



## Is inhalant use a risk factor for heroin and injection drug use among adolescents in the United States?

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### Abstract

*Purpose:* We examined whether inhalant use was associated with heroin and injection drug use (IDU) among adolescents aged 12 to 17 in the United States.

*Methods:* Data were drawn from the 2002/2003 administrations of the National Survey on Drug Use and Health (NSDUH). We conducted logistic regression analyses to estimate associations of inhalant use with heroin use, heroin injection, and IDU, respectively, among adolescent drug users ( $N=8161$ ).

*Results:* Approximately 30.9% of adolescents had ever used at least one illicit drug. More than one-fifth (22.2%) of adolescents were past-year or recent drug users. Among past-year adolescent drug users, 1.4% had progressed to heroin use and 1.2% reported IDU. Adolescents who had used inhalants and marijuana were 2.8 and 2.9 times as likely as adolescents who had used marijuana but not inhalants to report heroin use and any IDU, respectively. Adolescents who had used inhalants or other drugs but not marijuana were unlikely to use heroin. However, inhalant users, irrespective of their marijuana use histories, had greater odds of IDU than drug users who had not used inhalants. Adolescent drug users who were females, school dropouts, whites, or delinquents had significantly increased odds of heroin use and IDU. Cigarette smoking before the age of 15 was strongly associated with heroin use, and a history of foster care placement was associated with IDU.

*Conclusions:* This national study of American adolescents identifies several subgroups of recent drug users, such as females, school dropouts, and youth who have used inhalants and marijuana, which have substantially increased odds of heroin use and IDU. Screening, prevention, and treatment interventions targeted to these groups might reduce medical and social complications of heroin use and IDU.

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*Keywords:* Adolescents; Heroin use; Inhalant use; Injection drug use; Gender differences; Marijuana use; School dropouts

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## 1. Introduction

Heroin and injection drug use (IDU) are associated with significant morbidity and mortality, including HIV/AIDS, hepatitis, drug overdose, and accidents. Comorbid conditions commonly observed in heroin and injection drug users (IDUs), such as polydrug abuse and psychiatric disorders, further contribute to functional impairments (Ompad et al., 2005; Santibanez et al., 2005; Vlahov et al., 2004). Studies of heroin use and IDU have typically investigated adults and convenience samples (e.g., treatment-seeking drug users). Few investigations have examined correlates of heroin use and IDU among large, representative samples of adolescents (Hopfer, Khuri, Crowley, & Hooks, 2002). Thus, we determined the prevalence of heroin use, heroin injection, and any IDU in a nationally representative sample of adolescents with a focus on understanding their associations with inhalant use (Bennett, Walters, Miller, & Woodall, 2000; Dinwiddie, Reich, & Cloninger, 1991a; Johnson, Schutz, Anthony, & Ensminger, 1995).

Heroin use among adolescents appears to have increased in recent years (Hopfer, Khuri, & Crowley, 2003; Hopfer, Mikulich, & Crowley, 2000). National data from publicly-funded facilities show that treatment admissions for primary heroin addiction have increased in the past decade (Substance Abuse and Mental Health Services Administration [SAMHSA], 2002, 2004a). The proportion of heroin injection admissions among people under 30 increased from 21% in 1992 to 31% in 2002 (SAMHSA, 2004a). Clinical and descriptive studies indicate that many heroin-using youth are IDUs with histories of polysubstance use, psychiatric dysfunction, and criminality (Hopfer et al., 2000, 2002, 2003). Yet it is unclear whether and to what extent these findings generalize to adolescent heroin users in the general population.

IDU has contributed to more than one-third of AIDS cases in the United States and plays a significant role in HIV transmission among adolescents (Centers for Disease Control and Prevention [CDC], 2005a). In 2005, an estimated 25% of all new AIDS cases were directly attributable to IDU; further, some youth engage in prostitution and other high-risk behaviors in order to support their heroin use, which may contribute indirectly to sexually-acquired HIV/AIDS (CDC, 2005b).

Inhalant use is among the most prevalent, pernicious, and poorly understood forms of adolescent substance use (Brouette & Anton, 2001; Kurtzman, Otsuka, & Wahl, 2001). Commonly abused inhalants include toluene, acetone, and various halogenated hydrocarbons; these and other agents can be found in widely available commercial products. Inhalant users may inhale vapors from a bag into which a substance has been deposited, a rag soaked with a substance and placed over the nose or mouth, or directly from a container (American Psychiatric Association, 2000). Intoxication is rapid in onset and similar to alcohol intoxication in its signs. In 2004, 17% of eighth-graders participating in a national survey of middle and high-school American youth reported lifetime inhalant use (Johnston, O'Malley, Bachman, & Schulenberg, 2005).

Although prevalence figures derived from household surveys of inhalant use are typically lower than those identified in national school-based surveys, they are, nonetheless, substantial. Approximately 9% of adolescents aged 12 to 17 participating in the National Household Survey on Drug Abuse (NHSDA) had used inhalants, and 11% of adolescents who used inhalants in the past year met the criteria for inhalant abuse or dependence (Wu, Pilowsky, & Schlenger, 2004). National surveys also document a significant increase in the number of new inhalant users, from 0.6 million in 1994 to 1.2 million in 2000 (SAMHSA, 2003). Comparable figures for new marijuana users (1994: 2.5 million; 2000: 3.0 million) indicate that the rate of growth in new users has been

significantly greater for inhalant than marijuana users, although marijuana remains the more widely abused drug.

Inhalant use may be an important risk factor for heroin use and IDU (Dinwiddie et al., 1991a, Dinwiddie, Reich, & Cloninger, 1991b; Johnson et al., 1995; Schütz, Chilcoat, & Anthony, 1994; Storr, Westergaard, & Anthony, 2005). Dinwiddie et al. (1991b) reported that one-third of the adult IDUs in a convenience sample had used inhalants. The investigators found that adults with a history of inhalant use were 3 times as likely as adults without the history to be IDUs. Johnson et al. (1995) examined 600 African American youth residing in the Woodlawn area of Chicago at ages 16 and 32. Although relatively few inhalant users were identified, the investigators found that youth who had used inhalants prior to age 16 were 9 times as likely as inhalant nonusers to use heroin by age 32. Storr et al. (2005) examined a sample of 2311 urban youth attending public schools in a mid-Atlantic region. Approximately 9% of youth initiated inhalant use prior to age 14; inhalant users were twice as likely as inhalant nonusers to use opiates by young adulthood (Storr et al., 2005).

Like inhalant use (Novins, Beals, & Mitchell, 2001), marijuana use has been conceptualized as a gateway to other drug involvement. Researchers have observed a general developmental sequence of drug use, from initial use of alcohol and/or cigarettes to marijuana use, which is followed by the use of other drugs (Donnermeyer, 1993; Ellickson, Hays, & Bell, 1992; Kandel, Yamaguchi, & Chen, 1992; Yamaguchi & Kandel, 1984). Although questions regarding the nature of the causal relationship between marijuana use and subsequent drug use have been widely debated, the association between marijuana use and other drug use is well established (Kandel, 2003; Lynskey et al., 2003).

In this paper, we determined the independent and conjoint effects of inhalant use and marijuana use on heroin use, heroin injection, and any IDU among adolescents in the general population. Inhalants and marijuana are the drugs most widely used by adolescents and both have been considered “gateway drugs” by some investigators (Costello, Erkanli, Federman, & Angold, 1999; Donnermeyer, 1993; Novins et al., 2001; Vega et al., 2002). However, studies of either drug usually do not consider that many adolescents use both substances, and prior studies of adult, clinical, and convenience samples suggest that inhalant use may be a marker for heroin use and IDU (Bennett et al., 2000; Dinwiddie et al., 1991b).

By disaggregating adolescent drug users into those characterized by histories of inhalant use, marijuana use, inhalant and marijuana use, and other drug use, we were able to estimate the strength of each association with adolescent-onset heroin use and IDU in a recent, large nationally representative sample of American youth. We hypothesized that lifetime marijuana use and inhalant use would be associated with heroin use, heroin injection, and any IDU and that the strength of associations of these behaviors would be particularly elevated for adolescents with histories of marijuana and inhalant use (Wu, Pilowsky, & Schlenger, 2005). Using logistic regression to adjust for demographics while estimating associations of interest, we were also able to evaluate other factors potentially associated with heroin use and IDU, such as dropping out of school, a history of incarceration and foster care placement, the receipt of mental health treatment for emotional problems, early onset of substance use, and frequency of delinquent behaviors. Prior research indicates that family disruption, early cigarette smoking, poor academic performance, dropping out of school, early onset of drug use, polydrug use, delinquent conduct, and incarceration enhance the risk for seriously adverse drug use outcomes, including heroin use and IDU (Crofts, Louie, Rosenthal, & Jolley, 1996; Kiriisci, Vanyukov, & Tarter, 2005; Sutherland & Shepard, 2001; Vega & Gil, 2005).

## 2. Methods

### 2.1. Data source

This study is based on data from the public use files of the 2002 and 2003 National Surveys on Drug Use and Health (NSDUH) (SAMHSA, 2004b). NSDUH is designed to provide population estimates of substance use and its correlates in the U.S. general population. It utilizes multistage area probability sampling methods to select a representative sample of the U.S. civilian, noninstitutionalized population aged 12 or older for participation in the study (e.g., household residents; residents of shelters, rooming houses, and group homes; residents of Alaska and Hawaii; and civilians residing on military bases). Adolescents aged 12 to 17 years were oversampled to improve the precision of their drug use estimates.

NSDUH participants were interviewed in private at their place of residence. Potential participants were assured that their names would not be recorded and that their responses would be kept strictly confidential consistent with Section 501 of the Public Health Service Act. All field interviewers signed a confidentiality agreement, and the procedures and protections were carefully explained to potential participants in the informed consent protocol (e.g., data only be examined in group- rather than individual-level analyses and would be used for the research purpose only). Multiple levels and types of protection were afforded survey participants to enhance rates of participation, increase validity of responses, and ensure that respondents' rights were fully and continuously protected. For adolescents aged 12 to 17, the field interviewer first obtained verbal consent from a parent or guardian. Once parental permission was granted, the field interviewer approached the adolescent and introduced the study using the script to obtain the youth's agreement to participate. Parents were then asked to leave the interview setting to ensure the confidentiality of the youth's responses. Detailed NSDUH field interview methods are reported elsewhere (Research Triangle Institute, 2002a).

The 2002–2003 surveys utilized a computer-assisted interviewing (CAI) methodology to increase the likelihood of valid respondent reports of illicit drug use behaviors. The CAI methodology includes a combination of computer-assisted personal interviewing (CAPI) and audio computer-assisted self-interviewing (ACASI) methodologies. ACASI interviewing was used for questions of a sensitive nature (e.g., substance use). Respondents read questions on the computer screen or questions were read to respondents through headphones and they entered their responses directly into the computer.

In the 2002 and 2003 surveys, a total of approximately 70,000 respondents aged 12 or older completed the interview annually. In both years, a weighted screening response rate of 91% was achieved, and the weighted response rate for adolescents aged 12 to 17 was 90% (SAMHSA, 2004b). Each independent, cross-sectional NSDUH sample was representative of the U.S. general population aged 12 or older. NSDUH design and data collection procedures have been reported in detail elsewhere (SAMHSA, 2003, 2004b).

### 2.2. Study sample

Secondary data analyses were conducted on the public use data file of adolescents aged 12 to 17. There were no significant differences in the distribution of age, gender, school enrollment status, race/ethnicity, family income, and population density across respondents in the two survey years. In this combined sample of adolescents aged 12 to 17 ( $N=35,913$ ), 49% were females, 92% were students, and 37% were members of nonwhite minority groups.

## 2.3. Study variables

### 2.3.1. Heroin use and IDU variables

Principal outcome variables were adolescents' self-reported lifetime use of heroin (yes vs. no) and IDU (yes vs. no). Among heroin users, NSDUH assessed the route of heroin use, including having ever smoked, sniffed or snorted, or injected heroin with a needle. For IDU, additional questions assessed whether respondents had ever injected any other drug (e.g., cocaine, methamphetamine, or any other drug) that was not prescribed for the respondents or that the respondents took solely for the experience or feeling it caused.

### 2.3.2. Social and demographic variables

Social and demographic characteristics included age, gender, race/ethnicity (non-Hispanic white, African American [non-Hispanic black], Hispanic, Native American [American Indian and Alaska Native], Asian [Asian, Pacific Islander, and Native Hawaiian], and more than one race), school enrollment status, total family income, and population density of the area where the respondent resided. School enrollment status was identified using questions that asked respondents whether they were students and whether they were currently enrolled in school. School enrollment responses were dichotomized into *in school* and *not in school* categories. NSDUH classified population density into large metropolitan areas (population  $\geq 1$  million), small metropolitan areas (population  $< 1$  million), and nonmetropolitan areas (outside a standard metropolitan statistical area).

### 2.3.3. Substance use variables

NSDUH assessed respondents' use, recency of use, and age at first use of cigarettes, alcohol, and nine drug classes (inhalants, marijuana, cocaine/crack, heroin, hallucinogens, and nonmedical use of sedatives, tranquilizers, pain relievers, and stimulants). Assessments of drug use included a detailed verbal description of each drug group and lists of qualifying agents. We used lifetime inhalant and marijuana use variables to categorize all drug users into four mutually exclusive subgroups: (1) inhalant users (inhalant users who had never used marijuana, regardless of other drug use), (2) marijuana users (marijuana users who had never used inhalants, regardless of other drug use), (3) inhalant and marijuana users (drug users who had used inhalants and marijuana, regardless of other drug use), and (4) other drug users (drug users who had never used inhalants or marijuana).

*Any drug use* referred to the use of any of the nine drug classes in the lifetime (ever use) or past year (i.e., recent use), regardless of alcohol use status. *Onset of substance use* (cigarettes, alcohol, inhalants, and marijuana) referred to age at first use and was categorized into three subgroups: before 15 years, 15 to 17 years, and no use. The three groups examined in age-of-onset analyses represented youth who initiated relatively early in life (i.e., between ages of 12 and 14 or younger), later in adolescence (i.e., ages of 15 to 17), or who never initiated drug use prior to adulthood. Inhalant use was defined as sniffing or inhaling a substance "for kicks" or to "get high." NSDUH classified inhalants into eleven categories: correction fluid, degreaser, or cleaning fluid; gasoline or lighter fluid; glue, shoe polish, or toluene; ether, halothane, or other anesthetics; lighter gases, butane, or propane; nitrous oxide or whippets; spray paints; lacquer thinner and other paint solvents; amyl nitrite, poppers, rush, or locker room deodorizers; aerosol sprays; and any other inhalants not specified in the above

categories (Wu et al., 2004). The lifetime number of different types of inhalants used was grouped into four categories (1, 2, 3 or more, and no use).

#### *2.3.4. Delinquency and mental health variables*

We also examined the following potential correlates of heroin use and IDU: adolescents' self-reported history of incarceration (ever been in a jail or a detention center) and foster care placement (ever been in foster care), delinquent behaviors, and mental health treatment service utilization (Wu et al., 2004; Wu, Pilowsky et al., 2005; Wu, Schlenger, & Ringwalt, 2005). The following past-year delinquent behaviors were assessed: (a) getting into a serious fight at school or work, (b) taking part in a group fight against another group, (c) carrying a handgun, (d) selling illicit drugs, (e) stealing anything worth more than \$50, and (f) attacking someone with the intent to seriously hurt him or her. These six types of delinquent behaviors were grouped into three categories (none, 1–2, and 3 or more). Mental health service utilization was defined as any use of treatment or counseling at any service location (any medical or mental health setting or school) in the prior year for emotional or behavioral problems other than substance use-related problems (Wu, Schlenger et al., 2005).

#### *2.4. Data analysis*

Data were weighted to reflect the representativeness of the NSDUH sample and were analyzed by SUDAAN software (Research Triangle Institute, 2002b), which applies a Taylor series linearization method to account for NSDUH's complex design effects (weighting). All percentages reported in this paper are weighted estimates, whereas sample sizes are unweighted.

We first examined the prevalence of lifetime use of any drug, heroin use (smoking, sniffing, and injection), and any IDU among adolescents aged 12 to 17. Among the subsample of heroin users, we generated the prevalence of heroin use by their route of heroin use. We then determined the prevalence of heroin use and IDU by pattern of specific drug use, mental health characteristics, delinquency, and history of incarceration among the subsample of adolescents who reported any drug use. To hold constant variations in demographic characteristics, multiple logistic regression procedures (Hosmer & Lemeshow, 2000) were conducted to identify correlates of heroin use and IDU, respectively, among all drug users. We report odds ratios (ORs) to estimate the strength of identified associations.

### **3. Results**

#### *3.1. Prevalence of drug use among adolescents*

The prevalence of drug use by demographics is summarized in Table 1. Among adolescents aged 12 to 17 ( $N=35,913$ ), 31% reported any use of at least one illicit drug in their lifetime. More than one-fifth (22%) of adolescents, or 72% of all lifetime adolescent drug users, used at least one drug in the past year or recently. There were neither gender differences nor yearly variation in the prevalence of drug use. Lifetime drug use was associated with age, race/ethnicity, school enrollment status, and family income. Nearly one-half (47%) of adolescents aged 16 to 17 and Native Americans (49%) had ever used at least one drug. There was a high prevalence of drug use among school dropouts: 60% in their lifetime and 45% recently.

Table 1

Demographic characteristics and prevalence of drug use among adolescents aged 12 to 17 years in the 2002–2003 National Surveys on Drug Use and Health ( $N=35,913$ )

Demographics	2002 <sup>a</sup>	2003 <sup>a</sup>	2002–2003	Prevalence of lifetime drug use		Prevalence of past-year drug use	
	( $N=17,709$ )	( $N=18,204$ )		Column %	Row %	$\chi^2$ ( $df$ )	Row %
Weighted percentage	Column %	Column %	Column %	( $N$ )	$p$ -value <sup>b</sup>	( $N$ )	$p$ -value <sup>b</sup>
Age in years							
12–13	33.7	33.7	33.7 (12,291)	15.4 (1886)	1663.4 (2)	9.3 (1170)	1456.3 (2)
14–15	34.2	33.6	33.9 (12,046)	31.1 (3846)	<0.001	22.7 (2787)	<0.001
16–17	32.1	32.8	32.4 (11,576)	46.8 (5567)		35.1 (4204)	
Gender							
Male	51.1	51.1	51.1 (18,431)	31.7 (5897)	7.6 (1)	22.3 (4168)	0.18 (1)
Female	48.9	48.9	48.9 (17,482)	30.1 (5402)	0.006	22.1 (3993)	0.674
Race/ethnicity							
White	62.8	62.3	62.5 (23,198)	31.7 (7278)	78.5 (5)	23.7 (5425)	131.0 (5)
African American	14.6	15.0	14.8 (4982)	29.7 (1532)	<0.001	19.1 (1000)	<0.001
Hispanic	15.9	16.3	16.1 (5105)	31.1 (1655)		21.2 (1139)	
Native American <sup>c</sup>	0.7	0.7	0.7 (470)	49.2 (220)		34.9 (160)	
Asian <sup>d</sup>	4.4	4.2	4.3 (1165)	19.6 (265)		11.8 (175)	
More than one race	1.7	1.7	1.7 (993)	32.4 (349)		24.6 (262)	
School enrollment							
In school	98.3	98.2	98.3 (35,325)	30.4 (10,914)	103.9 (1)	21.8 (7870)	74.9 (1)
Not in school	1.7	1.8	1.8 (588)	59.8 (385)	<0.001	45.3 (291)	<0.001
Total family income							
\$0–\$19,999	17.7	18.2	18.0 (6474)	33.3 (2235)	34.9 (3)	22.3 (1523)	1.9 (3)
\$20,000–\$39,999	23.2	23.2	23.2 (8607)	32.5 (2914)	<0.001	22.8 (2062)	0.588
\$40,000–\$74,999	32.4	30.9	31.7 (11,876)	30.6 (3601)		22.3 (2629)	
≥\$75,000	26.6	27.6	27.1 (8956)	28.4 (2549)		21.7 (1947)	
Population density							
Large metro	44.8	45.1	45.0 (13,001)	29.9 (3886)	9.2 (2)	21.5 (2810)	4.9 (2)
Small metro	33.1	32.9	33.0 (12,879)	32.2 (4181)	0.010	23.0 (3025)	0.085
Nonmetro	22.1	22.0	22.0 (10,033)	31.3 (3232)		22.4 (2326)	
Survey year							
2002	100	....	49.8 (17,709)	31.0 (5555)	0.03 (1)	22.2 (4005)	0.02 (1)
2003	....	100	50.2 (18,204)	30.9 (5744)	0.858	22.3 (4156)	0.879

<sup>a</sup> Based on the chi-square tests, there was no statistically significant variation between each demographic variable and survey year.

<sup>b</sup> Owing to a large sample size, only  $p$ -values less than or equal to 0.001 are considered significant.

<sup>c</sup> Native American includes American Indians and Alaska Natives.

<sup>d</sup> Asian includes Asians, Pacific Islanders, and Native Hawaiians.

### 3.2. Prevalence of lifetime heroin use and IDU among adolescents

Table 2 displays the prevalence of lifetime heroin use and IDU. These categories of heroin use and IDU were not mutually exclusive. Among adolescents aged 12 to 17 ( $N=35,913$ ), 0.35% had ever used heroin and 0.29% were IDUs. Heroin smoking (0.17%) or sniffing (0.21%) were slightly more common than heroin injection (0.10%). The highest prevalence of heroin use was observed among adolescents

Table 2

Prevalence of lifetime heroin use and injection drug use among adolescents aged 12 to 17 in the 2002–2003 National Surveys on Drug Use and Health, by social and demographic characteristics ( $N=35,913$ )

Social and demographic characteristics	Ever used any heroin		Ever smoked heroin		Ever sniffed heroin		Ever injected heroin		Ever injected any drug	
Overall prevalence (%)	0.35		0.17		0.21		0.10		0.29	
	$\chi^2$ (df)	$p$ -value <sup>a</sup>	$\chi^2$ (df)	$p$ -value <sup>a</sup>	$\chi^2$ (df)	$p$ -value <sup>a</sup>	$\chi^2$ (df)	$p$ -value <sup>a</sup>	$\chi^2$ (df)	$p$ -value <sup>a</sup>
Age										
12–13	0.10	32.5 (2)	0.07	11.2 (2)	0.05	19.5 (2)	0.02	16.6 (2)	0.12	18.4 (2)
14–15	0.33	<0.001	0.17	0.004	0.17	<0.001	0.14	<0.001	0.36	<0.001
16–17	0.64		0.27		0.42		0.13		0.39	
Gender										
Male	0.27	4.0 (1)	0.11	5.3 (1)	0.14	5.3 (1)	0.06	5.6 (1)	0.27	0.2 (1)
Female	0.44	0.045	0.23	0.021	0.29	0.22	0.14	0.018	0.31	0.634
Race/ethnicity										
White	0.41	60.0 (5)	0.18	43.7 (5)	0.25	36.1 (5)	0.11	31.2 (5)	0.32	7.6 (5)
African American	0.07	<0.001	0.05	<0.001	0.01	<0.001	NA	<0.001	0.18	0.184
Hispanic	0.45		0.27		0.26		0.14		0.29	
Native American <sup>b</sup>	0.69		0.41		0.15		0.08		0.08	
Asian <sup>c</sup>	0.01		NA		0.01		NA		0.30	
More than one race	0.50		0.34		0.38		0.17		0.17	
School Enrollment										
In school	0.32	5.6 (1)	0.17	0.5 (1)	0.19	3.2 (1)	0.08	3.6 (1)	0.26	4.5 (1)
Not in school	2.04	0.019	0.39	0.481	1.25	0.070	1.08	0.058	1.70	0.035
Family income										
\$0–\$19,999	0.52	7.5 (3)	0.26	3.9 (3)	0.30	7.4 (3)	0.22	6.5 (3)	0.56	13.7 (3)
\$20,000–\$39,999	0.32	0.059	0.21	0.272	0.10	0.060	0.08	0.090	0.35	0.004
\$40,000–\$74,999	0.40		0.15		0.28		0.07		0.17	
≥\$75,000	0.21		0.10		0.16		0.05		0.20	
Population density										
Large metro	0.31	2.9 (2)	0.12	3.8 (2)	0.20	1.4 (2)	0.07	2.3 (2)	0.23	3.2 (2)
Small metro	0.32	0.240	0.18	0.153	0.17	0.486	0.11	0.323	0.31	0.205
Nonmetro	0.49		0.25		0.29		0.13		0.38	
Survey year										
2002	0.38	0.3 (1)	0.16	0.1 (1)	0.25	1.5 (1)	0.09	0.4 (1)	0.28	0.1 (1)
2003	0.33	0.583	0.18	0.796	0.17	0.229	0.11	0.547	0.30	0.770

NA: estimates are unavailable because of a small sample size.

<sup>a</sup>  $\chi^2$  test: owing to a large sample size, only  $p$ -values less than or equal to 0.001 are considered significant.

<sup>b</sup> Native American includes American Indians and Alaska Natives.

<sup>c</sup> Asian includes Asians, Pacific Islanders, and Native Hawaiians.

aged 16 or 17 (0.64%) and school dropouts (2.04%). African Americans (0.07%) and Asians (0.01%) had a lower prevalence of heroin use than Native Americans (0.69%), youth reporting more than one racial self-identification (0.50%), Hispanics (0.45%), and whites (0.41%).

The vast majority of heroin users either sniffed (60%) or smoked (48%) heroin (Table 3). More than one-fourth (29%) of all heroin users ( $N=135$ ) had ever injected heroin and/or other drugs. More than one-fifth of heroin smokers (22%) and heroin sniffers (21%) had also injected heroin. Close to one-half



Table 3

Prevalence of heroin smoking, heroin sniffing, heroin injecting, and any injection drug use among adolescent heroin users aged 12 to 17

Prevalence, %		Heroin smoking	Heroin sniffing	Heroin injecting	Any injection drug use <sup>a</sup>
Any heroin users	<i>N</i> =135	48.1	59.7	26.4	29.0
Heroin smokers	<i>N</i> =63	100	46.3	22.1	27.1
Heroin sniffers	<i>N</i> =77	37.3	100	21.5	25.9
Heroin injectors	<i>N</i> =46	39.0	47.2	100	100

<sup>a</sup> Having ever injected any drug (heroin, cocaine, methamphetamine, or any other drug) for nonmedical purposes (e.g., for the experience or feeling it causes).

(46%) of heroin smokers also sniffed heroin, and more than one-third (37%) of heroin sniffers also smoked heroin. Of all heroin injectors, 47% reported having ever sniffed heroin and 39% reported having ever smoked heroin.

### 3.3. Prevalence of heroin use and IDU among adolescent drug users

We then examined the prevalence of heroin use and IDU among the subsample of drug users (Table 4). We found that the pattern of the prevalence of heroin use and IDU among lifetime drug users was similar to that of past-year drug users. Here, we focused on heroin use and IDU among past-year drug users because they represent recent or active drug users and excluded former light or experimental drug users who might have tried a drug and had never used it again.

Among all past-year drug users aged 12 to 17 (*N*=8161), 1.4% used heroin and 1.2% were IDUs. The prevalence of heroin use was higher among users of cigarettes (1.8%), inhalants (2.7%), and marijuana (1.8%) than nonusers of these substances. Notably, users of inhalants and marijuana had higher prevalence of lifetime heroin use (4.3%) than users of marijuana but not inhalants (1.0%), users of inhalants but not marijuana (0.2%), or users of other drugs (0.2%). Several subgroups of drug users also had a higher prevalence of heroin use than others, including cigarette smokers who initiated cigarette use before the age of 15 (2.1%), inhalant users who initiated inhalant use between the ages of 15 and 17 (3.7%), and who had used 3 or more inhalants (3.4%), as well as adolescents who engaged in multiple delinquent behaviors recently (4.1%), had a history of incarceration (4.5%), or who received mental health treatment services recently (2.5%).

Of all “gateway” substances (i.e., cigarettes, alcohol, marijuana, and inhalants), only inhalant use was significantly associated with IDU in bivariate analyses. More than 2% of inhalant users were IDUs, with a high prevalence of IDU among adolescents who had initiated inhalant use before age 15 (2.6%), and adolescents who reported 3 or more delinquent behaviors in the past year (3.9%). Adolescents who had used inhalants and marijuana were more likely than users of either inhalants but not marijuana or marijuana but not inhalants and users of the other drugs to become heroin users and IDUs. Despite their young age, 4.3% and 3.0% of adolescents who had used inhalants and marijuana also reported heroin use and IDU, respectively.

### 3.4. Odds ratios for heroin use, injection heroin use, and IDU

To hold constant potentially confounding influences of demographics on dependent variables (e.g., heroin use), we conducted multiple logistic regression analyses (Table 5) to examine correlates of

Table 4

Prevalence of lifetime heroin use and injection drug use among past-year drug users aged 12 to 17 in the 2002 and 2003 National Surveys on Drug Use and Health (N=8161)

Weighted prevalence by lifetime drug use, row %	Ever used any heroin		Ever smoked heroin		Ever sniffed heroin		Ever injected heroin		Ever injected any drug	
Overall prevalence (%)	1.40		0.62		0.89		0.41		1.20	
Prevalence by substance use	$\chi^2$ (df)	p-value <sup>a</sup>	$\chi^2$ (df)	p-value <sup>a</sup>	$\chi^2$ (df)	p-value <sup>a</sup>	$\chi^2$ (df)	p-value <sup>a</sup>	$\chi^2$ (df)	p-value <sup>a</sup>
Cigarette smoking										
Yes	1.80	36.4 (1)	0.79	16.4 (1)	1.18	30.8 (1)	0.52	16.3 (1)	1.32	23.1 (1)
No	0.25	<.001	0.14	<.001	0.06	<.001	0.07	<.001	0.85	0.131
Alcohol use										
Yes	1.55	6.4 (1)	0.71	14.3 (1)	0.98	3.12 (1)	0.47	15.1 (1)	1.22	0.1 (1)
No	0.60	0.012	0.12	<.001	0.38	.078	0.06	<.001	1.08	.779
Inhalant use										
Yes	2.66	18.9 (1)	1.39	13.3 (1)	1.79	11.6 (1)	0.71	5.4 (1)	2.35	18.0 (1)
No	0.80	<.001	0.25	<.001	0.46	<.001	0.26	.021	0.64	<.001
Marijuana use										
Yes	1.83	42.7 (1)	0.83	30.4 (1)	1.17	25.7 (1)	0.54	21.5 (1)	1.29	1.2 (1)
No	0.17	<.001	0.02	<.001	0.10	<.001	0.03	<.001	0.92	.283
Inhalants and marijuana used										
Inhalant users only <sup>b</sup>	0.19	45.3 (3)	NA	32.2 (3)	0.14	29.2 (3)	NA	27.5 (3)	1.38	21.2 (3)
Marijuana users only <sup>b</sup>	0.95	<.001	0.31	<.001	0.56	<.001	0.31	<.001	0.69	<.001
Inhalant and marijuana users <sup>b</sup>	4.29		2.31		2.88		1.17		3.00	
Users of other drugs	0.16		0.03		0.06		0.07		0.46	
Age of first cigarette smoking										
≤14 years	2.13	47.8 (2)	0.94	31.7 (2)	1.39	31.1 (2)	0.63	29.0 (2)	1.49	12.8 (2)
15–17	0.13	<.001	NA	<.001	0.13	<.001	NA	<.001	0.41	0.002
No use	0.25		0.14		0.06		0.07		0.85	
Age of first alcohol use										
≤14 years	1.81	13.7 (2)	0.92	22.9 (2)	1.14	6.0 (2)	0.55	16.4 (2)	1.41	6.7 (2)
15–17	0.73	.001	0.07	<.001	0.50	.052	0.22	<.001	0.61	.035
No use	0.60		0.12		0.38		0.06		1.08	
Age of first inhalant use										
≤14 years	2.33	19.0 (2)	1.47	13.6 (2)	1.30	11.6 (2)	0.79	5.9 (1)	2.56	18.0 (1)
15–17	3.72	<.001	1.15	.001	3.34	.003	0.44	.053	1.71	<.001
No use	0.80		0.25		0.46		0.26		0.64	
Age of first marijuana use										
≤14 years	2.40	51.0 (2)	1.21	32.3 (2)	1.48	28.2 (2)	0.74	23.0 (2)	1.67	11.0 (1)
15–17	0.79	<.001	0.16	<.001	0.60	<.001	0.17	<.001	0.61	.004
No use	0.17		0.02		0.10		0.03		0.92	
Number of inhalants ever used										
None	0.80	19.6 (3)	0.25	13.6 (3)	0.46	12.1 (3)	0.26	7.6 (3)	0.64	19.0 (1)
1	2.50	<.001	0.82	.004	1.81	.007	0.52	.057	1.84	.003
2	1.88		1.26		0.81		0.30		2.12	
≥3 inhalants	3.40		2.20		2.42		1.21		3.18	
Past-year type of delinquent behaviors										
None	0.46	30.0 (2)	0.08	24.8 (2)	0.35	14.0 (3)	0.12	15.7 (3)	0.26	39.5 (3)
1–2	1.33	<.001	0.47	<.001	0.87	.001	0.24	<.001	1.11	<.001
≥3	4.08		2.43		2.39		1.61		3.90	

Table 4 (continued)

Weighted prevalence by lifetime drug use, row %	Ever used any heroin		Ever smoked heroin		Ever sniffed heroin		Ever injected heroin		Ever injected any drug		
Overall prevalence (%)	1.40		0.62		0.89		0.41		1.20		
Prevalence by substance use	$\chi^2$ (df) p-value <sup>a</sup>		$\chi^2$ (df) p-value <sup>a</sup>		$\chi^2$ (df) p-value <sup>a</sup>		$\chi^2$ (df) p-value <sup>a</sup>		$\chi^2$ (df) p-value <sup>a</sup>		
History of foster care placement											
Yes	3.37	3.1 (1)	1.20	0.70 (1)	1.73	0.92 (1)	2.10	3.8 (1)	5.63	8.9 (1)	
No	1.31	.084	0.60	.404	0.85	.338	0.33	.050	1.01	.003	
History of incarceration											
Yes	4.54	12.5 (1)	2.00	7.3 (1)	2.80	8.91 (1)	1.36	5.7 (1)	3.19	10.1 (1)	
No	1.00	<.001	0.45	.007	0.65	.003	0.29	.018	0.94	.002	
Past year use of mental health services											
Yes	2.48	11.8 (1)	1.25	9.0 (1)	1.48	4.9 (1)	0.80	6.5 (1)	2.02	8.4 (1)	
No	1.00	<.001	0.39	.003	0.67	.027	0.26	.011	0.89	.004	

NA: estimates are unavailable because of a small sample size.

<sup>a</sup>  $\chi^2$  test: owing to a large sample size, only *p*-values less than or equal to 0.001 are considered significant.

<sup>b</sup> Regardless of the use of other illicit drugs.

lifetime heroin use, injection heroin use, and any IDU, respectively. The pattern of the findings among lifetime drug users was similar to the pattern of the findings reported here for past-year drug users.

### 3.4.1. Heroin use

Consistent with our bivariate analyses, past-year adolescent drug users who reported a history of inhalant and marijuana use were 2.8 times as likely as those using marijuana but not inhalants to use heroin (adjusted OR [AOR]=2.81, 95% confidence interval [CI]=1.67–4.73). Compared with marijuana users who had not used inhalants, “drug users who had never used marijuana or inhalants” and “inhalant users who had not used marijuana” had very low odds of heroin use, and those associations were marginally significant.

Gender, race/ethnicity, school enrollment status, age of first cigarette smoking, frequency of past-year delinquent behaviors, and history of incarceration also were associated with heroin use. Female drug users were twice as likely as male drug users to use heroin. Whites were similar to Hispanics in heroin use, but they were five (reciprocal of an AOR of 0.19) and ten (reciprocal of an AOR of 0.10) times as likely as African Americans and Asians, respectively, to use heroin. Drug users who initiated cigarette smoking before the age of 15, who engaged in multiple delinquent behaviors recently, or who had a history of incarceration also had elevated odds of heroin use.

### 3.4.2. Injection heroin use

Similar to the pattern of the findings for heroin use, adolescents who had used marijuana and inhalants were twice as likely as those who had used marijuana but not inhalants to inject heroin. This association was marginally significant, which is probably related to a small sample of injection heroin users. The findings also suggested a pattern of very low odds of injection heroin use among the other drug use groups. Female drug users were 3.9 times as likely as male drug users to inject heroin. Increased odds of injection heroin use also were found among school dropouts, those engaging in 3 or more delinquent behaviors recently, and those with a history of foster care placement. Early cigarette smoking was marginally associated with heroin injection.

Table 5

Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) for heroin use, heroin injection, and injection drug use among past-year drug users aged 12 to 17 ( $N=8161$ )

Logistic regression	Any heroin use <sup>3</sup>	Injection heroin use <sup>3</sup>	Any injection drug use <sup>3</sup>
	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Use of inhalants or marijuana			
Inhalant only vs. marijuana only	0.30 (0.06–1.46) <sup>†</sup>	0.23 (0.03–1.90) <sup>†4</sup>	2.38 (1.03–5.49)*
Inhalants and marijuana vs. marijuana only	2.81 (1.67–4.73)***	1.98 (0.92–4.27) <sup>†</sup>	2.86 (1.58–5.20)**
Other drugs vs. marijuana only	0.35 (0.10–1.21) <sup>†</sup>	NA	0.88 (0.27–2.86)
Age group			
14–15 vs. 12–13	.....	.....	.....
16–17 vs. 12–13	.....	.....	.....
Gender			
Female vs. male	2.36 (1.30–4.29)**	3.91 (1.62–9.47)**	1.77 (1.03–3.04)*
Race/ethnicity			
African American vs. white	0.19 (0.05–0.67)**	0.17 (0.03–1.02) <sup>†5</sup>	0.55 (0.20–1.54)
Hispanic vs. white	0.98 (0.45–2.15)	0.61 (0.22–1.70)	0.67 (0.30–1.50)
Native American <sup>1</sup> vs. white	0.55 (0.14–2.21)	NA	0.07 (0.01–0.63)*
Asian <sup>2</sup> vs. white	0.10 (0.01–0.75)*	NA	2.29 (0.29–17.80)
More than one race vs. white	0.68 (0.17–2.74)	NA	0.48 (0.06–3.64)
School enrollment			
No vs. yes	2.32 (1.04–5.20)*	5.48 (1.81–16.59)**	2.85 (1.17–6.96)*
Total family income			
\$0–\$19,999 vs. \$75K+	.....	.....	.....
\$20K–\$39,999 vs. \$75K+	.....	.....	.....
\$40K–\$74K vs. \$75K+	.....	.....	.....
Population density			
Large metro vs. nonmetro	.....	.....	.....
Small metro vs. nonmetro	.....	.....	.....
Age of first cigarette smoking			
≤14 vs. ≥15 years and no use	3.72 (1.82–7.59)***	4.05 (0.85–19.22) <sup>†</sup>	
Age of first alcohol use			
≤14 vs. ≥15 years and no use	.....	.....	.....
Age of first inhalant use			
≤14 vs. ≥15 years and no use	.....	.....	.....
Age of first marijuana use			
≤14 vs. ≥15 years and no use	.....	.....	.....
Number of inhalants used			
1–2 vs. none	.....	.....	.....
3 or more vs. none	.....	.....	.....
Past year delinquent behaviors			
1–2 vs. none	2.33 (1.12–4.82)*	1.73 (0.56–5.37)	3.78 (1.70–8.40)***
3 or more vs. none	5.15 (2.38–11.15)***	11.12 (3.90–31.72)***	12.31 (5.57–27.25)***
History of incarceration			
Yes vs. no	2.87 (1.55–5.31)***	.....	1.69 (0.94–3.02) <sup>†</sup>
History of foster care placement			
Yes vs. no	.....	4.20 (1.85–9.54)***	4.13 (2.04–8.34)***
Mental health service use			
Yes vs. no	.....	.....	.....

### 3.4.3. Any IDU

Adolescents who had used inhalants but not marijuana (AOR=2.38, 95% CI=1.03–5.49) and adolescents who had used marijuana and inhalants (AOR=2.86, 95% CI=1.58–5.20) had increased odds of any IDU compared to youth who had used marijuana but not inhalants. Similar to injection heroin use, females, whites (relative to American Indians or Alaska Natives), school dropouts, youth engaging in delinquent behaviors, and those with a history of foster care placement had increased odds of IDU.

## 4. Discussion

Substance use is normative among U.S. adolescents. Nearly half of all 16–17 year-olds participating in the NSDUH reported a history of illicit drug use. In bivariate analyses, a history of inhalant use, age at onset of inhalant use, and the number of inhalants used were each associated with heroin use and IDU. Perhaps the most salient finding was the elevated prevalence of heroin use and IDU among users of marijuana and inhalants and of IDU among inhalant users who had not used marijuana as compared with marijuana users who had not used inhalants. These findings are consistent with prior studies indicating that inhalant use is a key marker of risk for heroin use and IDU (Dinwiddie et al., 1991b; Johnson et al., 1995; Storr et al., 2005). Our findings also suggest that the risk is elevated when inhalant use is in conjunction with marijuana use, and they extend previous findings to a nationally representative sample of adolescents.

Logistic regression analyses controlling for potentially confounding factors documented the importance of co-occurring inhalant and marijuana use in elevated odds for adolescent-onset heroin and IDU. Adolescent drug users who were females, nonstudents, and those with recent histories of recurrent delinquent behaviors also had increased odds of progression to heroin use and IDU. A history of incarceration and cigarette use before the age of 15 were associated with heroin use, whereas prior foster care placement was associated with IDU. The association between a history of incarceration and IDU did not attain conventional levels of statistical significance, which may be due to low power. These findings are consistent with studies indicating that poor academic performance, dropping out of school, conduct problems, and other indicators of serious psychosocial maladjustment or family disruption are significant predictors of severe drug use problems (Fuller et al., 2002; Kirisci et al., 2005; Neumark & Anthony, 1997; Sutherland & Shepard, 2001). Recent research also suggests that early intervention to reduce early onset of tobacco use (Vega & Gil, 2005) and other forms of substance use and psychosocial dysfunction that typically precede inhalant and marijuana use may also prove useful in disrupting progression to these and other malignant forms of substance use (Kirisci et al., 2005).

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#### Notes to Table 5:

<sup>†</sup> $p < 0.10$ ; \* $p \leq 0.05$ ; \*\*\* $p \leq 0.01$ ; \*\*\*\* $p \leq 0.001$ . <sup>1</sup>Native American includes American Indians and Alaska Natives. <sup>2</sup>Asian includes Asians, Pacific Islanders, and Native Hawaiians. <sup>3</sup>Due to the small sample of heroin users and IDUs, variables with a  $p$ -value  $\leq 0.10$  were included in each of the logistic regression models. <sup>4</sup>Users of inhalants only and users of other drugs were combined into one group. <sup>5</sup>African Americans, Native Americans, Asians, and adolescents reporting more than one race were combined into one group.

NA: estimates not available.

.....: Variables not included in the final model.

The NSDUH survey methods have implications for interpreting our study findings. Our analyses were based on self-reports of drug use. While adolescents' self-reports of drug use are generally considered reliable and valid (Johnson, 2001), underreporting of use can occur in household studies (Gfroerer, Wright, & Kopstein, 1997) and there is some evidence that the validity of self-reports may covary with the extent of the respondents' drug use behaviors (Colon, Robles, & Sahai, 2002). Nonetheless, computer-assisted survey methods employed in the NSDUH have been found to increase the validity of adolescents' drug use reports (Turner et al., 1998).

Like almost all household surveys, the NSDUH does not include a small group of high-risk respondents who are homeless, incarcerated, or otherwise institutionalized. Studies have suggested that the exclusion of these respondents may not significantly affect population estimates for drug use, given that such respondents constitute only about 2.0% of the national population (Anthony & Helzer, 1991), although NHSDU figures may underestimate drug use prevalence in the general population. Other study limitations included the cross-sectional nature of the survey and the relatively small samples of heroin users and IDUs, which reduced the statistical power to detect associations and prevented us from conducting stratified statistical analysis by age group (e.g., 12 to 15 vs. 16 to 17).

Notwithstanding these limitations, this investigation possesses several strengths. It is the largest and most recent study to examine the independent and conjoint roles that inhalant and marijuana use (in addition to other factors) play in adolescent-onset heroin use and IDU in a nationally representative sample of adolescents. The survey participation rate was high; audio computer-assisted surveying methods likely enhanced the validity of participants' responses; and assessments of inhalant use, heroin use, and IDU were detailed.

Findings from this population-based study of adolescents have important implications for further research and prevention interventions. In particular, the female excess in both heroin use and IDU is a cause of concern. Studies have suggested a pattern of younger age of first drug use and increasing drug use behaviors among recent cohorts in females (Grant, 1996; Warner, Kessler, Hughes, Anthony, & Nelson, 1995; Wu, Schlenger, & Galvin, *in press*). Female youth have been found to be more likely than their male counterparts to use multiple drugs (Wu et al., *in press*). Moreover, young female IDUs are more likely than young male IDUs to engage in sexual and injection risk behaviors that place them at high risk of contracting hepatitis and HIV (Evans et al., 2003). Garfein, Vlahov, Galai, Doherty, and Nelson (1996) found a very high prevalence of hepatitis C, hepatitis B, and HIV (64.7%, 49.8%, and 13.9%, respectively) among IDUs who had injected for only 1 year or less. Given that adolescent girls are as likely as adolescent boys to use one or more illicit drugs and that, among those who use drug(s), adolescent girls have greater odds of becoming heroin users and IDUs, additional focused efforts of drug use prevention and interventions are recommended to target at the young female population.

Generally, our findings suggest that adolescent drug users who have progressed to heroin use tend to initiate cigarette smoking early, use inhalants and marijuana, leave school early, and engage in delinquent or criminal activities. Early family disruption, as indicated by a prior history of foster care placement, plays a crucial role of later IDU. Adolescents who had ever been in the foster care system are likely to experience a variety of risk factors, such as parental substance use or abuse, conduct problems, childhood abuse or neglect, poverty, and psychiatric problems, which make them vulnerable to serious drug use problems (McMillen et al., 2005; Pilowsky, 1995; Stein, Evans, Mazumdar, & Rae-Grant, 1996; Pilowsky & Wu, 2006). Our findings are consistent with the problem behavior theory (Jessor & Jessor, 1977) and a model of multiple risk and protective factors in determining adolescent drug use involvement and adverse outcomes (Jessor, 1998; Newcomb, 1997), which specifies that family factors,

peer groups, individual's psychosocial characteristics, and societal factors interact with each other in influencing an adolescent's drug use and consequences.

Additional studies of adolescent inhalant users are needed, given the catastrophic consequences of heroin use and IDU (e.g., overdose or HIV infection) and the fact that adolescents have not passed through the period of greatest risk for heroin use and IDU (Neaigus et al., 2001; Ompad et al., 2005). More than a million Americans become inhalant users each year (SAMHSA, 2003) and inhalants were the only drug type in 2003 to display clear indications of increasing use (Johnston et al., 2005). Our findings suggest that prevention and treatment specialists charged with reducing heroin use and IDU would do well to focus their efforts on youth who have used inhalants and marijuana and who otherwise evidence characteristics consistent with the risk profile identified in this study.

## Acknowledgments

This work was supported by the National Institute on Drug Abuse (R21DA015938, Dr. Wu). The Substance Abuse and Mental Health Data Archive and the Inter-university Consortium for Political and Social Research provided the public use data files of the National Survey on Drug Use and Health, which is sponsored by the Office of Applied Studies, Substance Abuse and Mental Health Services Administration.

## References

- American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders, fourth edition—Text revision*. Washington, DC: American Psychiatric Association.
- Anthony, J. C., & Helzer, J. E. (1991). Syndromes of drug abuse and dependence. In L. N. Robins, & D. A. Regier (Eds.), *Psychiatric disorders in america: The epidemiologic catchment area study* (pp. 116–154). New York: The Free Press.
- Bennett, M. E., Walters, S. T., Miller, J. H., & Woodall, W. G. (2000). Relationship of early inhalant use to substance use in college students. *Journal of Substance Abuse, 12*, 227–240.
- Brouette, T., & Anton, R. (2001). Clinical review of inhalants. *The American Journal on Addictions, 10*, 79–94.
- Centers for Disease Control and Prevention. (2005, May 1–4). *HIV/AIDS among youth*.
- Centers for Disease Control and Prevention. (2005). *A glance at the HIV epidemic* (pp. 1–3).
- Colon, H. M., Robles, R. R., & Sahai, H. (2002). The validity of drug use self-reports among hard core drug users in a household survey in Puerto Rico: Comparison of survey responses of cocaine and heroin use with hair tests. *Drug and Alcohol Dependence, 67*, 269–279.
- Costello, E. J., Erkanli, A., Federman, E., & Angold, A. (1999). Development of psychiatric comorbidity with substance abuse in adolescents: Effects of timing and sex. *Journal of Clinical Child Psychology, 28*, 298–311.
- Crofts, N., Louie, R., Rosenthal, D., & Jolley, D. (1996). The first hit: Circumstances surrounding initiation into injecting. *Addiction, 91*(8), 1187–1196.
- Dinwiddie, S. H., Reich, T., & Cloninger, C. R. (1991). The relationship of solvent use with other substance use. *The American Journal of Drug and Alcohol Abuse, 17*, 173–186.
- Dinwiddie, S. H., Reich, T., & Cloninger, C. R. (1991). Solvent use as a precursor to intravenous drug abuse. *Comprehensive Psychiatry, 32*(2), 133–140.
- Donnermeyer, J. F. (1993). Rural youth usage of alcohol, marijuana, and "hard" drugs. *The International Journal of the Addictions, 28*, 249–255.
- Ellickson, P. L., Hays, R. D., & Bell, R. M. (1992). Stepping through the drug use sequence: Longitudinal scalogram analysis of initiation and regular use. *Journal of Abnormal Psychology, 101*, 441–451.

- Evans, J. L., Hahn, J. A., Page-Shafer, K., Lum, P. J., Stein, E. S., Davidson, P. J., et al. (2003). Gender differences in sexual and injection risk behavior among active young injection drug users in San Francisco (the UFO Study). *Journal of Urban Health, 80*, 137–146.
- Fuller, C. M., Vlahov, D., Ompad, D. C., Shah, N., Arria, A., & Strathdee, S. A. (2002). High-risk behaviors associated with transition from illicit non-injection to injection drug use among adolescent and young adult drug users: A case-control study. *Drug and Alcohol Dependence, 66*, 189–198.
- Garfein, R. S., Vlahov, D., Galai, N., Doherty, M. C., & Nelson, K. E. (1996). Viral infections in short-term injection drug users: The prevalence of the hepatitis C, hepatitis B, human immunodeficiency, and human T-lymphotropic viruses. *American Journal of Public Health, 86*, 655–661.
- Gfroerer, J., Wright, D., & Kopstein, A. (1997). Prevalence of youth substance use: The impact of methodological differences between two national surveys. *Drug and Alcohol Dependence, 47*, 19–30.
- Grant, B. F. (1996). Prevalence and correlates of drug use and DSM-IV drug dependence in the United States: Results of the National Longitudinal Alcohol Epidemiologic Survey. *Journal of Substance Abuse, 8*, 195–210.
- Jessor, R. (1998). New perspectives on adolescent risk behavior. In R. Jessor (Ed.), *New perspectives on adolescent risk behavior* (pp. 1–10). Cambridge, UK: Cambridge University Press.
- Jessor, R., & Jessor, S. L. (1977). *Problem behavior and psychosocial development: A longitudinal study of youth*. New York, NY: Academic Press.
- Hopfer, C. J., Khuri, E., & Crowley, T. J. (2003). Treating adolescent heroin use. *Journal of the American Academy of Child and Adolescent Psychiatry, 42*, 609–611.
- Hopfer, C. J., Khuri, E., Crowley, T. J., & Hooks, S. (2002). Adolescent heroin use: A review of the descriptive and treatment literature. *Journal of Substance Abuse Treatment, 23*, 231–237.
- Hopfer, C. J., Mikulich, S. K., & Crowley, T. J. (2000). Heroin use among adolescents in treatment for substance use disorders. *Journal of the American Academy of Child and Adolescent Psychiatry, 39*, 1316–1323.
- Hosmer, D. W., & Lemeshow, S. (2000). *Applied logistic regression*. New York, NY: John Wiley & Sons, Inc.
- Johnson, T. P. (2001). The reliability of self-reported age of onset of tobacco, alcohol, and illicit drug use. *Addiction, 96*, 1187–1198.
- Johnson, E. O., Schütz, C. G., Anthony, J. C., & Ensminger, M. E. (1995). Inhalants to heroin: A prospective analysis from adolescence to adulthood. *Drug and Alcohol Dependence, 40*, 159–164.
- Johnston, L. D., O'Malley, P. M., Bachman, J. G., & Schulenberg, J. E. (2005). *Monitoring the future national results on adolescent drug use: Overview of key findings, 2004*. Rockville, MD: National Institute on Drug Abuse.
- Kandel, D. B. (2003). Does marijuana use cause the use of other drugs? *The Journal of the American Medical Association, 289*, 482–483.
- Kandel, D. B., Yamaguchi, K., & Chen, K. (1992). Stages of progression in drug involvement from adolescence to adulthood: Further evidence for the gateway theory. *Journal of Studies on Alcohol, 53*, 447–457.
- Kirisci, L., Vanyukov, M., & Tarter, R. (2005). Detection of youth at high risk for substance use disorders: A longitudinal study. *Psychology of Addictive Behaviors, 19*, 243–252.
- Kurtzman, T. L., Otsuka, K. N., & Wahl, R. A. (2001). Inhalant abuse by adolescents. *Journal of Adolescent Health, 28*, 170–180.
- Lynskey, M. T., Heath, A. C., Bucholz, K. K., Slutske, W. S., Madden, P. A., Nelson, E. C., et al. (2003). Escalation of drug use in early-onset cannabis users vs. co-twin controls. *The Journal of the American Medical Association, 289*, 427–433.
- McMillen, J. C., Zima, B. T., Scott, L. D. Jr., Auslander, W. F., Munson, M. R., Ollie, M. T., et al. (2005). Prevalence of psychiatric disorders among older youths in the foster care system. *Journal of American Academy of Child and Adolescent Psychiatry, 44*, 88–95.
- Neaigus, A., Miller, M., Friedman, S. R., Hagen, D. L., Sifaneck, S. J., Ildefonso, G., et al. (2001). Potential risk factors for the transition to injecting among non-injecting heroin users: A comparison of former injectors and never injectors. *Addiction, 96*, 847–860.
- Neumark, Y. D., & Anthony, J. C. (1997). Childhood misbehavior and the risk of injecting drug use. *Drug and Alcohol Dependence, 15*, 48(3), 193–197.
- Newcomb, M. D. (1997). Psychosocial predictors and consequences of drug use: A developmental perspective within a prospective study. *Journal of Addictive Diseases, 16*, 51–89.
- Novins, D. K., Beals, J., & Mitchell, C. M. (2001). Sequences of substance use among American Indian adolescents. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*, 1168–1174.



- Ompad, D. C., Ikeda, R. M., Shah, N., Fuller, C. M., Bailey, S., Morse, E., et al. (2005). Childhood sexual abuse and age at initiation of injection drug use. *American Journal of Public Health, 95*, 703–709.
- Pilowsky, D. (1995). Psychopathology among children placed in family foster care. *Psychiatric Services, 46*, 906–910.
- Pilowsky, D. J., & Wu, L. T. (2006). Psychiatric symptoms and substance use disorders in a nationally representative sample of adolescents involved with foster care. *Journal of Adolescent Health, 38*, 351–358.
- Research Triangle Institute. (2002a). *2003 National Survey on Drug Use and Health: National Findings: Field Interview Manual*. Rockville, MD: Office of Applied Studies, Substance Abuse and Mental Health Services Administration. Available at <http://www.oas.samhsa.gov/nhsda/2k3MRB/2k3FIManual/cover.htm>
- Research Triangle Institute. (2002b). *SUDAAN user's manual: Release 8.0*. Research Triangle Park, NC: Research Triangle Institute.
- Santibanez, S. S., Garfein, R. S., Swartzendruber, A., Kerndt, P. R., Morse, E., Ompad, D., et al. (2005). Prevalence and correlates of crack-cocaine injection among young injection drug users in the United States, 1997–1999. *Drug and Alcohol Dependence, 77*, 227–233.
- Schütz, C. G., Chilcoat, H. D., & Anthony, J. C. (1994). The association between sniffing inhalants and injecting drugs. *Comprehensive Psychiatry, 35*, 99–105.
- Storr, C. L., Westergaard, R., & Anthony, J. C. (2005). Early onset inhalant use and risk for opiate initiation by young adulthood. *Drug and Alcohol Dependence, 78*, 253–261.
- Stein, E., Evans, B., Mazumdar, R., & Rae-Grant, N. (1996). The mental health of children in foster care: A comparison with community and clinical samples. *Canadian Journal of Psychiatry, 41*, 385–391.
- Substance Abuse and Mental Health Services Administration. (2002). *The DASIS report: Heroin treatment admissions increase: 1993–1999*. Rockville, MD: Office of Applied Studies, Substance Abuse and Mental Health Services Administration.
- Substance Abuse and Mental Health Services Administration. (2003). *Results from the 2002 National Survey on Drug Use and Health: National findings*. Rockville, MD: Substance Abuse and Mental Health Services Administration, Office of Applied Studies.
- Substance Abuse and Mental Health Services Administration. (2004). *The DASIS report: Heroin — Changes in how it is used, 1992–2002*. Rockville, MD: Office of Applied Studies, Substance Abuse and Mental Health Services Administration.
- Substance Abuse and Mental Health Services Administration. (2004). *Results from the 2003 National Survey on Drug Use and Health: National findings. H-25, DHHS Publication No. SMA 04-3964*. Rockville, MD: Office of Applied Studies, Substance Abuse and Mental Health Services Administration.
- Sutherland, I., & Shepard, J. P. (2001). Social dimensions of adolescent substance use. *Addiction, 96*, 445–458.
- Turner, C. F., Ku, L., Rogers, S. M., Lindberg, L. D., Pleck, J. H., & Sonenstein, F. L. (1998). Adolescent sexual behavior, drug use, and violence: Increased reporting with computer survey technology. *Science, 280*, 867–873.
- Vega, W. A., Aguilar-Gaxiola, S., Andrade, L., Bijl, R., Borges, G., Caraveo-Anduaga, J. J., et al. (2002). Prevalence and age of onset for drug use in seven international sites: Results from the International Consortium of Psychiatric Epidemiology. *Drug and Alcohol Dependence, 68*, 285–297.
- Vega, W. A., & Gil, A. (2005). Revisiting drug progression: Long-range effects of early tobacco use. *Addiction, 100*, 1358–1369.
- Vlahov, D., Wang, C., Galai, N., Bareta, J., Mehta, S., Strathdee, S., et al. (2004). Mortality risk among new onset injection drug users. *Addiction, 99*, 946–954.
- Warner, L. A., Kessler, R. C., Hughes, M., Anthony, J. C., & Nelson, C. B. (1995). Prevalence and correlates of drug use and dependence in the United States. Results from the National Comorbidity Survey. *Archives of General Psychiatry, 52*, 219–229.
- Wu, L. T., Pilowsky, D. J., & Schlenger, W. E. (2004). Inhalant abuse and dependence among adolescents in the United States. *Journal of the American Academy of Child and Adolescent Psychiatry, 43*, 1206–1214.
- Wu, L. T., Pilowsky, D. J., & Schlenger, W. E. (2005). High prevalence of substance use disorders among adolescents who use marijuana and inhalants. *Drug and Alcohol Dependence, 78*, 23–32.
- Wu, L. T., Schlenger, W. E., & Ringwalt, C. L. (2005). Use of nitrite inhalants (“poppers”) among American youth. *Journal of Adolescent Health, 37*, 52–60.
- Wu, L.T., Schlenger, W.E., and Galvin, D.M. (in press). Concurrent use of methamphetamine, MDMA, LSD, ketamine, GHB, and flunitrazepam among American youths. *Drug and Alcohol Dependence*.
- Yamaguchi, K., & Kandel, D. B. (1984). Patterns of drug use from adolescence to young adulthood: II. Sequences of progression. *American Journal of Public Health, 74*, 668–672.