New Developments in Biological Measures of Drug Prevalence

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ABSTRACT

Drug use among different populations such as household members, students, and arrestees vary substantially and the accuracy of their self-reports may be questionable. The accuracy of prevalence estimates based on self-report data can be monitored by chemical drug testing of biological specimens such as urine, saliva, sweat, and hair. Each biological specimen is unique and offers a somewhat different pattern of information regarding drug use over time. Also, each specimen has unique strengths and weaknesses regarding the type of information obtained from drug testing. The performance characteristics of the assay methodology may also be important. The validation of self-report data by drug testing must be performed with careful consideration of the limitations imposed by the testing methodology and the biological specimen.

INTRODUCTION

Illicit drug administration is often perceived by society to be risky or antisocial in nature. Such behavior can lead to many unfavorable outcomes for the individual and for society at large. The frequency of illicit drug use within various populations is a subject of much speculation and study. Drug policy decisions and intervention efforts aimed at reduction of illicit drug usage are often predicated on drug use measurements obtained through self-reports of drug use history. In the United States, drug prevalence estimates are obtained primarily from three sources: National Household Survey on Drug Abuse, Monitoring the Future survey, and Drug Abuse Warning Network (DAWN). Each involves data collection based partially or totally on self-reported drug use.

The validity of self-reported drug use data is subject to many influencing factors, such as the population examined, type of drugs used, environment, and methods used to elicit information (Magura et al. 1987). In addition, accurate recall of drug use by an individual can be affected directly by their current mental and physical status.

Underreporting of drug use is common in some populations, particularly those in which real or perceived punitive measures may result from admission of drug use. The problem of underreporting led the National Institute of Justice to establish the national Drug Use Forecasting (DUF) program in 1987 as a new source of drug prevalence estimates in which recent drug use trends in arrestees were measured by urinalysis. Early data from that program indicated that urinalysis revealed substantially higher rates of cocaine use than was indicated by self-report data (Wish 1990-1991).

The inclusion of more objective measures of drug use, such as urinalysis, complements self-report data and provides added assurance of the accuracy of prevalence estimates. The technology of urinalysis has progressed rapidly over the past decade because of widespread implementation of drug testing programs by the Federal Government, the military, and private industry. The need for reliable, inexpensive urine-based drug tests led to significant efforts in research and commercial development of such tests. At the same time, research has progressed on the evaluation of other biological fluids and tissues as useful matrices for drug detection.

Currently, there is growing interest in the use of alternate body fluids and tissues such as saliva, sweat, and hair in addition to urine for the diagno-sis of drug use. The following discussion provides an overview of the validity of drug testing and the potential uses and limitations of urine, saliva, sweat, and hair testing for drugs of abuse as objective drug prevalence estimates in different populations.

CHARACTERISTICS OF DRUG-TESTING METHODS

The usefulness of a drug test resides in its ability to accurately detect the presence of parent drug or metabolite in a biological fluid or tissue following human drug administration. This ability has been referred to as the validity of the test system (Gorodetzky 1977). This definition reflects both chemical factors that influence test outcome such as sensitivity (the least amount of detectable drug), specificity (how selective the assay is for the drug), and accuracy, and pharmacologic considerations including dose, time of drug administration, and route of drug administration. Individual differences in rate of absorption, metabolism, and excretion are also pharmacologic variables that may influence test outcome. With the recent emphasis on forensic drug testing, Cone and colleagues (1988) suggested that the definition of validity be extended to include

confirmation of initial test results by a different chemical method (e.g., gas chromatography-mass spectrometry (GC/MS)). When there is a possibility of litigation, it is extremely important to use assay methods that are highly accurate, reliable, and specific for the analyte of interest.

A variety of commercial assays and published methodologies may be employed for urine drug testing. For the most part, these methods can be grouped into two categories: screening assays and confirmation assays. The performance characteristics of these assays are listed in table 1. The assays can also be adapted for measurement of drugs in other body fluids, but must be properly validated before use. Generally, screening assays (immunoassays and thin-layer chromatography (TLC)) are commercially based tests that are inexpensive and simple to perform. In contrast, confirmation assays (gas chromatography (GC) and GC/MS) are more expensive and more labor intensive, but sensitivity and specificity are usually higher than screening tests. Immunoassay-based screening tests may cross-react with a variety of similar chemical substances. For example, most commercial immunoassays for opiates give positive test results for specimens containing either morphine or codeine. In this case, a more specific methodology is needed if it is important to distinguish between these two drugs. Often, the less expensive screening tests are employed to eliminate specimens containing no drug or drug below the cutoff concentration. The more expensive, labor-intensive tests are employed for absolute drug identification and accurate quantitation.

For drug prevalence studies in which individuals are not identified, it becomes less important to employ expensive confirmation techniques unless there are known interferences within a particular assay. Indeed, some screening assays have shown exceptionally high correlations with GC/MS methods. For example, Cone and associates (1988) reported that urine test results from a specific assay for cocaine metabolite significantly correlated with results by GC/MS with no evidence of assay bias. Consequently, in many cases it may be more cost effective to use a highly selective immunoassay than to pay for the additional costs of confirmation. An added bonus often is realized when immunoassays are employed because of their rapid turnaround time. Results may be available immediately in some cases, and almost always are provided within 24 hours of receipt at the laboratory. It is also important to select an assay system with results that can be compared with those from other studies. Many comparisons between different assay systems are not valid

TABLE 1. *Performance characteristics of different types of assays for drugs of abuse.*

Assay	Sensitivity	Specificity	Accuracy	Turnaround time	Cost
Onsite	Moderate-high	Moderate	Qualitative*	Minutes	$4-25
EMIT, FPIA, RIA, KIMS	Moderate-high	Moderate	Low-high	1-4 hours	$1-5
TLC	Low-high	High	Qualitative*	1-4 hours	$1-4
GC	High	High	High	Days	$5-20
GC/MS	High	High	High	Days	$10-100

KEY: EMIT = enzyme-multiplied immunoassay technique; FPIA = fluorescent polarization immunoassay; RIA = radioimmunoassay; KIMS = kinetic interaction of microparticles in solution; TLC = thin layer chromatogra phy; GC = gas chromatography; GC/MS = GC/mass spectrometry. * = Results for onsite tests and TLC assays are generally expressed only in qualitative terms (i.e., positive/negative); consequently, accuracy may be difficult to assess.

simply because the immunoassay antibodies utilized in the assay were not targeted toward the same drug or metabolite. Further, even in situations in which the same assay system is employed, comparisons must be made on equal ground. A simple change in the cutoff concentration of an assay can substantially alter the detectability of a drug. Figure 1 illustrates the influence of detection time on cutoff concentrations. Obviously, it is important to select drug assays with equivalent performance characteristics if comparisons within and between studies are anticipated.

Urine

Urine is produced continuously by the kidney as an ultrafiltrate of blood. During urine production, essential substances are reabsorbed by the kidney, and excess water and waste products such as urea, organic substances, and inorganic substances are eliminated from the body. The daily amount and composition of urine varies widely depending upon

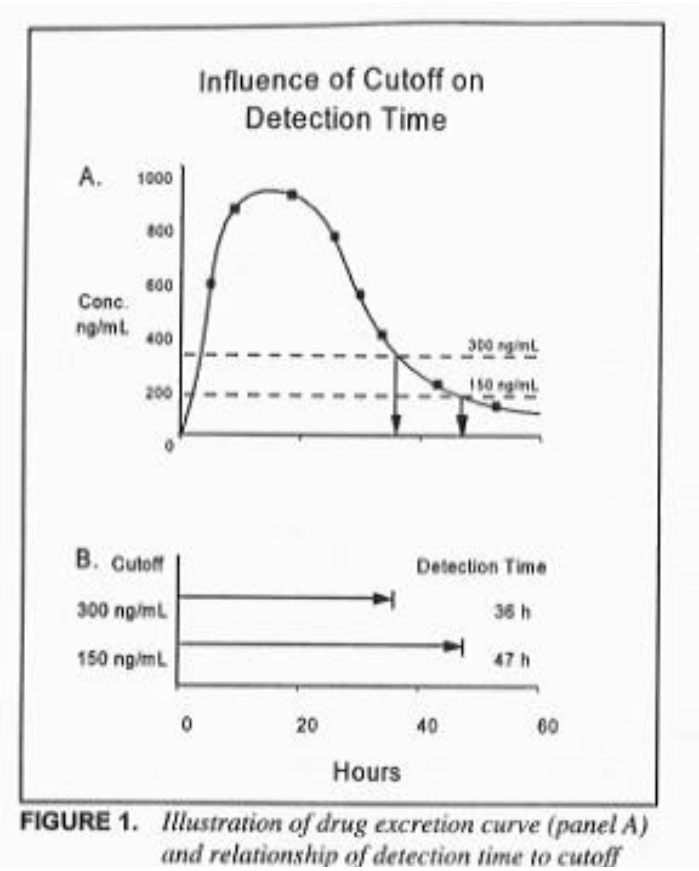


FIGURE 1. *Illustration of drug excretion curve (panel A) and relationship of detection time to cutoff*

many factors such as fluid intake, diet, health, drug effects, and environmental conditions. The volume of urine produced by a healthy adult in a 24-hour period ranges from 1 to 2 liters, but normal values outside these limits are frequently encountered. Creatinine, a protein byproduct of muscle metabolism, is present at a relatively constant concentration in blood and is excreted in urine. Consequently, the average 24-hour output of creatinine in urine also is constant. Comparison of creatinine concentration in urine and blood provides a means of assessing renal function. For most people, urine creatinine concentrations exceed 20 milligrams per deciliter (mg/dL) although concentrations lower than 20 mg/dL are occasionally encountered.

Urine specimens with creatinine concentrations below 20 mg/dL can be produced by excessive water intake. Drug users who are being urine tested sometimes attempt evasion by drinking large amounts of water or herbal teas in an attempt to dilute drug concentrations below cutoff concentrations. Consequently, many laboratories also test for creatinine and report specimens with creatinine concentrations below 20 mg/dL. Medical review officers who review results with abnormally low creatinine concentrations may request retesting the

subject for drugs. Drug/creatinine ratios can be evaluated for evidence of attempted dilution of urine. A highly dilute specimen might test negative, but evaluation of the drug/creatinine ratio could provide convincing evidence that the sample would have been positive if normal water intake had occurred.

When a drug is administered by an intravenous or smoking route, absorption is nearly instantaneous and excretion in urine begins almost immediately. Absorption is slower when a drug is administered by the oral route and excretion in urine may be delayed for several hours. Normally, specimens voided within 6 hours after drug administration contain the highest concentration of parent drug and metabolites. Because drug excretion in urine normally occurs at an exponential rate, the majority of the drug dose of most illicit drugs is eliminated within 48 hours after administration. Detection times for drugs of abuse vary according to dose, frequency of administration, cutoff concentration, and numerous other factors. Despite wide variance, it is helpful to know average detection times when interpreting urine test data. Table 2 con-tains a list of average detection times and commonly used cutoff concentrations.

Most drugs of abuse have detection times of 2 to 4 days unless accumu-lation has occurred as a result of frequent, multiple dosing over an extended period of time. In drug prevalence studies, the relatively brief historical record of drug exposure provided by urinalysis must be considered when compared to retrospective self-report data. Urinalysis may cover only 2 to 4 days, but self-report data may encompass longer periods. Subjects who accurately report drug use within the past month could easily have negative urine results. In this case, the urine result does not support the self-report data. A better comparison can be made through the use of discrete multivariate analysis in which self-report data are compared with positive urine test results (Bishop et al. 1975; Magura et al. 1987). The reports of subjects with negative urine results are ignored, and subjects with a positive urine test who fail to report recent

TABLE 2. *Typical screening and confirmation cutoff concentrations and detection times for drugs of abuse.*

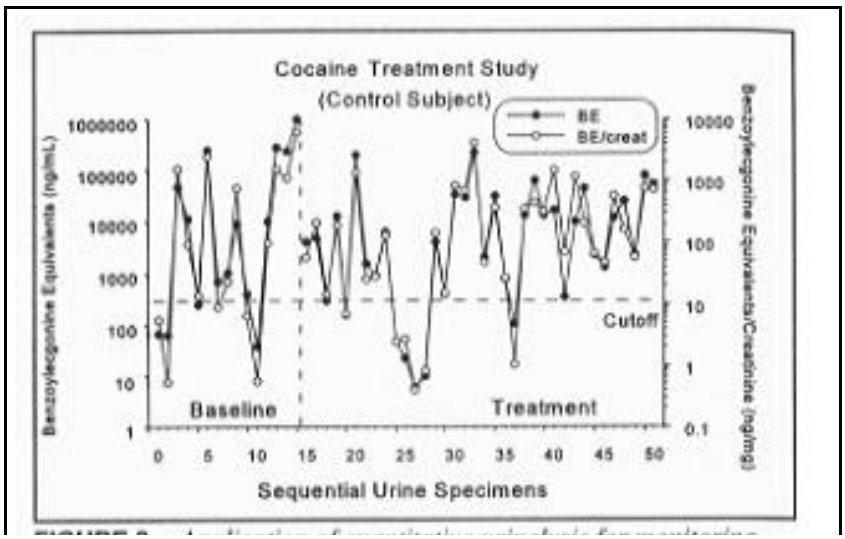
Drug	Screening cutoff concentrations ng/mL urine	Analyte tested in confirmation	Confirmation cutoff concentrations	Urine detection time
Amphetamine	1,000	Amphetamine	500	2-4 days
Barbiturates	200	Amobarbital, secobarbital, other barbiturates	200	2-4 days for short acting; up to 30 days for long acting
Benzodiazepines	200	Oxazepam, diazepam, other benzodiazepines	200	Up to 30 days
Cocaine	300	Benzoylecgonine	150	1-3 days
Codeine	300	Codeine, morphine	300; 300	1-3 days
Heroin	300	Morphine, 6-acetylmorphine	300; 10	1-3 days
Marijuana	100; 50; 20	Tetrahydrocannabinol	15	1-3 days for casual use; up to 30 days for chronic use
Methadone	300	Methadone	300	2-4 days
Methamphetamine	1000	Methamphetamine, amphetamine	500; 200	2-4 days
Phencyclidine	25	Phencyclidine	25	2-7 days for casual use; up to 30 days for chronic use

drug use are considered inaccurate reporters. Using this approach, Magura and associates (1987) found that self-reporting of methadone clients was least valid for opiates, while benzodiazepine and cocaine reporting were moderately and highly valid, respectively.

Self-reported drug use data can be compared with either qualitative (positive/negative) or quantitative urinalysis. Most comparisons that involve collection of a single urine specimen are made in the qualitative mode. In situations where multiple specimens are collected, particularly treatment and rehabilitation, quantitative urinalysis provides additional information that may be useful in determining whether drug use has decreased (Batki et al. 1993). Since cocaine metabolite is excreted for periods up to 4 days following use,

several sequential samples collected within a short time period may be positive as a result of a single drug episode. Qualitative urinalysis provides multiple positive results from these episodes and overestimates the frequency of cocaine use. This problem is illustrated in figure 2, which shows results from a control subject in a cocaine treatment study who was urine tested 3 times a week. The study consisted of an initial 5-week period (baseline) during which all subjects reported to the outpatient treatment clinic and received counseling, followed by a 12-week period in which some subjects received contingency management therapy. The urine test data indicated that this subject was using cocaine sporadically throughout the baseline and treatment periods. Qualitative analysis indicated that the subject produced specimens positive for cocaine 73 percent of the time during the baseline period and 81 percent of the time during the treatment phase.

Clearly, some specimens were positive as a result of new cocaine use, while others simply represented carryover from earlier dosing. If one evaluates these data in a quantitative mode with rules that would identify instances of new drug use, an estimate of the frequency of drug use can be obtained. The rules for estimating instances of new cocaine use must be based on the known pharmacokinetic parameters of the cocaine metabolite, benzoylecgonine. Because this metabolite has an excretion half-life of approximately 7.5 hours (Ambre 1985), sequential urine specimens that are collected at intervals > 24 hours should have declined in concentration by more than 25 percent of the concentration of the previous positive specimen. For example, the third specimen in figure 2 showed a concentration of 48,810 nanograms (ng)/mL of benzoylecgonine equivalents and the fourth sample contained 11,540 ng/mL. Thus, the fourth sample likely was positive as a result of carryover. The fifth sample continued to decline in concentration (241 ng/mL), whereas the sixth sample represented a new occurrence of cocaine use (252,000 ng/mL). Application of new-use rules to figure 2 indicate that only 53 percent of the specimens represented instances of new use compared to positive rates of 73 percent and 81 percent by qualitative analysis.



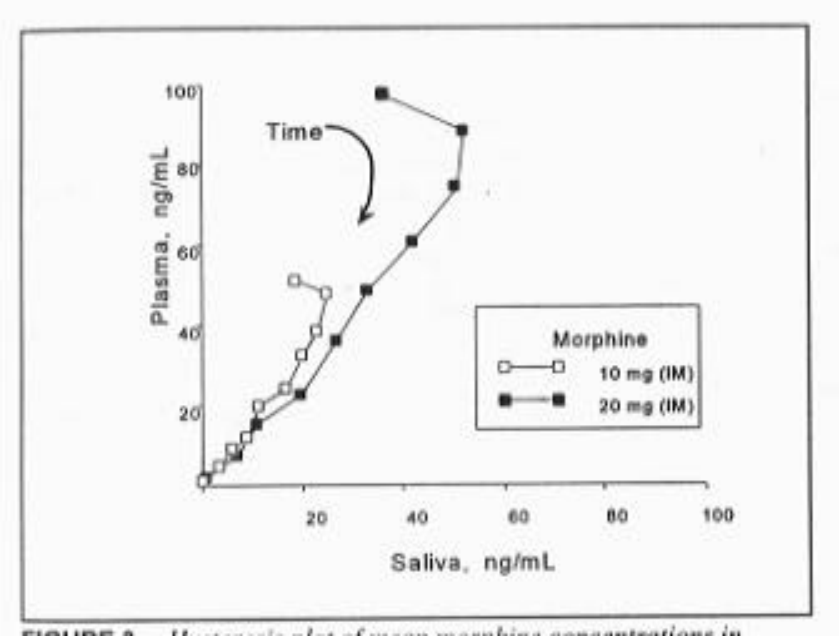
The value of quantitative urine test data is also evident when samples are tested for water dilution. Water loading can cause positive samples to test negative in the qualitative mode. However, the use of benzoylecgonine/creatinine ratios can provide evidence that a dilute sample would ordinarily have tested positive. In the example shown in figure 2, the benzoylecgonine/creatinine ratios closely parallel benzoylecgonine concentrations, indicating no evidence of attempted dilution by this individual.

Saliva

Saliva is secreted primarily by three glands: the parotid, submandibular, and sublingual glands. Secretions from serous and mucousal cells in these glands form saliva. Serous cells secrete watery fluid containing electro-lytes and amylases and mucous cells produce mucins (mucoproteins and mucopolysaccharides). The flow of saliva is dependent upon neurotrans-mitter stimulation and can vary widely from zero flow to rates as high as 10 mL/minute. The pH of saliva generally is slightly acidic but increases with saliva flow rate from a low of pH 5.5 to pH 7.9. Saliva composition is also dependent upon flow, but generally consists of approximately 90 percent water with the remainder being electrolytes (e.g., sodium, calcium, bicarbonates, magnesium), amylase, organics (glucose, urea, lipids), proteins (low concentrations), and hormones (cortisol, testosterone, estrogens, progesterone).

Drugs may enter saliva by passive diffusion from blood, ultrafiltration, and active secretion. Of these processes, passive diffusion represents the most important route of entry for most drugs with the possible exception of ethanol, a molecule small enough to enter by ultrafiltration. Several reports and reviews have appeared on the occurrence of drugs of abuse in saliva (Caddy 1984; Cone 1993; Schramm et al. 1992).

Saliva offers a number of advantages and some disadvantages in compari- son to urine testing for drugs. The major advantages of saliva as a test medium include its ready accessibility for collection, less objectionable nature (compared to urine), presence of parent drug in higher abundance relationship between plasma morphine concentrations and saliva morphine following the injection of morphine by the intramuscular route (Cone 1993) is illustrated in figure 3. Saliva concentrations are reduced relative



to plasma by approximately one-third, equivalent to the amount of plasma protein binding for morphine. After a very short equilibration phase (15 to 30 minutes), saliva morphine declined in a manner parallel to plasma concentrations. Significant correlations of saliva drug concentrations with plasma have also been reported for cocaine. Cone and colleagues (1988) reported finding significant correlations of saliva than metabolites, and high correlation of saliva drug concentration that can be obtained with the free fraction of drug in blood (table 3). The cocaine concentrations with plasma and with responses on self-rating scales for drug sensation, psychotomimetic effects and feelings of rush, and heart rate. Figure 4 illustrates the temporal relationship between saliva cocaine concentrations, plasma, and heart rate changes following a 25 mg dose of cocaine hydrochloride (HCl) salt to a cocaine user by the intravenous route. It is clear from this illustration that saliva and plasma concentrations are similar for most of the time period and decline with heart rate in a parallel manner. The equivalent concentrations of cocaine in saliva and plasma are the result of pH influences and the lack of protein binding by cocaine in plasma.

Despite the numerous advantages of saliva, it does have some disadvan-tages. The use of saliva drug concentrations to predict blood concen- trations is limited because of the possibility of contamination of saliva from drug use by the oral, smoked, and intranasal routes of drug admini-stration. When drugs are administered by these routes, contamination of the oral cavity and saliva can greatly distort saliva/plasma ratios, thereby distorting useful pharmacokinetic relationships. Even with this obvious limitation, saliva measurements can be used as evidence of recent drug use even in situations in which oral contamination is likely to be involved (e.g., marijuana smoking). Cone (1993) reported that marijuana smoking produced contamination of the oral cavity by tetrahydrocannabinol (THC). Even though saliva concentrations of THC were derived from contami- nation, they were highly correlated with plasma concentrations.

The short time course for detectability of drugs in saliva prevents this biological fluid from being used to detect historical drug use. At the same time, this feature of saliva makes it useful for detection of very recent drug use. Most drugs disappear from saliva and blood within 12 to 24 hours after administration. There is often a temporal relationship between the disappearance of drugs in saliva and the duration of pharmacologic effects. Consequently, saliva is useful in the detection of recent drug use in automobile drivers, accident victims, and for testing employees before they engage in safety-sensitive activities.

TABLE 3. *Comparison of usefulness of urine, saliva, sweat, and hair as a biological matrix for drug detection.*

Biological matrix	Drug detection time	Major advantages	Major disadvantages	Primary use
Urine	2-4 days	Mature technology; onsite methods available; established cutoffs	Only detects recent use	Detection of recent drug use
Saliva	12-24 hours	Easily obtainable; samples "free" drug fraction; parent drug presence	Short detection time; oral drug contamination; collection methods influence pH and saliva/plasma ratios; only detects recent use; new technology	Linking positive drug test to behavior and performance impairment
Sweat	1-4 weeks	Cumulative measure of drug use	High potential for environmental contamination; new technology	Detection of recent drug use
Hair	months	Long-term measure of drug use; similar sample can be recollected	High potential for environmental contamination; new technology	Detection of drug use in recent past (1-6 months)

Sweat

Sweat is a watery fluid produced primarily by eccrine glands distributed widely across the skin surface of humans. The primary purpose of sweat production is heat regulation; consequently, the amount of sweat produced is highly dependent upon environmental conditions. Sweat consists mostly of water (99 percent) with the greatest concentrated solute being sodium chloride (Robinson and Robinson 1954). Routine sweat collection is difficult because of large variations in the rate of sweat production and the lack of devices suitable for collection of this type of biological fluid.

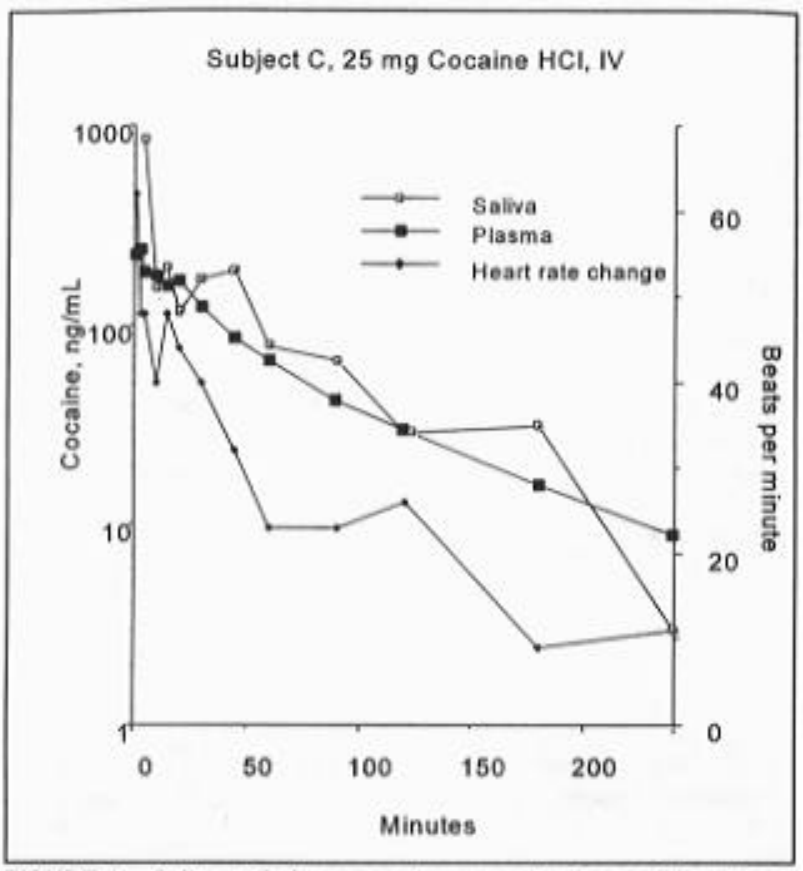


FIGURE 4. *Saliva and plasma cocaine concentrations and heart rate*

A variety of drugs of abuse have been identified in sweat, including amphetamine, cocaine, ethanol, methadone, methamphetamine, morphine, nicotine, and phencyclidine. The mechanism for drug entry into sweat is unclear, but most likely occurs by passive diffusion from blood to the sweat gland. An alternate mechanism could involve drug diffusion through the stratum corneum to the skin surface where drug would be dissolved in sweat.

Research on sweat testing for drugs has been limited because of the difficulty in collecting sweat samples. Recently, a sweat-collection device was developed that appeared to offer promise for the collection of sweat for drug monitoring. The device resembles an adhesive bandage that is applied to the skin and can be worn for a period of several days to several weeks. The "sweat patch" consists of an adhesive layer on a thin transparent film of surgical dressing to which a rectangular absorbent cellulose pad (14 square centimeters

(cm^2)) is attached. Sweat is absorbed and concentrated on the cellulose pad. The transparent film allows oxygen, carbon dioxide, and water vapor to escape, but prevents loss of drug constituents excreted in sweat. Over a period of several days, sweat should saturate the pad and drug should slowly concentrate. The patch is then removed, and the absorbent pad is detached from the device and analyzed for drug content.

Sweat testing for cocaine was recently evaluated by Cone and associates (1994). Cocaine was administered in doses of 1 to 25 mg by the intra-venous route to four cocaine-experienced, drug-free subjects. Sweat patches were worn for 24 to 48 hours following drug administration. Following removal, the patches were extracted and analyzed for cocaine and metabolites by GC/MS. The primary analyte excreted in sweat was parent cocaine, followed by ecgonine methyl ester and benzoylecgonine. Figure 5 illustrates the relationship between amount of cocaine collected by the sweat patch versus dose. Generally, there appeared to be a dose-concentration relationship; however, there was wide intersubject variability. Limited data were also collected in the same study on the excretion of heroin in sweat. Like cocaine, parent heroin was excreted in sweat along with metabolites that consisted of 6-acetylmorphine and morphine. Drug appeared in sweat as early as 1 hour following drug administration and peaked in concentration within 24 hours.

Apparent advantages of the sweat patch for drug monitoring include the following: high subject acceptability of wearing the patch, low incidence of allergic reactions to the patch adhesive, and ability to monitor drug intake for a period of several weeks with a single patch. In addition, the patch appears to be relatively tamper-proof (i.e., the patch adhesive is specially formulated so that the patch can only be applied once and cannot be removed and successfully reapplied to the skin surface).

Disadvantages of the sweat patch includes high intersubject variability, possibility of environmental contamination of the patch before applica-tion or after removal, and risk of accidental removal during a monitoring period. During patch application, extreme care must be taken to cleanse the skin surface prior to placement of the patch and also to avoid

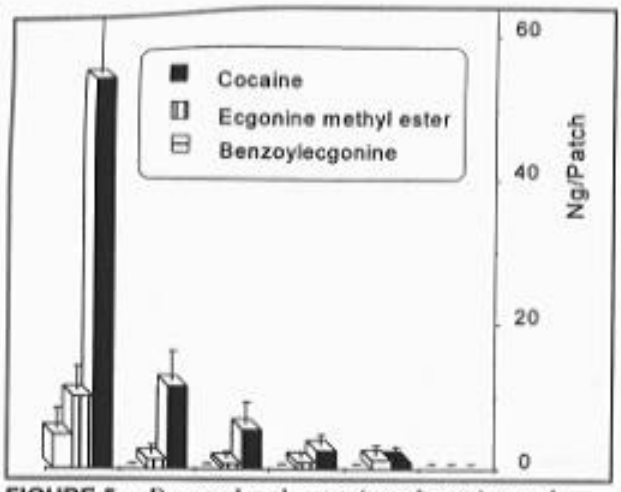


FIGURE 5. *Dose-related excretion of cocaine and*

contaminatio n of the cellulose pad during handling. Similar care must be taken when removing the patch and handling for analysis.

Hair

Hair is composed primarily of a fibrous network of keratin strands that are intertwined to form elongated strands. The strands are stabilized by interlinking disulfide and hydrogen bonds, which gives hair a semicrys-talline structure. The inner structure of hair is protected by a layer of cuticle cells that restricts or retards entry of environmental pollutants. As hair ages, the cuticle deteriorates from exposure to ultraviolet radiation, chemicals, and mechanical stresses. Head hair grows at an average rate of 1.3 cm/month, although there is some variation according to sex, age, and ethnicity (Saitoh et al. 1969). Collection of hair for testing is most often performed by cutting locks of hair near the scalp surface at the vertex of the head. During collection, the root and tip of the hair lock are identified for later use. Other types of hair, such as pubic, axillary, and arm hair, have also been used for drug testing.

Hair testing for drugs was first reported by Goldblum and associates (1954). Guinea pigs were administered varying doses of barbiturates and newly grown hair was found to be positive for parent drug. Baumgartner and colleagues (1982) reported the first evidence of drug in human hair by analyzing head hair of cocaine abusers by RIA for benzoylecgonine, the major metabolite of cocaine. Many other reports have subsequently appeared regarding the presence of drugs in hair. Drug representatives from virtually all classes of abused drugs have now been detected in hair. Currently, hair testing for drugs of abuse is performed in numerous laboratories, some of which offer commercial drug-testing services.

When hair is analyzed for drugs of abuse, the parent drug is often present in greater abundance than is found in urine. For example, the major ana-lyte found in hair of cocaine users is parent cocaine. Benzoylecgonine, the primary urinary metabolite, is present in hair in amounts varying from trace concentrations to approximately one-third of parent cocaine (Cone et al. 1991). Heroin is found in hair in varying amounts together with 6-acetyl- morphine and morphine (Goldberger et al. 1991). 6-Acetylmorphine is usually found in greatest abundance in hair, whereas conjugated morphine is the major metabolite in urine. Patterns of parent drug and metabolite distribution in hair and other biological matrices are listed in table 4.

Although the technology of hair assay has progressed rapidly over the last decade, several highly controversial aspects of hair testing remain unresolved. It remains unclear how drugs enter hair. The most likely entry routes involve: (a) diffusion from blood into the hair follicle and hair cells with subsequent binding to hair cell components; (b) excretion in sweat, which bathes hair follicles and hair strands; (c) excretion in oily secretions into the hair follicle and onto the skin surface; and (d) entry from the environment. The possibilities of drug entry from sweat and from the environment are particularly troubling, because this allows the possibility of the production of false positives if an individual's hair absorbs drugs from the environment or from another person's drug-laden sweat. Another controversial issue in hair analysis is the interpretation of dose and time relationships. Although it has been generally assumed that segmental analysis of hair provides a record of drug usage, studies with labeled cocaine have not supported this interpretation. At best, only limited dose and time relationships were found. Henderson and colleagues

TABLE 4. *Relative occurrence of parent drug and metabolite(s) in urine, saliva, sweat, and hair.*

Drug	Urine	Saliva	Sweat	Hair
Amphetamine	Amphetamine	Amphetamine	Amphetamine	Amphetamine
Cocaine	BE > EME > cocaine	Cocaine > BE ë EME	Cocaine > EME > BE	Cocaine > BE > EME
Marijuana	Carboxy-metabolite	THC	THC	?
Heroin	MO-glucuronide > MO	Heroin ë 6-AM > MO	Heroin ë 6-AM > MO	6-AM > heroin ë MO
CO	CO-glucuronide > CO > norcodeine	CO	CO	CO > MO
Metham	Metham > amphetamine	Metham	Metham	Metham > amphetamine
Phencyclidine	Phencyclidine	Phencyclidine	Phencyclidine	Phencyclidine
MO	MO-glucuronide > MO	MO	MO	MO

KEY: Metham = methamphetamine; MO = morphine; CO = codeine; BE = benzoylecgonine; EME = ecgonine methyl ester; THC = tetrahydrocannabinol; 6-AM = 6-acetylmorphine.

(1993, p. 2) concluded that "…there is not, at present, the necessary scientific foundation for hair analysis to be used to determine either the time or amount of cocaine use." Other controversial issues that remain unresolved are the possibility of ethnic bias in hair testing, appropriate means of differentiating drug users' hair from environmentally contami-nated hair, appropriate applications of hair testing, and the feasibility of hair testing for marijuana usage.

Despite the controversial nature of some aspects of hair testing, this technique is being used on an increasingly broad scale in a variety of circumstances. One of the most promising applications of hair testing appears to be its use in prevalence studies. The time record of drug use available from hair is considerably longer than any other biological specimen currently employed for drug testing (figure 6). Self-reported drug use over a period of several months can be compared to hair test results from a hair strand (about 3.9 cm length) representative of the same time period. It is expected that this type of comparison would be more effective than urine testing because urine provides a historical record of only 2 to 4 days under most circumstances. Indeed, Mieczkowski and associates (1991) compared self-reported cocaine use

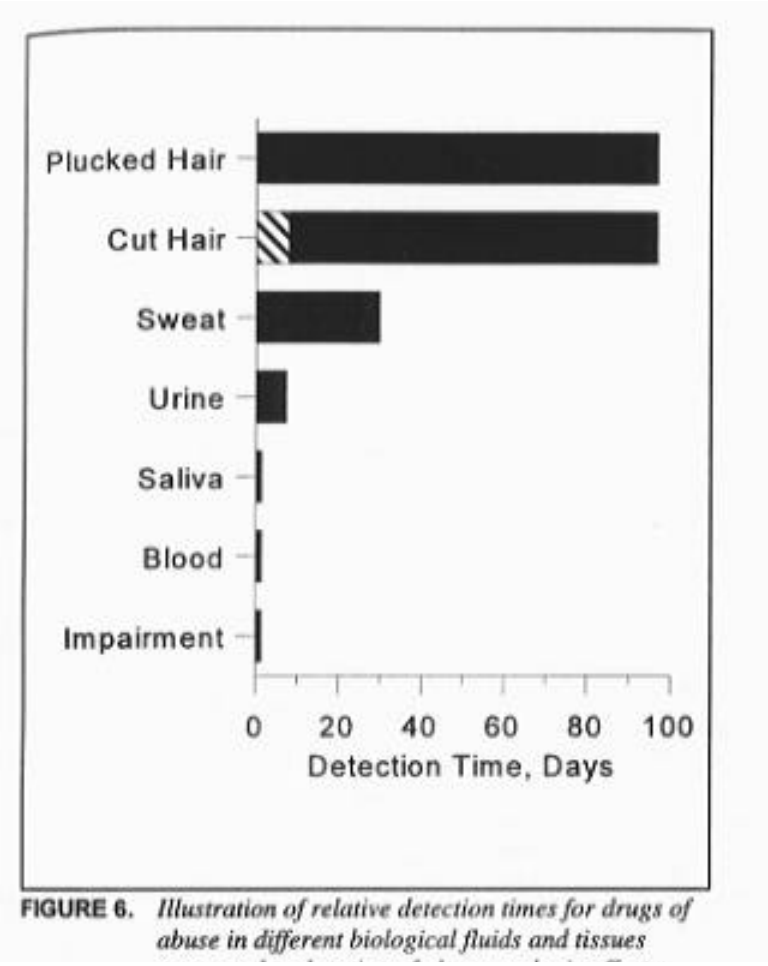


FIGURE 6. *Illustration of relative detection times for drugs of abuse in different biological fluids and tissues*

with hair and urine analysis in a group of 256 arrestees and found that hair analysis detected more drugs than either urinalysis or self-report. Of the 256 interviewed, 8.5 percent of the arrestees reported cocaine use within the past 30 days and 21.8 percent had positive urine tests, whereas 55 percent had positive hair tests. In a similar study involving 88 juvenile

arrestees, Feucht and colleagues (1994) found that only 3 individuals (3.4 percent) admitted cocaine use in the past month and only 7 subjects (8 percent) were positive by urinalysis, whereas 50 individuals (56.8 per-cent) were positive by hair analysis.

Other populations have shown somewhat higher concordance between hair assay and urinalysis or self-report. Magura and associates (1992) studied heroin addicts (N = 134) in which hair test results for opiates and cocaine were compared to confidential urinalysis and self-reporting. Hair test results were equivalent to urinalysis and/or self-report in 87 percent and 84 percent of the cases for cocaine and heroin, respectively. These data suggest the reliability of self-report data is highly dependent upon the population and the circumstances under which the data are collected.

Generally, hair analysis provides a longer estimate of drug use than either self-report measures or urinalysis. The wider window of detection is an advantage of hair testing as a prevalence measure for drug use. Other advantages include ease of obtaining, storing, and shipping specimens; ability to obtain a second sample for reanalysis; low potential for evasion or manipulation of test results; and low risk of disease transmission in the handling of samples. A potential disadvantage of hair analysis would be its inability to detect recent drug usage because of slow growth rate; however, this has not been investigated. Mounting evidence points to the likelihood that drug excretion in sweat is an important route of drug entry into hair. This allows the possibility of drug appearing in hair within hours of drug administration. Also, plucked hair should not have this limitation because hair below the scalp is removed (figure 6). Another consideration regarding the use of hair analysis is the limited number of laboratories offering commercial hair-testing services. Clearly, as demand for hair-testing services grows, commercial development also will proceed in simultaneous fashion. In addition, as more attention is focused on this new area of drug testing, many of the early controversies may be resolved by additional research.

SUMMARY

Drug use among different populations such as household members, students, and arrestees vary substantially and the accuracy of their self-reports may be questionable. Accurate assessment of drug prevalence in different populations helps policymakers identify vulnerable groups and geographical areas with high rates of drug use.

The accuracy of prevalence estimates based on self-report data can be monitored by drug testing biological specimens such as urine, saliva, sweat, and hair. Qualitative urinalysis (positive/negative drug use) is the most widely used technique and provides an objective measure of determining whether recent drug use has occurred over the past 2 to 4 days. Recently, interest has grown in the use of quantitative urine testing (concentration-based testing). Quantitative urine testing may further improve the usefulness of urinalysis by allowing intra- and intergroup comparisons of frequency and extent of drug use. Saliva testing, in comparison to urinalysis, offers different information regarding recency of drug use. The detection times for drugs in saliva are similar to those for blood (4 to 24 hours). Consequently, saliva testing may offer the possibility of revealing current drug use that affects an individual's performance in such complex psychomotor tasks as driving and operating heavy equipment.

Sweat testing has recently become feasible through the development of a new sweat patch device designed to collect nonvolatile drugs of abuse from human skin. The device is applied to the skin like an adhesive bandage. Substances with volatility equal to or greater than water leave the device through a membrane barrier. Less volatile substances (such as drugs) are concentrated on an absorption pad inside the patch. Subjects can wear the patch for periods up to several weeks, followed by removal, storage, and analysis of the contents of the absorption pad. Preliminary studies with the sweat patch indicate that it may be useful for detection of single and multiple drug use over a period of 1 to 4 weeks. Currently, its usefulness as a quantitative measure of drug use is being evaluated.

Hair testing appears to offer the possibility of monitoring drug use over an extended period of time that is dependent upon the length of an individual's hair. Drugs are sequestered in hair and remain bound for an extensive period of time. Because hair grows at an average rate of 1.0 to 1.5 cm per month, analysis of segments of hair for drug content can reveal historical drug use dating back months to years. Recent prevalence studies have indicated that substantially higher drug use rates are generally revealed by hair analysis than by urinalysis or self-report.

How each of the new drug-detection technologies will be used in the future for measuring drug prevalence is uncertain; however, it is clear that even greater reliance will be placed on chemical testing as a means of validating self-report. The technological base and general understanding of the usefulness of urine, saliva, sweat, and hair as

specimens for drug detection are certain to evolve at an even greater rate. The use of different biological specimens offers uniquely different information regarding the extent, frequency, and impact of drug use in selected populations.

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