# Estimating the prevalence of problematic drug use: a review of methods and their application

**M. HICKMAN**

*Centre for Research on Drugs and Health Behaviour, Imperial College, University of London, London*

**C. TAYLOR**

*National Addiction Centre, London*

**A. CHATTERJEE**

*Joint United Nations Programme on HIV/AIDS, Geneva, Switzerland*

**L. DEGENHARDT**

*National Drug and Alcohol Research Centre, University of New South Wales, New South Wales, Australia*

**M. FRISCHER**

*Department of Medicines Management, Keele University, Keele, United Kingdom of Great Britain and Northern Ireland*

**G. HAY**

*Centre for Drug Misuse Research, University of Glasgow, Glasgow, United Kingdom*

**K. TILLING**

*Department of Social Medicine, University of Bristol, Bristol, United Kingdom*

**L. WIESSING**

*European Monitoring Centre for Drugs and Drug Addiction, Lisbon*

**P. GRIFFITHS and R. McKETIN**

*United Nations Office on Drugs and Crime, Vienna*

## ABSTRACT

*Policy makers increasingly need estimates of the prevalence of problematic drug use, such as injecting and the use of "crack". In the present article, the authors review indirect methods of estimating the prevalence of problematic drug use. Those methods utilize existing data on a sample of problematic drug users as "raw" material and then "indirectly" estimate the proportion of the total number of problematic drug*

*users sampled in the raw material; that is, the methods estimate the sampling inten-sity of the raw data. That analogy is used to explain a number of indirect estimation techniques, focusing on capture-recapture and multiplier methods, the methods most often used in settings in developing countries. Assumptions underpinning indirect estimation techniques are presented, together with examples of their application. In addition, there is a discussion of the need to develop routine data sources that can be used in indirect prevalence estimation procedures.*

*Keywords*:   injecting drug use; problem drug use; capture-recapture; multipliers; indirect estimation; prevalence; epidemiology.

## Introduction

Injecting drug use affects over 135 countries. It is estimated that there are as many as 3 million injecting drug users worldwide who have been infected with the human immunodeficiency virus (HIV). Between 5 and 10 per cent of all HIV infec-tions were acquired through injecting drug use; in some countries in Asia and Europe, injecting drug use accounts for over one half of HIV infections [1]. Policy makers need prevalence estimates to inform them and help guide them in formu-lating drug policy [2]; yet there is a dearth of reliable and valid estimates of inject-ing drug use around the world. Prevalence estimates, such as estimates of the number of heroin users or injecting drug users in the population, are required for several aspects of policy-making: planning and allocating resources for the control, treatment and prevention of problematic drug use and its consequences; monitor-ing key targets of drug policy, such as assessing coverage of treatment and harm reduction activities; and assisting in the interpretation of other data and research on drug-related consequences. Because of the limitations of the survey methodol-ogy in making such prevalence estimates [3], alternative, less costly techniques have been developed by drug abuse epidemiologists. That has led to an increasing number of manuals and review papers on prevalence estimation methods [4-8].

## Limitations of survey approaches

Properly conducted population or general household surveys can be considered the "gold standard" for estimating how many people are in a target population and can be effective in monitoring common drug use behaviour, such as tobacco, alco-hol or cannabis use, among the population. However, population surveys are less effective in estimating more problematic forms of drug use, such as heroin use or injecting drug use. There are several reasons for that. First, those forms of drug use are uncommon; even in surveys involving tens of thousands of people, only a few hundred people will experience problematic drug use behaviour, and even fewer will willingly report on such behaviour because of the stigma associated with it. Secondly, survey respondents tend to underreport the more serious forms of drug use. Thirdly, general household surveys tend to "miss" a lot of problematic drug users because of the lifestyle of the drug user. In particular, problematic drug users

tend to cluster in certain geographical areas and are less likely to reside in conventional housing; and usually, a certain proportion of such users are incarcerated in residential treatment or other similar facilities and are therefore not taken into account in such surveys. Such biases usually result in an underestimation of the population size of problematic drug users; that means that patterns of problematic drug use, such as injecting drug use, are simply not measured reliably enough or in sufficient numbers to measure prevalence or detect significant changes over time [9].

## Indirect estimation methods

Several methods have been developed to make indirect estimates of the prevalence of problematic drug use and other socially stigmatized behaviours:

> Capture-recapture methods—closed populations
> Capture-recapture methods—open populations
> Multiplier methods
> Event-based multipliers
> Synthetic estimation/multiple indicator methods
> Truncated Poisson
> Back-calculation

The methods are based on having access to existing data sources that correctly identify cases of problematic drug use and on being able to then establish what proportion of the population of problematic drug users is represented in those data sources.

To more accurately measure the size of the population of problematic drug users, a number of indirect estimation methods have been developed. In the present article, the authors review the more common indirect estimation methods, their assumptions and their application. The article focuses on heroin use and injecting drug use, as they are the subject of many indirect estimation techniques and are perhaps responsible for the greatest public health burden.

## Capture-recapture

Bishop and others were among the first to identify the potential for capture- recapture methods in estimating the prevalence of addiction [10]. Capture-recapture methods had been developed by animal ecologists as one method among others of estimating animal abundance [11, 12]. Early in the twentieth century they were co-opted for use in estimating the undercount of census populations; more recently, they have been used extensively in epidemiological studies, in particular to estimate the underreporting of surveillance systems [13-16]. (For a fuller discussion of capture-recapture methods, see Fienberg [14] and Hook and Regal [15].)

In essence, capture-recapture involves the collection of two or more sources of data on problematic drug users. Information on the number of matches between the data sources (the number of people that occur in more than one data source)

is used to estimate the proportion of the total number of problematic drug users in the sample. These are then combined to generate the prevalence estimate. An example for two samples is shown in figure I.

Figure I shows the number of people in two data sources, $n_1$ and $n_2$, and $m$ matches of people registered in both data sources. Together, those parameters are used to estimate $N$, the total population of problematic drug users. The method assumes that $n_1/N$ is equivalent to $m/n_2$. For example, Mastro and others carried out a two-sample study in Bangkok in 1991 [17] (see figure II). The first sample consisted of 4,064 heroin users in methadone treatment, and the second consisted of 1,540 arrested persons whose urine samples were found to be opioid-positive. There were 171 people listed in both samples, giving an estimate of 36,600 opiate users, or 0.5 per cent of the total population of Bangkok in 1991. Capture-recapture can also be used with multiple samples and without lists of names as the data sources. Those methods will be discussed following consideration of the assumptions underpinning capture-recapture methodology.

Figure I.   Using the capture-recapture method with two data sources

|  |  | Data source 2 (S2) | | |
|---|---|---|---|---|
|  |  | Yes | No |  |
| Data source 1 (S1) | Yes | a (m) | b | $n_1$ |
|  | No | c | ? (x) |  |
|  |  | $n_2$ |  | N |

Assuming $n_1/N = m/n_2$,

then the population estimate $N = (n_1 \times n_2)/m$

Number observed $n = a + b + c$

Number unobserved/hidden $x = N - n$, or $(c \times b)/a$

Confidence interval 95 per cent $= 1.96 \sqrt{(n_1 \times n_2 \times b \times c)/m^3}$

*Source*: T. D. Mastro and others, "Estimating the number of HIV-infected injection drug users in Bangkok: a capture-recapture method", *American Journal of Public Health*, vol. 84, No. 7 (1994), pp. 1094-1099.

*a* or *m* = matches or marks; number of people in both S1 and S2

*b*  = number of people in S1 but not in S2

*c*  = number of people in S2 but not in S1

*x*  = hidden population; number of people not in S1 or S2

$n_1$  = number of people in S1

$n_2$  = number of people in S2

*N*  = total population

Figure II.   Estimating the number of injecting drug users in Bangkok, 1991

| Data Source | | Arrestees with opioid-positive urine samples (S2) | | |
| --- | --- | --- | --- | --- |
| | | Yes | No | |
| Methadone maintenance (S1) | Yes | 171 | 3 893 | 4 064 |
| | No | 1 369 | ? ($x$) | |
| | | 1 540 | | $N$ |

Population estimate $N = (n_1 \times n_2)/m = (4{,}064 \times 1{,}540)/171 = 36{,}599$

Number observed $n = a + b + c = 171 + 3{,}893 + 1{,}369 = 5{,}433$

Number hidden $x = N - n$ (or $(c \times b)/a$) = $36{,}599 - 5{,}433$ (or $(1{,}369 \times 3{,}893)/171$) = $31{,}166$

Confidence interval 95 per cent = $1.96 \sqrt{(n_1 \times n_2 \times b \times c)/m^3}$

$= 1.96 \sqrt{(1{,}540 \times 4{,}064 \times 3{,}893 \times 1{,}369)/171^3} = 4{,}516$

Rounded estimate of the number of injecting drug users in Bangkok in 1991: 36,600 (32,000-40,800)

*Source*: T. D. Mastro and others, "Estimating the number of HIV-infected injection drug users in Bangkok: a capture-recapture method", *American Journal of Public Health*, vol. 84, No. 7 (1994), pp. 1094-1099.

$a$ or $m$ = matches or marks; number of people in both S1 and S2

$b$ = number of people in S1 but not in S2

$c$ = number of people in S2 but not in S1

$x$ = hidden population; number of people not in S1 or S2

$n_1$ = number of people in S1

$n_2$ = number of people in S2

$N$ = total population

The main assumptions of the capture-recapture method are: *(a)* independence of the data sources; *(b)* homogeneity of the data sources; *(c)* correct classification of cases; *(d)* having a closed population; and *(e)* the data sources being representative of the population that is being studied. In practice, it is inevitable that almost all of the assumptions are violated to some extent. That does not detract from the value of the prevalence estimate and the exercise, but it is important to "treat and tread cautiously" in critically reviewing capture-recapture studies of problematic drug use.

The assumption of independence refers to the likelihood that, if a person is listed in one data source, his or her listing in a second data source being used in

the capture-recapture estimation is random and independent of the first data source. That assumption cannot be tested with only two data sources; however, if three or more sources of data are available, then violating that assumption can be overcome to some extent. That advantage comes at a slight cost as more complex statistical methods are required. Log-linear models are used to fit "dependencies", or interactions between the data sources, and to generate an adjusted prevalence estimate. The methods can be taught relatively quickly to someone with rudimentary statistical knowledge using statistical software, such as SPSS or Stata or Generalized Linear Interactive Modelling (GLIM) [6]. Alternatively, estimates can be calculated using formulae provided by Bishop and others [10]. Instead of assuming independence of data sources, multi-source capture-recapture assumes that there is no interaction or interdependency between all of the data samples. Evidence of relationships between each pair of sources may suggest that that assumption has been violated.

Homogeneity of the data sources requires that all problematic drug users are equally likely to turn up on a data source. When certain subgroups of drug users are more likely to show up in a particular data source (for example, representation on treatment admission data would be affected by the accessibility of services, the severity of the drug problem and so on), then heterogeneity of the data sources becomes a problem. Hook and Regal have argued that heterogeneity is inevitable when using health data [15] and therefore comparisons of key variables across data sets should always be conducted prior to final analysis. The effects of heterogeneity can be limited by stratifying the subjects on those characteristics that may confound the analyses and running separate models (for males and females or for different age groups). The only problem with that solution is that the data required to run separate models may be missing. At the least, stratification should be carried out to check for evidence of heterogeneity. More complex models have been developed that allow the fitting of covariates within a single model, but they require greater statistical expertise and have not yet been conducted in studies of problematic drug use [18].

Correct classification refers to the extent to which all the subjects in the data sources are correctly identified as problematic drug users and that all matches between data sources are correctly identified. Bias due to misclassification is reduced if there are sufficient data to identify matches adequately and the data sources are accurate and reliable—both of which may be challenging when collecting data on problematic drug users.

Maintaining a closed population would require that there was no migration, no deaths and no new cases of problematic drug users during the study period. That is clearly impossible, but the bias can be limited if the study time interval is short in comparison with the life cycle of the subject (for example, one year or less).

The assumption of representativeness refers to whether the data sources used in the study are representative of the target population. That is less of an issue with animal studies or many epidemiological capture-recapture studies: for example, fish caught from a lake clearly represent the target population ("fish in the

lake"). There are implications, however, for problematic drug use as each potential data source only partially covers the target population. At any particular point in time, the definition of a problematic drug user as "a person who experiences social, psychological, physical or legal problems and/or dependence as a consequence of his or her own use of drugs" implies that studies should include treatment and criminal justice data sources. Similarly, it is questionable whether studies that use only data sources of problematic drug users in treatment are able to estimate the total population of "problematic drug users".

Capture-recapture studies of problematic drug use need to be scrutinized more carefully than studies of other health problems because of the difficulties in obtaining either large or representative samples of problematic drug users [19-21].

Finally, in capture-recapture there remains what Cormack calls a "leap of faith" [22]. It is assumed that the model that fits the observed data applies also to the "unobserved" population. But there is no way of testing that assumption. It is important, therefore, to use other knowledge and expertise to judge whether the estimates make sense—and ideally seek corroborating evidence.

## Example of a capture-recapture study with multiple data sources

Data from a capture-recapture study with multiple data sources are shown in tables 1 and 2 [23]. Table 1 shows the data after matching four data sources: *(a)* HIV tests mentioning injecting drug use; *(b)* attendees of specialist drug treatment centres; *(c)* attendees of needle exchange programmes; and *(d)* police arrests for possession of heroin or benzodiazepines. All the data sources provided information on the date of birth, sex and initials of the drug user (the first character of his or her first name and the first character of his or her surname), which could be used for matching. A total of 3,760 records were collected from the four data sources, representing 2,866 individual reports after matching, 4 of which were represented in all four data sources.

Table 1.   Capture-recapture study in Glasgow: 3,760 reports of injecting drug users from four data sources, 1990

| | Data source | | | | | |
|---|---|---|---|---|---|---|
| | | *HIV test* | *Yes* | *Yes* | *No* | *No* |
| *Police* | *Needle exchange programme* | *Drug treatment centre* | *Yes* | *No* | *Yes* | *No* |
| *Yes* | *Yes* | | 4 | 2 | 13 | 56 |
| *Yes* | *No* | | 8 | 17 | 50 | 358 |
| *No* | *Yes* | | 41 | 52 | 147 | 864 |
| *No* | *No* | | 116 | 267 | 871 | X |

*Source:* M. Frischer and others, "Estimating the population prevalence of injection drug use and infection with human immunodeficiency virus among injection drug abusers in Glasgow, Scotland", *American Journal of Epidemiology,* vol. 138, No. 3 (1993), pp. 170-181.

Table 2.  Capture-recapture study in Glasgow: prevalence estimates overall and by sex and age group, 1990

| Group | Known | Estimate of hidden | Total | Prevalence (percentage) |
|---|---|---|---|---|
| All | 2 866 | 5 628 | 8 494 | 1.4 |
| Males | 1 977 | 3 567 | 5 544 | 1.8 |
| Females | 889 | 2 349 | 3 238 | 1.0 |
| Age group | | | | |
| 15-19 | 264 | 640 | 904 | 1.0 |
| 20-24 | 1 137 | 1 613 | 2 750 | 2.6 |
| 25-29 | 878 | 1 724 | 2 602 | 2.7 |
| 30-34 | 342 | 796 | 1 138 | 1.4 |
| 35 or older | 245 | 1 273 | 1 518 | 0.6 |

*Source*: M. Frischer and others, "Estimating the population prevalence of injection drug use and infection with human immunodeficiency virus among injection drug abusers in Glasgow, Scotland", *American Journal of Epidemiology*, vol. 138, No. 3 (1993), pp. 170-181.

Log-linear models were used to estimate $x$ the hidden number of injecting drug users who were not included in any of the data sources in the study. Such analysis is aimed at selecting the model that is the simplest (the one with the fewest interactions) and the best fitting to estimate the prevalence. Model selection is tested in a number of ways. The absolute goodness of fit ($G^2$, or deviance between the observed and the expected values) of the model approximates to a chi-square distribution, with a lower deviance implying that the model fits the data better (that is, that the observed and the expected values were closer). Rival models also can be compared using a log-likelihood ratio test (LRT) [24] for models with different degrees of freedom (for example, independent versus a model with one interaction or a model with one interaction versus a model with two interactions). Recently, two other methods (the Akaike information criterion (AIC) and the Bayesian information criterion (BIC)) have been proposed to support $G^2$, which can be used to compare models that have the same degrees of freedom (for example, a model with interaction between data sources S1 and S2 compared with a model with interaction between data sources S2 and S3) [25, 26].

The best-fitting model in the Glasgow example (see table 2) found positive interactions between three data sources (three two-way interactions and one three-way interaction between HIV tests, needle exchange programmes and drug treatment centres). That means that injecting drug users on one of the lists were more likely to be on the others. The police source, arrests for drug possession, was independent of the other data sources. It was estimated that there were 8,500 injecting drug users (1.35 per cent of persons aged 15-54). There were sufficient data to provide prevalence estimates by sex and age group. Those estimates, which were used extensively by local policy makers, led to an increase in needle exchange services in the city [27]. Ninety-five per cent confidence intervals were calculated around the overall estimate as 7,500-9,700 (1.2-1.5 per cent).

Confidence intervals can be estimated directly from the models based on standard equations of variance, as given by Bishop and others [10]. Alternatively, a goodness-of-fit approach, where values for the lower and upper confidence intervals are inputted into the contingency table until a difference of 3.84 (95 per cent) is found in $G^2$ [28, 29]; or through bootstrap methods [30]. Confidence intervals are useful statistical measures of uncertainty about the sample, based on the size of the data sources, the number of matches and the complexity of the model; however, they say nothing about the reliability of the model or about how true the estimate is.

## Capture-recapture: without lists or routine data sources

The examples of capture-recapture presented above (and many studies in the literature) are based on collecting data sources with names or some form of identifier (such as initials, date of birth and sex). That is not always possible, but there are other ways of doing capture-recapture studies. An example of one of those approaches was a study conducted in Bangladesh to estimate the number of street-based sex workers in Dhaka using ethnographic fieldwork. In the study, which was carried out as part of the SHAKTI Project established by CARE Bangladesh, several categories of key informants were interviewed (sex workers, pimps, rickshaw and taxi drivers, police and local *mastans* ("toughs")) to map the dimensions of the sex-work scene (by location and time). With the help of sex workers, red cards were distributed in all known locations of the city, from late in the evening to midnight. The red card could be used for a free health check-up in one of the clinics for reproductive health and primary health care in the city. Since the cards were numbered, a sample of the number of cards distributed (that is, the capture sample ($n_1$)), was easily obtained. Then green cards were distributed. The green cards could also be used for free health care ($n_2$). The sex workers were asked only one question: whether they had received a red card earlier ($m$). The estimated number of street-based sex workers ($N$) was around 5,000; that number was derived from the data using the simple calculation presented in figure I. If the study had been extended over a series of nights with different coloured cards corresponding to different sampling days, more sophisticated "open" capture-recapture models could have been used.

A more sophisticated version of that methodology was used to estimate the number of street prostitutes in Glasgow [31]. It involved identifying how many street prostitutes were working over a period of time and noting how many were working on each night and if they had been observed on previous nights. In total, 206 women (of whom 147, or 71 per cent, were injecting drug users) were interviewed. The capture histories of the women suggested that the population remained constant at around 200 per night but that the population changed by approximately 8 per cent per week, giving an annual total of about 1,150 prostitutes.

## Multiplier methods

Multiplier methods, also referred to as ratio-estimation, come in a variety of guises [5]. In essence, they have two elements in common:

*(a) The benchmark*. The benchmark ($B$) is a data source that captures the number of problematic drug users who have experienced a particular event, such as the number of problematic drug users who have been in treatment, who have been arrested or who have died of an overdose;

*(b) The multiplier*. The multiplier ($M$) is an estimate of the proportion of problematic drug users who have experienced the event recorded by the benchmark, such as the proportion of such drug users who have been in treatment, who have been arrested or who have died of an overdose. That information is usually obtained independently of the benchmark data. The inverse of that proportion is the multiplier, which is an indirect estimate of the proportion of the total population of problematic drug users represented in the benchmark data. For example, if the proportion is 10 per cent, then the multiplier is 1/0.1, or 10, and the sampling intensity is 1 in 10.

The prevalence is calculated by multiplying the benchmark by the multiplier ($B$ x $M$). For example, if the benchmark is 100 and the multiplier is 10, then the prevalence is 1,000.

Theoretically, the two-sample capture-recapture mentioned above (see figures I and II) could be reduced to a multiplier method—with the first data source as the benchmark and the proportion of problematic drug users from the first data source also found in the second data source as the multiplier. However, capture-recapture involves the collection and merging of data sources that are explicitly linked together. That is even true when the capture-recapture is done without identifiers, as linkage is formed by asking the second study sample whether they were included in the first sample. In contrast, it is not a necessity in multiplier studies for the benchmark and multiplier to be collected together; it is only necessary that they refer to each other. The benchmark could be simply a number given to the researchers by a service, and the multiplier could be obtained from another study or the literature.

Nomination also has been used to obtain a multiplier [5, 32, 33]. In such a case, a sample of people (for example, injecting drug users) is asked questions about their friends or acquaintances (that is, their "nominees") who also are injecting drug users. For example, Parker, Bakx and Newcombe conducted a study with 60 injecting drug users who were asked to nominate their five closest acquaintances and say how many of them had been in treatment during the previous year. The 60 injecting drug users reported 300 other injecting drug users. After removing duplicates, that number was reduced to 170, of whom 55 were identified as being in treatment. That gave a proportion of 32.4 per cent and a multiplier of 3.1 [32]. Hartnoll and others also used the nomination technique in one of their studies in London [33].

Figure III shows a multiplier study produced by Archibald and others for Toronto, Canada [34]. Laboratory reports of HIV tests indicating injecting drug use as the reason for testing were used as the benchmark; and a survey in which injecting drug users were asked whether they had been tested for HIV in the previous year was used as the multiplier. In multiplier studies of mortality, estimates of the overdose mortality rate among injecting drug users are used as the multiplier and the number of deaths caused by opiate overdose is used as the benchmark [5, 33]. Multiplier methods have also been applied in settings in developing countries [35].

Figure III.    Multiplier study based on human immunodeficiency virus (HIV) tests in Toronto

| | | |
|---|---|---|
| Benchmark (*B*) | Number of HIV tests by injecting drug users in 1996:[a] | 4,050 |
| Multiplier (*M*) | Proportion of injecting drug users reporting having had an HIV test in the previous year:[b] 23 per cent 1/0.23 = 4.35 | |
| Prevalence estimate (*B* x *M*) | 4,050 x 4.35 = 17,600 | |

[a]Based on laboratory reports.
[b]Based on community-recruited survey of injecting drug users.

## Assumptions

The key assumptions of the multiplier approach are that the estimate of the multiplier (or the estimate of the proportion of those in the target population who experienced the event recorded by the benchmark) is representative and unbiased. Ideally, the estimate is obtained from a representative sample of problematic drug users and collected in the time period and in a place corresponding to the benchmark. That rarely happens. Archibald and others [34] used a multiplier from a survey of injecting drug users that had been carried out in one city and assumed that it would be the same in Toronto. Truly random representative samples of problematic drug users do not exist. The best that can be done is to recruit subjects in a way that limits any potential bias [36]. For example, it would be foolhardy to attempt to generate an unbiased estimate of the proportion of registered injecting drug users for a multiplier estimate by recruiting injecting drug users directly outside a needle exchange facility and asking how many are registered with a needle exchange programme.

In practice, it is assumed that the benchmark event is common enough and significant enough to be remembered or detected in a sample of problematic drug

users and that it is truthfully reported. It is assumed, for example, that going to treatment or being arrested for drug possession will be accurately reported by a sample of problematic drug users (and that there is no conflict of interest that may influence willingness to respond). It is also assumed that the benchmark data are accurate and complete. Unfortunately, routine data sources can be notoriously unreliable because of underreporting or incomplete data collection. In the Canadian study described above, for example, it was noted that the laboratories might undercount the number of tests carried out and that clinicians ordering tests did not always specify whether the person to be tested was an injecting drug user. Therefore, the benchmark might need to be adjusted to take into account underreporting.

Violation of one or all of the above-mentioned assumptions is possible, introducing bias into the estimation. Studies need to be critically evaluated in terms of how the multiplier was obtained and how reliable it is for problematic drug users in a specific time and place, as well as how the benchmark was obtained and how reliable it is. Confidence intervals around the estimate may give a spurious sense of precision, since they do not take into account potential bias. It would be better to make an "evidence-based judgement"—that is, to compare the findings from a single multiplier study with other estimates generated in other multiplier studies or using other methodologies to give a range of prevalence estimates. Multi-method studies spread the risk and expand the evidence base. For example, in Tolgliatti, Russian Federation, approximately 1,000 km south of Moscow, a community-recruited survey of injecting drug users was used to collect saliva to estimate HIV prevalence [37], behavioural data and a number of multipliers. The multipliers included the proportion of injecting drug users in treatment (narcology), listed in a central addict register, registered with a needle exchange programme, arrested for possession of drugs, tested for HIV and treated at a hospital for overdose. In addition, data from treatment facilities, HIV tests and police arrests are being collected for a capture-recapture study.

## Advanced estimation methods

The use of some indirect estimation methods in estimating the number of problematic drug users (see the list in the beginning of the present article) is still being developed. Current examples of their use are limited mostly to settings in developed countries.

An advanced "multiplier" method, utilizing the number of events as a multiplier, has been piloted in the United States of America, in Chicago [38]. The benchmark data are numbers of events (for example, the number of times that a heroin user has turned up at a shelter or the number of heroin users arrested by the police), which are collected as systematically as possible. The multiplier is a rate (the annual rate at which a heroin user turns up at a shelter or is arrested). What is novel in that approach is that advanced statistics are used to generate an "unbiased" event rate by "reweighting" three or more potentially biased samples

(for example, asking problematic drug users in police cells, shelters or treatment facilities whether they have been arrested). There are plans to pilot the procedure in Mexico [39]; if successful, that will have important implications for the application of the procedure in other settings.

While capture-recapture methods require two or more sources of data on drug use, a method known as truncated Poisson can sometimes provide prevalence estimates from a single source of data [40]. That method can be applied when data are available in the form of counts of individuals who appear in a single data source once, twice and so on. That comprises the "raw" material. Those who are never seen fall into the zero-frequency class and are missing from the observed series of frequencies. Naturally, the total population size equals the number of persons "ever seen" plus the number of persons "never seen". If the number of unseen drug users can be estimated then, as with the capture-recapture method, the total prevalence of drug use can be found. That can be done by fitting a Poisson distribution to the complete series of count data that estimate the probability of being seen once, twice and so on, giving the sampling intensity and a prediction of the number not seen. The Poisson process assumes that the counts are random and independent of each other, which some view as restricting its application in prevalence estimation [41].

Finally, Law and others have used back-calculation methods developed in acquired immunodeficiency syndrome (AIDS) epidemiology to estimate the prevalence of heroin injecting from long-term trends in overdose deaths [42]. The "raw" materials are the long-term trends in overdose mortality deaths; estimates of the sampling intensity are generated through the modelling process, which makes assumptions over the overdose mortality rate and cessation rate to estimate trends in the incidence of heroin injecting over time. That is, an estimate of the number of injecting heroin users over time that would yield the observed trends in overdose deaths. Projecting the estimates of the incidence forward, allowing for drug cessation and mortality, will give an estimate of the cumulative prevalence of heroin-injecting. The method is still in the initial throes of development; it is unlikely that the use of the method in developing countries will be feasible in the short term, but it could prove exciting and useful if empirical data on mortality and cessation rates of injecting drug users are strengthened.

## City versus country

In general, indirect estimation methods are appropriate for towns and cities where there are sufficient numbers of problematic drug users and existing data sources to allow for a viable study. As an exception to that rule, Hay, McKeganey and Hutchinson updated the estimates for Glasgow and for the rest of Scotland [43] using four sources of data on drug misuse that were available—drug treatment services, general practitioners, the police (arrests for possession of opiates or benzodiazepines) and the court system (mainly in connection with crimes such as theft). The four-sample capture-recapture method was used in most areas of

Scotland. However, in some areas there were insufficient data from general practitioners; therefore those data were combined with drug treatment data in a single "treatment" source. There were only two small areas where there were insufficient data to undertake a capture-recapture analysis; in those areas, a modification of the multiplier method was used to obtain prevalence estimates. By combining the various local estimates from 77 models in 15 health boards and 32 local councils in Scotland, an estimate for Scotland as a whole was generated: 55,800 (43,700-78,400) persons aged 15-54. Thus, the estimate was built up from separate capture-recapture studies within discrete geographical areas.

The use of capture-recapture in cities and areas in Scotland was a unique piece of work that provided credible estimates for most of Scotland (except for certain rural or unpopulated areas, where there were not enough data to run any models). That may not be practicable or possible elsewhere. (An equivalent study in England, for example, would require over 150 separate capture-recapture studies and data collection exercises.) Synthetic estimation or the multiplier indicator method aims to derive a national estimate from prevalence estimations in selected sites (called "anchor points") and indicators of problematic drug use in all sites [44]. In terms of the definition of an indirect method provided here—the "anchor points" are the "raw" material or information about a proportion of the problematic drug use population. The indicators (that is, drug seizures, arrests, drug treatment, deaths resulting from overdose and laboratory reports) are used to estimate the sampling intensity (that is, the proportion of the total population of problematic drug users within the "anchor points"). Regression equations are generated between the "anchor points" and indicators. These are then applied to geographical areas with indicators but without "anchor points" to estimate the prevalence. Summing across all the geographical areas provides a national estimate. This method is possible only after several prevalence studies in areas or cities of a country have been carried out.

## Potential data sources for capture-recapture and benchmarks for multiplier studies

There is a range of data sources that could be used in prevalence estimation, either as a data source for capture-recapture or as a benchmark for a multiplier study:

| *Data source* | *Example* |
| --- | --- |
| Specialized drug treatment facilities | Drug users on methadone, attending treatment agencies or in residential care |
| Low-threshold drug agencies | Drug users attending drop-in sites or contacted by outreach workers |
| Needle exchange programmes | Drug users registered in needle exchange programmes |
| Hospital records | Drug users treated in hospitals because of an overdose |

| | |
|---|---|
| Laboratory reports | Drug users tested for HIV, hepatitis B or hepatitis C |
| Police or prisons | Drug users arrested or imprisoned for drug offences; drug users arrested or imprisoned for other crimes |
| Probation | Drug users on probation |
| Social services—assessments | Drug users assessed by local social services |
| Shelters (hostels) for drug users | Drug users living in shelters (hostels) |
| Addict registers | Drug users reported to a central register |
| Surveys of problematic drug users | Community surveys of drug users |
| Deaths resulting from overdose | Number of deaths due to opiate overdose |

For capture-recapture, data sources can be underestimates of the total number of cases, but each person's name and date of birth need to be accurate in order to avoid misclassification errors. For multiplier studies, however, information on an individual can be missing or wrong but the total number of persons in contact with the service needs to be accurately recorded or capable of being estimated. In addition, the data sources for capture-recapture should be carefully chosen to reduce to a minimum both dependence and heterogeneity. Finally, if the available data sources are poor, it is recommended that steps be taken to improve them for future estimation work. Collecting the data is the most time-consuming part of prevalence estimation work. The time involved in doing such work could be dramatically reduced if contributing to prevalence estimates was one of the objectives of routine data on problematic drug use.

## Conclusions

Indirect estimation techniques provide a relatively cost-effective and accurate method for estimating the extent of problematic drug use (injecting drug use, the use of heroin or "crack" etc.) when compared with conventional population surveys. As such, they provide a particularly attractive option for measuring the extent of problematic drug use in settings in developing countries. Two methods in particular, capture-recapture and multiplier methods, are likely to be appropriate in developing countries. It is important that policy makers and researchers are aware of the assumptions underpinning the methods to aid interpretation and critical evaluation of the findings obtained using an indirect method. Finally, the evidence base on the prevalence of problematic drug use is sorely lacking in many countries. The number of prevalence estimation exercises needs to be increased to address that shortcoming. During that process, attention needs to be given to improving the routine data sources from which estimates are derived and to using multiple methods where possible. Taking those steps will make it easier to derive updated estimates and to improve the robustness of estimates.

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