrequent and, consequently, less likely to be detected in hair specimens. In contrast, though typically characterized by a short detection period, urine testing can often detect marijuana up to several weeks post-use (Cone, 1997; Fendrich et al., 2004b). Our findings also show that urine testing was better than hair testing at detecting unreported marijuana use.

Similarly, our findings suggest that urine testing is more efficacious than hair testing in detecting benzodiazepines, validating just over half of self-reported use. To our knowledge, only one other validity study within the past several decades has included benzodiazepines in their analyses (Li et al., 2019). Though their findings were limited to sexual

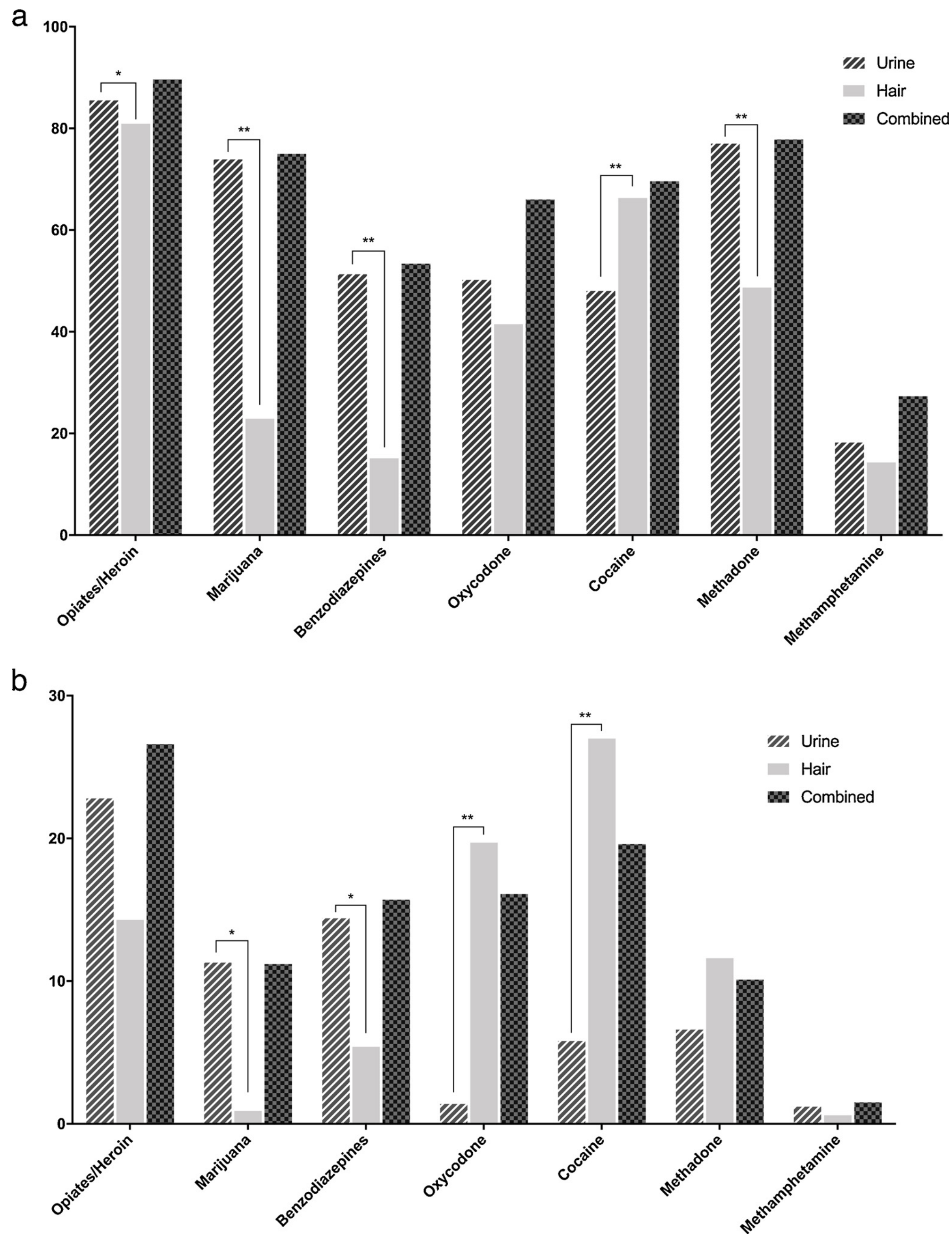

Fig. 1. (a) Drug Detection Results among Those Self-Reporting Past-Month Use (b) Drug Detection Results among Those Denying Past-Month Use. a: *$p < .05$, **$p < .001$; b: *$p < .01$, **$p < .001$.

minorities, Li et al. also reported a fair level of agreement between urine test results and self-report of benzodiazepine use. Our findings further show that both biological tests are moderately effective at detecting oxycodone and methadone, though hair testing was more likely to detect unreported use of oxycodone than urine testing. While we did consider both prescribed and illicit use of methadone in our study, we did not ask about recent prescribed use of benzodiazepines, opiates, or oxycodone, so it is possible that we detected medical use in some cases.

Neither biological test was efficacious for detecting methamphetamine use, but it should be noted that only 2.3% of our sample reported use. Relatively few validity studies have included methamphetamine in analyses, but existing findings generally indicate that self-report of methamphetamine use is typically quite consistent with urine testing (Napper et al., 2010) and hair testing (Gryczynski et al., 2014; Polettini et al., 2012). However, as may be the case with infrequent or sporadic marijuana use, researchers have warned about extrapolating findings to light or occasional methamphetamine use (Han et al., 2011). While both hair and urine tests are moderately effective at detecting reported cocaine use, hair tests were more likely to detect both reported and unreported use than urine testing. This corroborates existing findings showing that hair specimens were more useful in detecting underreporting of cocaine than urine and salivary specimens (Fendrich et al., 2004b; Musshoff et al., 2006).

When examining the utility of hair versus urine testing in detecting past-month drug use, we must keep in mind that urine testing is typically more efficacious in detecting very recent drug use (i.e., use in the past few days), with the exception of marijuana, which can be detected for up to a month if used frequently (Smith-Kielland et al., 1999). In contrast, hair testing appears more efficacious in detecting use that occurred beyond the past few days, likely because it can take 7–10 days

Table 4
Correct classification of past-month drug use by urine- and hair-testing.

	Sensitivity	Specificity	PPV	NPV
Opiates/Heroin	%	%	%	%
Urine	85.5	77.2	95.5	48.4
Hair	80.9	85.7	98.1	32.6
Urine and Hair	98.6	73.4	95.0	55.2
Marijuana	%	%	%	%
Urine	73.9	88.7	94.2	57.8
Hair	22.9	99.1	98.1	39.6
Urine and Hair	75.0	88.8	94.3	59.0
Benzodiazepines	%	%	%	%
Urine	51.3	85.6	83.7	55.1
Hair	15.1	94.6	80.5	43.3
Urine and Hair	53.4	84.3	83.0	55.8
Cocaine	%	%	%	%
Urine	48.0	94.2	88.6	66.3
Hair	66.3	73.0	73.1	66.1
Urine and Hair	69.6	80.4	76.5	74.2
Oxycodone	%	%	%	%
Urine	50.2	98.6	96.9	68.8
Hair	41.5	80.3	59.2	66.5
Urine and Hair	66.0	83.9	78.6	73.4
Methadone	%	%	%	%
Urine	77.0	93.4	83.8	90.2
Hair	48.7	88.4	66.3	78.7
Urine and Hair	77.8	89.9	77.3	90.2
Methamphetamine	%	%	%	%
Urine	18.2	98.8	25.0	98.3
Hair	14.3	99.4	33.3	98.3
Urine and Hair	27.3	98.5	27.3	98.5

Note. The reference standard is self-reported past-month use. PPV = positive predictive value; NPV = negative predictive value.

for hair to grow long enough to expose the proximal segment that is needed to be cut for analysis (Kintz et al., 2015). Indeed, the main finding of this study was that hair testing is less effective than urine testing for detecting recent self-reported use of marijuana, benzodiazepines, and methadone, but more effective at detecting both reported and unreported cocaine use. Furthermore, hair testing adds substantial detection power to urine testing with regard to oxycodone use. Therefore, utilizing both biological tests may be complementary since each test can better detect distinct time periods of use of various drugs.

An additional consideration is that hair testing may "over-detect" recent use insofar as it is unfeasible to precisely measure and cut one month's worth of hair growth, so hair tests may detect use that occurred beyond the past month. We believe this limitation may be a strength when utilizing hair tests to detect use within a more extensive time period, such as past year or past 3-month use. However, for this reason, it is also unknown if recent drug use (e.g., cocaine use) was under-reported or over-detected. While we did not expect under-reporting to occur among this population, it is possible that individuals with more extensive drug repertoires may have forgotten that they recently used a specific drug, or the specific time-frame within which they used. Others may have simply been unaware which drug(s) they were ingesting. For example, unknown exposure to adulterant drugs is common among users of illegal drugs. Recent hair-testing studies have determined extensive unknown exposure to drugs like "bath salts" and methamphetamine among ecstasy users (Palamar et al., 2017, 2016). Therefore, it is possible that some participants experienced unintentional exposure to drugs such as cocaine. Underreporting may also be a result of satisficing, as some participants may have denied use of some drugs in response to survey exhaustion (e.g., to avoid follow-up questions).

Finally, there are several factors for future researchers to deliberate prior to implementing urine and/or hair testing. Hair testing tends to be expensive (e.g., ~$70 USD for the hair test used in this study), but hair samples are typically easy to obtain and can be collected in almost any environment (Palamar et al., 2018). Rapid urine tests tend to be more affordable (e.g., ~$7 USD for the *i*Cups utilized in this study purchased in bulk), though collection, storage, and shipping of non-rapid urine test samples tend to incur refrigeration and shipping costs. Furthermore, researchers must consider proper disposal protocols for urine. Testing urine can be messy depending on the environment in which it is collected as spills may occur (Measham et al., 2000), and gives rise to sanitary considerations, including the need for hand sanitization.

Hair methods are often simplified, though a notable limitation is some participants' unwillingness or inability to provide a sample of sufficient quantity to be analyzed (as was the case with several males in this study with short hair). Participants are more likely to consider urine testing as invasive (Fendrich et al., 2004b), though no participants refused to provide urine samples in our study (although five were unable to urinate). The location where samples are collected may also be an important factor, given that obtaining urine samples may be less convenient than obtaining hair samples in street environments without access to bathrooms. Although urine samples can be immediately tested on-site as was done in this study, mass-produced tests are only able to test for a narrow range of drugs. Quantitative analysis and detection of a wider range of drugs often requires storage (including refrigeration) and shipping, which requires adherence to laws regarding shipping of biologically hazardous samples.

4.1. Limitations

We could not collect hair samples from a fifth of participants, and of those who provided a hair sample, 23% were not long enough for full quantitative analysis. Therefore, we could not directly compare urine and hair results for all participants. Future studies may be improved by allowing for collection of body hair (Palamar et al., 2018, 2017; Palamar et al., 2016). We only queried nonmedical use of drugs so medical use might have been detected in some cases. It is possible that we over- or under-detected recent use via hair testing as detection is based on rate of hair growth, how close to the scalp the hair was cut, and how much hair was available to be examined. Likewise, there are other limitations to biological testing aside from limited time frames of detection, such as the inability to detect drugs/metabolites below analytical detection cutoffs. Hair color, type of hair, and use of cosmetic hair treatments can also affect ability to detect drug consumption (Kintz et al., 2015).

As this study was conducted on a sample of opiate/opioid users, results may not be fully generalizable to other populations. For example, under- or over-reporting may be more common in a high-risk sample versus a more general population sample. Opiate/opioid use was also an inclusion criterion in this study, which could have biased findings toward increased likelihood of detection as these individuals may engage in higher levels of use than other samples. RDS could have biased results (Rudolph et al., 2013), in part, because we did not utilize probability weights to account for nonrandom recruitment. Finally, like previous studies (Fendrich et al., 2004b; Norwood et al., 2016), we assumed that overreporting in this adult population was minimal. Therefore, we assumed that affirmative self-report was correct and did not utilize biological results to "correct" affirmative self-reported use that was not biologically verified.

4.2. Conclusions

While hair testing is efficacious in detecting drug use in wide window periods (e.g., past-year use), it appears to be less efficacious than urine testing when testing for past-month use of select drugs in opiate/opioid-using samples. However, hair testing does appear to be particularly efficacious in detecting unreported recent use of cocaine and/or oxycodone, and it often adds to the detection power of urine. We believe including urine and/or hair testing as an adjunct to surveys can help "correct" prevalence estimates that are influenced by unreported use.

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Contributors

All authors are responsible for this reported research. J. Palamar conceptualized and designed the study and conducted the statistical analyses. All authors drafted the initial manuscript, interpreted results, and critically reviewed and revised the manuscript. All authors approved the final manuscript as submitted.

Conflict of interest

No conflict declared.

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