ESTIMATING DRUG ABUSE EPISODES FROM A SAMPLE OF HOSPITAL EMERGENCY ROOMS

Arthur L. Hughes, National Institute on Drug Abuse
Steven D. Elliott, James D. Colliver, and Richard E. Gruberg CSR, Inc.
Arthur L. Hughes, 5600 Fishers Lane, Rockwall II, Suite 615, Rockville, MD 20857

Key Words: Hospital emergency rooms, drug abuse data, empirical study

1. Introduction

This paper presents the results of an empirical study of several estimators of drug abuse episodes in hospital emergency rooms (ERs) in the coterminous United States. The impetus for conducting such a study was the recent implementation of a new probability sample of hospitals and the need to identify viable estimators for the nonrandom sample used in prior years.

Data on hospital emergency room episodes resulting in the abuse of licit and illicit drugs are collected by the Drug Abuse Warning Network (DAWN) which is a voluntary reporting system sponsored by the National Institute on Drug Abuse (NIDA). The major objectives of DAWN are

- to identify drugs or substances that are currently being abused;
- to determine and monitor drug abuse patterns and trends associated with the detection of new abuse entities, and new combinations of drugs and substances;
- to assess the health hazards of drug abuse; and
- to provide data for national and local area drug abuse policy and planning.

For the purpose of reporting to the DAWN system, drug abuse is the nonmedical use of a drug or substance for psychic effect, dependence, or suicide attempt or gesture (NIDA, 1991).

DAWN is a longitudinal sample survey of hospitals which provides data on the number of drug abuse episodes and the number of drug mentions. A drug abuse episode is a reported ER admission that involved drug abuse. Since one person may make repeated visits to an ER, this number is not synonymous with the number of unique persons involved (NIDA, 1991). Up to four substances can be mentioned in a drug abuse episode. The use of alcohol is reported separately if it is used in combination with another substance. DAWN-eligible hospitals include those operating in the coterminous U.S. which are non-Federal, general surgical and medical, short stay (patient stays less than 30 days) facilities with a 24-hour emergency room. DAWN data are compiled and transmitted in machine-readable form to NIDA on a monthly basis.

2. DAWN Sample Design and Estimation

2.1 Previous Design

DAWN was initiated in September 1972 and was sponsored by the Drug Enforcement Administration (DEA). In 1973, the sample design consisted of 100 percent sampling in 20 metropolitan areas and less than 100 percent sampling in three metropolitan areas and an area called the "National Panel" which is associated with the balance of the coterminous U.S. The National Panel sample was allocated to strata proportional to the number of hospital beds. A 25 percent oversample in the National Panel was drawn to account for initial nonresponse and attrition over time (DEA, 1974). Projection factors based on the number of hospital days on the sampling frame relative to the number of days in the responding sample were calculated for each DAWN area to inflate the reported data. The sample eventually deteriorated to the point where hospitals which dropped out of the sample were replaced in a nonrandom manner with hospitals exhibiting similar demographic and geographic characteristics (NIDA, 1982). Therefore, sample integrity was lost and population representation was suspect.

2.2 Design of the New Sample

NIDA assumed responsibility of DAWN in 1980 and began plans to redesign the hospital sample. In 1982, Ericksen (1982) and Ericksen, Bucher, and Hall (1982) developed a sample design and estimation strategy for DAWN which was later modified by Gfroerer (1988). Implementation of this design began in 1986. By 1989, recruitment progressed to the point where reliable national and selected area estimates could be published from the new sample. The new sample design consisted of a stratified random sample in 21 metropolitan areas and the National Panel (Tables 1 and 2). The target relative standard error (RSE) on the estimate of total drug abuse episodes is 6 percent for the Nation; 6 percent for New York, Chicago, and Los Angeles-Long Beach; and 8 percent for all other areas except: Baltimore, Buffalo, Denver, San Diego, and San Francisco, where all eligible hospitals were selected. The sampling frame was constructed from the American Hospital Association's (AHA) annual survey data file. A total of 685 hospitals were selected from the sampling frame (N=5410) while maximizing the retention of hospitals randomly selected in 1973. Currently, the overall response rate is about 80 percent. Quarterly estimates are produced from weights based on a combined ratio estimator (Cochran, 1977) with an adjustment for unit nonresponse and a ratio adjustment using auxiliary data from the AHA. A sample maintenance procedure was developed to randomly select 'newly eligible' hospitals from the most recent AHA file using the same stratum definitions and selection probabilities.

3. Description of Empirical Study

3.1 The Estimators

Nine estimators were evaluated. In the formulations to follow, each estimator is specified

for a given DAWN area and calendar quarter. Estimates of drug abuse episodes for the coterminous United States are equal to the sum of the DAWN area estimates; quarterly estimates are summed to obtain annual estimates. A unit nonresponse adjustment is either explicitly or implicitly defined in each estimator; however, a partial nonresponse adjustment that will be included in practice was omitted in this study. This quantity is an adjustment that accounts for hospitals reporting data for part of the quarter, and for some estimators is written as

$$D_h = \frac{\sum_j^{r_h} x_{jh}(d/d_{jh})}{\sum_j^{r_h} x_{jh}}$$

where x_{jh} and d_{jh} are the number of ER visits collected from the survey and the number of days reported by hospital j in stratum h respectively. The quantity d is the number of calendar days in the quarter. D_h was excluded from the estimators because its value is usually very close to unity; thus, it will not contribute significantly to the sampling weight.

3.1.1 Design-Based Estimators

Y_{c1}, Y_{c1+}, Y_{c3}, and Y_{c3+} given below are all combined ratio estimators that use ER visit information from the AHA which is available for respondents, nonrespondents, and nonselected facilities.

Estimators Y_{c1} and Y_{c1+}

$$Y_{c1} = \frac{\sum_h \frac{1}{f_h}\sum_j^{r_h} y_{jh}}{\sum_h \frac{1}{f_h}\sum_j^{r_h} X_{jh}} \sum_h \sum_j^{N_h} X_{jh}$$

$$Y_{c1+} = \frac{\sum_h \frac{1}{f_h}\sum_j^{r_h} y_{jh}}{\sum_h \frac{1}{f_h}\sum_j^{r_h} x_{jh}} \sum_h \sum_j^{N_h} X_{jh}$$

where in stratum h:

$f_h = n_h/M_h$ = selection probability,

n_h = number of sample units,

M_h = number of sampling frame units,

r_h = number of respondents,

N_h = number of units in the population,

y_{jh} = number of drug episodes from hospital j,

X_{jh} = number of AHA ER visits, and

x_{jh} = number of DAWN survey ER visits.

Estimators Y_{c3} and Y_{c3+}

$$Y_{c3} = \frac{\sum_h \frac{A_h}{f_h}\sum_j^{r_h} y_{jh}}{\sum_h \frac{A_h}{f_h}\sum_j^{r_h} X_{jh}} \sum_h \sum_j^{N_h} X_{jh}$$

$$Y_{c3+} = \frac{\sum_h \frac{B_h}{f_h}\sum_j^{r_h} y_{jh}}{\sum_h \frac{B_h}{f_h}\sum_j^{r_h} x_{jh}} \sum_h \sum_j^{N_h} X_{jh}$$

where $A_h = \sum_j^{n_h} X_{jh} / \sum_j^{r_h} X_{jh}$ and $B_h = n_h/r_h$.

Unlike Y_{c1} and Y_{c1+}, these two estimators have explicit stratum-level unit nonresponse adjustment factors A_h and B_h. The denominator of Y_{c1} and Y_{c3} contain the number of AHA ER visits while the denominator of Y_{c1+} and Y_{c3+} contain the number of ER visits from the DAWN survey.

Y_{c1} and Y_{c3} performed quite well in Gfroerer's (1988) empirical study of estimators of total episodes in the Chicago PMSA (other estimators in this paper have not been evaluated before). Y_{c3+} is currently used to produce estimates from the new sample. This estimator was chosen because it is similar to Y_{c3} and incorporates a nonresponse adjustment, B_h, that will generally be less extreme than A_h.

3.1.2 Model-Based Estimators

Five estimators were developed without the incorporation of the selection probability so that a comparison between model-based and design-based estimators can be made when used on the new sample. Also, these estimators should provide some insight on potential estimators for the old sample. With the exception of the regression estimator, these estimators resemble poststratification estimators similar in form to the separate ratio and combined ratio estimators.

Estimators Y_{m0} and Y_{m0+}

$$Y_{m0} = \sum_h \left[\sum_j^{N_h} X_{jh} / \sum_j^{r_h} X_{jh}\right] \sum_j^{r_h} y_{jh}$$

$$Y_{m0+} = \sum_h \left[\sum_j^{N_h} X_{jh} / \sum_j^{r_h} x_{jh} \right] \sum_j^{r_h} y_{jh}$$

The bracketed expressions represent the weight for hospital j in stratum h.

Estimators Y_{m1} and Y_{m2}

$$Y_{m1} = \frac{\sum_h \frac{N_h}{r_h} \sum_j^{r_h} y_{jh}}{\sum_h \frac{N_h}{r_h} \sum_j^{r_h} x_{jh}} \sum_h \sum_j^{N_h} X_{jh}$$

$$Y_{m2} = \frac{\sum_h \frac{N_h}{r_h} \sum_j^{r_h} y_{jh}}{\sum_h \frac{N_h}{r_h} \sum_j^{r_h} X_{jh}} \sum_h \sum_j^{N_h} X_{jh}$$

the term N_h/r_h in both of these estimators is similar to the term B_h/f_h in Y_{c3+} which is the product of the inverse selection probability and a unit nonresponse adjustment factor.

Estimator Y_{reg}

The regression-based estimator evaluated was

$$Y_{reg} = \sum_h \sum_j^{r_h} y_{jh} + (a_r + b_r \sum_h \sum_j^{N_h - r_h} X_{jh})$$

where a_h and b_h are ordinary least squares (OLS) regression parameter estimates based on respondent data and the summation, $\sum_j^{N_h - r_h}$, is over the nonrespondents and nonselected units.

3.2 The Simulated Population

The population used to determine "truth" was defined as the set of sampled hospitals that provided data consistently for each month in 1989 (there were 442 out of 504 respondents that met the criterion of reporting at least 98 percent of the time). Each year, about 3 percent of the DAWN-eligible hospitals on the AHA file did not have a chance of selection in the sample (births). For the purpose of this study, 16 birth units were randomly selected and excluded from the allocation and selection of simulated samples; however, these units were included in the population values used in the estimators.

3.3 Determination of Sample Size and Number of Samples

The use of 426 hospitals as the simulated sampling frame resulted in many sparse and empty cells when stratifying based on the area x stratum definitions for the actual sample. As a result, three "pseudo" areas were created by combining the 21 DAWN metropolitan areas based on the rate of cocaine episodes. The criteria for area inclusion are: Area 1—morethan 5 cocaine episodes per 1,000 ER visits; Area 2—between 2 and 5 episodes per 1,000 ER visits; and Area 3—lessthan or equal to 2 episodes per 1,000 ER visits. The National Panel remained intact and was defined to be Area 99 (Table 1).

Each simulated sample contained 170 of the 426 facilities on the frame. Like the sample size for DAWN, the sample size for the simulation investigation (n_{sim}) was determined such that a predetermined level of precision would be achieved. The level of precision necessary for this investigation was that which allows identification of differences between estimators.

In order to calculate n_{sim}, let Δ = 2,272. The total number of episodes on the simulation frame is 113,588, and the value for Δ is 2% of the total. The correlation needed to estimate the variance of the difference between a pair of estimators was assumed to be 0.5. Given these assumptions and a 6 percent RSE on total episodes, the minimum for n_{sim} should be 144 in order to achieve a power of .95 to detect a difference greater than or equal to 2,272 given the null hypotheses of equal estimators. This means that the relative standard error of total episodes based on 144 samples will be 0.5 percent.

3.4 Sample Allocation and Selection Procedures

Optimal allocation was performed using the simulation frame to produce parameter estimates such as the population variance. A 6 percent RSE on total episodes was the target level of precision for National estimates. The optimal sample sizes by pseudo area are presented in Table 3. If the sample size for a particular stratum was less than 4, it was set equal to 4 (provided $N_h \geq 4$). This was done to ensure that enough facilities would be present to allow some to be designated as nonrespondents.

The procedure for selecting the samples was as follows:

1. Assign random numbers to each hospital and sort hospitals within area x stratum by the random number.
2. Select a random start between 0 and the sampling interval ($1/f_h$) to initialize the counter.
3. Select the first hospital whose number equals 1+greatest integer of the random start.
4. Increment the counter by $1/f_h$ and select the next hospital whose number equals 1+greatest integer of the counter.
5. Repeat step 4 until the desired sample size is reached.

The 144 simulated samples were checked to ensure that no samples were duplicated.

Nonresponse adjustment in DAWN influences the sampling weight more than any other factor; therefore, the behavior of the estimators under nonresponse is an important aspect of their overall performance. In order to simulate nonresponse, a subset of facilities was randomly identified in each of the 144 samples and not used in the

estimation. The proportion of facilities in the nonresponse subset was determined for each stratum on the basis of the actual nonresponse pattern in the 1989 DAWN sample.

3.5 Analysis of the Estimators

The performance of the estimators was evaluated on the basis of descriptive statistics on the sampling weights as well as the average relative bias and average mean-square-error. The principal evaluation tool used was the average percent relative bias defined for each estimator as

$$Rel\ bias = 1/144 \sum_{s=1}^{144} \frac{Y_s - Y}{Y} 100$$

where Y_s is the estimate from sample s and Y is the population value. While estimates were computed for each quarter in 1989, only annual estimates are presented. The specific drugs evaluated were total episodes, cocaine, marijuana/hashish, alcohol-in-combination, heroin/morphine, diazepam, methamphetamine/speed, PCP/PCP combinations, and phenobarbital.

4. Results

From the 144 samples, descriptive statistics on the sampling weights for each estimator were produced (Table 4). Compared to the base weight, the mean weight of Y_{c1}, Y_{c3+}, Y_{c1+}, Y_{m1}, and Y_{m2} was about 25 to 40 percent higher. Mean weights for Y_{c3}, Y_{m0}, and Y_{m0+} were somewhat higher due to the presence of several extreme weights that were encountered in some of the National Panel samples. In addition, the maximum weights for these three estimators were 8 to 9 times higher than the maximum base weight. This was due to the relatively high amount of variability in ER visits (either from DAWN or AHA) within a stratum.

Tables 5-9 show the average relative bias of annual estimates for various drugs. Also shown are the "true values" from the simulated population of 442 hospitals. The regression estimator does well when estimating characteristics with large values such as total episodes and alcohol-in-combination but performs much more poorly on less common drugs such as PCP, diazepam, and phenobarbital (Tables 5 and 6). All of the ratio estimators had a relative bias of less than 4.5 percent for National level estimates (Tables 5 and 6).

Much more variability in estimator performance was exhibited in the central city and noncentral city subdomains, and by pseudo area. Y_{m0+} underestimated alcohol-in-combination in the National Panel by 12.4 percent; Y_{m0+} and Y_{c1} underestimated cocaine mentions by 14.6 percent and 10 percent respectively in the National Panel (Tables 8 and 9). In spite of the presence of extreme weights, Y_{m0} generally had lower bias than the other estimators. In this study, hospitals with large weights had little influence on the estimate because they had very few episodes to report. The estimators that performed fairly well overall were Y_{c3+} and Y_{m2}.

5. Summary and Recommendations for Further Work

Several estimators of drug abuse episodes and mentions occurring in hospital emergency rooms were evaluated in a simulation study. Y_{c3+} and Y_{c1} are preferred among the designed-based estimators; Y_{m1} and Y_{m2} are preferred among the model-based estimators. However, much work remains to be done before a suitable estimator for the nonrandom sample is developed. The results on the performance of the model-based estimators may be inconclusive since the simulated samples do not adequately reflect the nature of the nonrandom sample.

The weights for Y_{c3}, Y_{m0}, and Y_{m0+} can be excessive and may inflate the variance for specific drugs. Y_{reg} performed very unpredictably and is not recommended. Of the remaining estimators, Y_{c3+}, Y_{m1}, and Y_{m2} performed well for subdomains such as central city and for individual areas while Y_{c1}, Y_{c3+}, and Y_{m2} did well on topside counts. So overall, Y_{c3+} and Y_{m2} performed very well. The following are recommendations for further work:

- Conduct trend analysis of estimators under various patterns of wave nonresponse (much interest and attention is given to analyzing trends produced from quarterly estimates).
- Select simulated samples which take on the characteristics of the nonrandom samples observed in DAWN so that various model-based estimators can be more realistically assessed.
- Examine more licit drugs such as over-the-counter and other prescription-type drugs.
- Examine the characteristics of bias and variance of the estimates by age, sex, and race/ethnicity.
- Increase the number of simulated samples in order to take a closer look at the performance of estimators within smaller subdomains; in particular, the individual metropolitan areas oversampled in DAWN.

Acknowledgement

The authors wish to thank Eugene Ericksen for his useful comments on an earlier version of this paper.

References

Cochran, W., (1977), Sampling Techniques, 3rd Edition, John Wiley and Sons, New York: 164-169.

Drug Enforcement Administration, (1974), DAWN 2 Analysis, Phase II Report, July 1973-March 1974: i-xi.

Ericksen, E., (1982), Report of the Methods Used to Select a Sample of Emergency Rooms for the Drug Abuse Warning Network (DAWN), Prepared for NIDA by Professional Management Associates, Inc and Mathematica Policy Research, Inc: 18-20.

Ericksen, E., Bucher, R. H., and Hall, J., (1982), Final Report: DAWN Survey Design, Prepared for NIDA by Professional Management Associates, Inc and Mathematica Policy Research, Inc: 45-51.

Gfroerer, J., (1988), Development and Implementation of a Probability Sample Design for the Drug Abuse Warning Network (DAWN), Internal NIDA Working Paper, September 14, 1988.

National Institute on Drug Abuse, (1982), Annual Data 1981, Series I, Number 1, DHHS No. (ADM) 82-1227: 1-3.

National Institute on Drug Abuse, (1991), Annual Emergency Room Data 1990, Series I, Number 10-A, DHHS No. (ADM) 91-1839: 1-13, 115-116.

Table 1. List of DAWN Areas and Definition of Pseudo Areas

Area 1	Area 2	Area 3	Area 99
Wash D.C.	Chicago	Baltimore	Nat. Panel
New Orleans	Seattle	Buffalo	
Newark	Denver	Minneapolis-SP	
Philadelphia	Boston(NECMA)	San Diego	
San Francisco	Dallas	St. Louis-MO-IL	
New York	Miami-Hialeah		
Atlanta	Phoenix		
Detroit			
Los Angeles-LB			
Average cocaine mentions per ER visit (x1000)			
6.1	2.8	1.2	1.2

Table 2. Definition of Sampling Strata

For each of the 21 metropolitan areas:

Stratum	ER Visits	Location	Outpatient department or an Alcohol/Chemical dependency inpatient unit
0	80000+	N/A	N/A
1	<80000	Central city	Both
2	<80000	Central city	One only
3	<80000	Central city	Neither
4	<80000	Suburb	Both
5	<80000	Suburb	One only
6	<80000	Suburb	Neither

For the National Panel:

Stratum	ER Visits	Outpatient department or an Alcohol/Chemical dependency inpatient unit
0	80000+	N/A
7	<80000	Both
8	<80000	One only
9	<80000	Neither

Note: All hospitals were selected with certainty in stratum 0.

Table 3. Distribution of Simulated Population and Sample

Area	Population		Sample Size	No. of Resp
	Frame	Births		
1	158	8	71	58
2	123	4	49	42
3	65	2	32	25
99	80	2	18	15
Total	426	16	170	140

Table 4. Characteristics of Sampling Weights

Est	Mean	Maximum	%CV
Yc1	4.8	21.0	74
Yc3	5.2	73.1	82
Yc3+	4.7	19.1	69
Yc1+	4.5	17.5	66
Ym0	5.9	86.4	112
Ym0+	5.6	74.3	106
Ym1	4.8	20.0	69
Ym2	5.1	24.0	77
Basewgt	3.7	9.3	68

Note: Basewgt=inverse of selection prob.
Minimum weight=1.0 for each estimator.
CV=coefficient of variation.

Table 5. Average % Relative Bias of Annual Estimates

Est	Episodes	Marijuana	Heroin	PCP
Yc1	0.4	1.4	2.5	2.4
Yc3	-0.3	0.2	0.6	0.9
Yc3+	0.2	1.5	2.1	3.5
Yc1+	0.5	2.2	3.5	4.4
Ym0	-1.1	-0.1	-0.3	-0.8
Ym0+	0.1	2.2	2.5	4.1
Ym1	-0.3	1.3	1.2	2.7
Ym2	-0.4	0.5	0.2	1.0
Yreg	0.6	17.1	-0.7	10.7
Pop	117441	7610	16562	4065

Table 6. Average % Relative Bias of Annual Estimates

Est	Alco	Diaz	Phbl	Meth
Yc1	0.9	-1.8	-0.8	-1.4
Yc3	0.2	-1.0	-0.5	-0.5
Yc3+	0.9	-1.6	-1.2	-0.4
Yc1+	1.1	-2.7	-2.0	-2.2
Ym0	-0.2	-1.1	-1.0	-1.0
Ym0+	1.2	-2.2	-2.6	0.3
Ym1	0.6	-1.4	-1.3	0.0
Ym2	0.4	-0.6	-0.1	0.9
Yreg	-1.2	-22.5	-15.8	-1.2
Pop	35394	3140	787	2228

Key: Alco=Alcohol-in-Combination, Diaz=Diazepam, Phbl=Phenobarbital, Meth=Methamphetamine/Speed.

Table 7. Average % Relative Bias of Annual Estimates by Location
(Pseudo areas 1-3 combined, Area 99 excluded)

Est	COCAINE		MARIJUANA	
	Central City		Central City	
	Yes	No	Yes	No
Yc1	3.1	-4.7	3.0	-3.7
Yc3	0.8	-2.9	0.2	-0.5
Yc3+	2.7	-0.6	1.8	1.5
Yc1+	4.7	-2.5	4.3	-2.1
Ym0	-0.4	-0.3	-0.7	1.0
Ym0+	2.8	2.3	2.5	3.0
Ym1	1.1	2.0	0.2	4.6
Ym2	-0.4	0.1	-1.0	3.2
Pop	36195	10265	5220	2102

Table 8. Average % Relative Bias of Annual Estimates by Location

Est	AREAS 1-3 COMBINED				AREA 99	
	Alco		Phbl		Alco	Phbl
	Central City		Central City			
	Yes	No	Yes	No		
Yc1	2.7	-5.2	1.1	-9.4	6.6	7.1
Yc3	0.3	-1.0	-0.9	-1.3	4.3	4.2
Yc3+	1.6	0.5	-0.7	-0.9	-4.5	-5.0
Yc1+	3.7	-3.9	1.0	-9.1	-6.6	-5.9
Ym0	-0.8	1.6	-1.2	-1.5	-0.7	1.3
Ym0+	1.9	2.8	-1.5	-3.1	-12.4	9.2
Ym1	0.0	3.4	-2.0	2.3	-4.4	-4.9
Ym2	-0.9	2.4	-1.9	2.5	5.7	5.3
Pop	23858	9240	525	184	2296	78

Key: Alco=Alcohol-in-Combination, Phbl=Phenobarbital.

Table 9. Average % Relative Bias of Annual Cocaine Estimates by Pseudo Area

Est	Area 1	Area 2	Area 3	Area 99	All Areas
Yc1	0.6	4.7	-0.6	10.0	1.7
Yc3	-0.2	1.1	-1.3	6.1	0.2
Yc3+	3.1	-0.3	-5.7	-1.2	1.8
Yc1+	3.8	2.8	-5.1	-3.3	2.9
Ym0	-0.4	-0.1	-1.7	-2.6	-0.5
Ym0+	4.5	-1.3	-6.6	-14.6	2.1
Ym1	2.3	-0.5	-6.2	-1.5	1.2
Ym2	-0.5	1.1	-1.9	7.7	0.0
Pop	34624	9439	2397	1782	48242