

ORIGINAL ARTICLE

Volatile Substance Misuse in the United States

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Volatile substance misuse (VSM) is prevalent in the United States and associated with manifold deleterious outcomes. This review summarizes research on: (1) the prevalence of VSM in the United States and its trends since 1975, (2) population subgroups at an elevated risk for VSM, (3) key correlates of VSM, (4) psychosocial consequences of VSM, including emerging public health threats, and (5) etiological and contextual considerations of VSM use. Implications for future research and practice with volatile substance misusers in the United States are identified.

Keywords inhalants, solvent misuse, United States, volatile substance misuse

INTRODUCTION

Inhalation of ether and nitrous oxide for nonmedical purposes emerged early in the history of the United States (Dormandy, 2006). Showmen traveling to county fairs in the 1830s touted the intoxicating properties of nitrous oxide and made entertainment via “laughing gas” available to interested persons for a fee. By the 1840s, “gas frolics” involving the use of ether, nitrous oxide, or chloroform (discovered in 1831) were freely advertised. Use of nitrous oxide as an intoxicant became prevalent among medical students during the latter half of the 19th century and luminaries, such as the philosopher-psychologist William James, prized the agent for its capacity to induce mystical experiences (Wallace, 2008).

Ether was taken in liquid and vaporized forms during the Prohibition years of the 1920s and 1930s, particularly by women (for whom the use of alcohol was especially stigmatized; Dormandy, 2006). During the mid-20th century, recreational inhalation of volatile sub-

stances in glue, paint, and gasoline became prevalent, with some observers tracing the first mention of the “glue-sniffing” problem to a *Denver Post* article published in 1959 (Brecher, 1973). Misuse of the propellant gases propane and butane became (and remained) problematic during the 1980s, when they replaced chlorofluorocarbons in commercial products (Marsolek, White, & Litovitz, 2010). In the United States, nitrous oxide, volatile solvents, and propellant gases are widely used to the present day.

Although volatile substance misuse (VSM) has been practiced in the United States for nearly 200 years, relatively little social or scientific attention has been accorded to the issue until relatively recently (Balster, 1996). Neglect of this “hidden epidemic” has had malign consequences, as these agents are among the most toxic of all psychoactive substances. This review summarizes the prevalence of VSM in the United States together with trends in use since the mid-1970s, identifies population subgroups at an elevated risk for VSM, describes its key correlates and harmful consequences, including emerging threats to public health, and considers the etiology and contextual factors associated with VSM.

VOLATILE SUBSTANCE MISUSE IN THE UNITED STATES: PREVALENCE AND TRENDS

Three major population-based surveys have evaluated the prevalence of VSM in varied samples of adolescents and adults using different methods and definitions of VSM. The largest and the most informative nationally representative surveys include the National Survey on Drug Use and Health (NSDUH), Youth Risk Behavior Survey (YRBS), and Monitoring the Future (MTF). Each of these surveys provides important information regarding VSM

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in the United States. However, as a caution, these surveys differ in their design, including target populations, sampling frames, and survey administration methods and measurements, and, therefore, are addressed separately in the discussion that follows.

National Survey on Drug Use and Health

The NSDUH is an annual survey of the US population aged 12 years and older (Substance Abuse and Mental Health Services Administration [SAMHSA], 2008a) that reside in a representative sample of households, noninstitutionalized group quarters, and civilians living on military bases (see <http://www.oas.samhsa.gov/NSDUH/2k8NSDUH/appA.htm>). It is unlike the YRBS or MTF, which involves survey administration in schools targeting students in middle and high schools. The 2007 survey asks a number of questions about the lifetime use and use in the past 30 days of “liquids, sprays, and gases that people sniff or inhale to get high or to make them feel good,” including amyl nitrite; correction fluid; gasoline; glue, shoe polish, or toluene; halothane, ether, or other anesthetics; lacquer thinner or other paint solvents, butane or propane; nitrous oxide; or spray paints and other aerosol sprays.

In 2007, 67,870 persons completed the survey and results indicated that approximately 22.5 million Americans had ever engaged in VSM, a figure approximating 9.1% of respondents aged 12 years and older. A total of 616,000 persons had misused volatile substances in the prior month and an estimated 5,012,000 respondents had initiated VSM between 2002 and 2007. Of the 2.7 million persons who initiated illicit drug use in 2007, 10.7% reported that volatile substances were the first substance they misused.

From 2002 through 2007, NSDUH conducted surveys with household members independently sampled within each of the 50 states and the District of Columbia (Table 1). More than 450,000 lifetime volatile substance misusers resided in each of 19 states. Six states (Alaska, New Hampshire, Vermont, Colorado, Oregon, and Delaware) had lifetime VSM prevalence rates of at least 12%, whereas seven states (Iowa, Kansas, Nebraska, North Dakota, Mississippi, South Carolina, and Tennessee) had lifetime VSM prevalence rates of 7% or less (for a map, see Figure 1).

Additional reports based on NSDUH findings: (1) identified high prevalence of VSM among youth who had experienced a recent major depressive episode (SAMHSA, 2008b); (2) indicated that glue, shoe polish, or toluene; spray paints; and gasoline or lighter fluid were the most commonly misused classes of volatile substances among 12- to 15-year-olds (SAMHSA, 2008c); (3) found higher levels of use of four classes of volatile substances among girls compared to boys (SAMHSA, 2007); (4) indicated that nearly 20% of recent adolescent VSM initiates had used inhalants on at least 13 occasions in the past year (SAMHSA, 2006); (5) noted that youth with early-onset VSM use were five-fold more likely than their noninhalant using peers to have used an illicit drug (SAMHSA, 2005);

and (6) indicated that more than 17% of youth who initiated illicit drug use in the past year reported that volatile substances were the first intoxicating substances they had ever used (SAMHSA, 2009).

Youth Risk Behavior Survey (YRBS)

The YRBS is a biannual survey of adolescent risk behaviors (<http://www.cdc.gov/mmwr/PDF/rr/tr5312.pdf>). In 2007, 14,103 students participated in the YRBS (Youth Risk Behavior Survey, 2008). Overall, 13.3% of 9th–12th graders reported lifetime VSM. Lifetime prevalence rates for 9th (15.0%), 10th (14.6%), 11th (12.5%), and 12th graders (10.2%) displayed a pattern of declining prevalence rates in older grade respondents similar to that observed in the MTF (see below). The pattern of declining lifetime rates of VSM among older youth is generally attributed to higher dropout rates by youth who initiated VSM in earlier grades. Table 2 presents trends in lifetime VSM and other drug use for 9th–12th graders between 1995 and 2007. Comparatively high levels of VSM were observed in the mid-1990s, which decreased significantly by 2003 and remained stable thereafter.

Significant variability in the prevalence of lifetime VSM from 9th to 12th graders was observed across the states, with West Virginia (19.2%), Idaho (18.1%), Wyoming (16.7%), and Montana (16.2%) evidencing high rates, whereas Iowa (9.8%), Rhode Island (9.9%), Wisconsin (10.5%), and Florida (10.8%) had comparatively low rates. Of the metropolitan areas surveyed, only Los Angeles (17.4%) had a lifetime VSM prevalence rate that significantly exceeded the national average.

Monitoring the Future (MTF)

The MTF is the largest school-based survey of inhalant use in the United States. In 2008, more than 48,000 students participated in the survey; 15.7% of 8th graders, 12.8% of 10th graders, and 9.9% of 12th graders reported lifetime VSM (Johnston, O’Malley, Bachman, & Schulenberg, 2009). Trends in lifetime VSM among 12th graders between 1975 and 2008 are presented in Table 3. VSM prevalence increased steadily between 1976 and 1990 and declined steadily thereafter to the present.

Volatile substance misuse tended to begin early, with 58.0% of volatile substance users (specifically inhaling) reporting onset of misuse by ninth grade. Only 33.9% and 59.2% of eighth graders, respectively, saw use of volatile substances “once or twice” or “regularly” as a “great risk.” These percentages are lower than comparable figures dating back nearly two decades. Likewise, rates of disapproval of persons who use volatile substances once or twice or regularly were at nearly their lowest levels since 1991. More than one-quarter of eighth graders in 2007 reported that one or more of their friends used volatile substances. Taken together, these findings are suggestive of a growing underestimation of the dangers of VSM coupled with increasingly normative perceptions of VSM among youth.

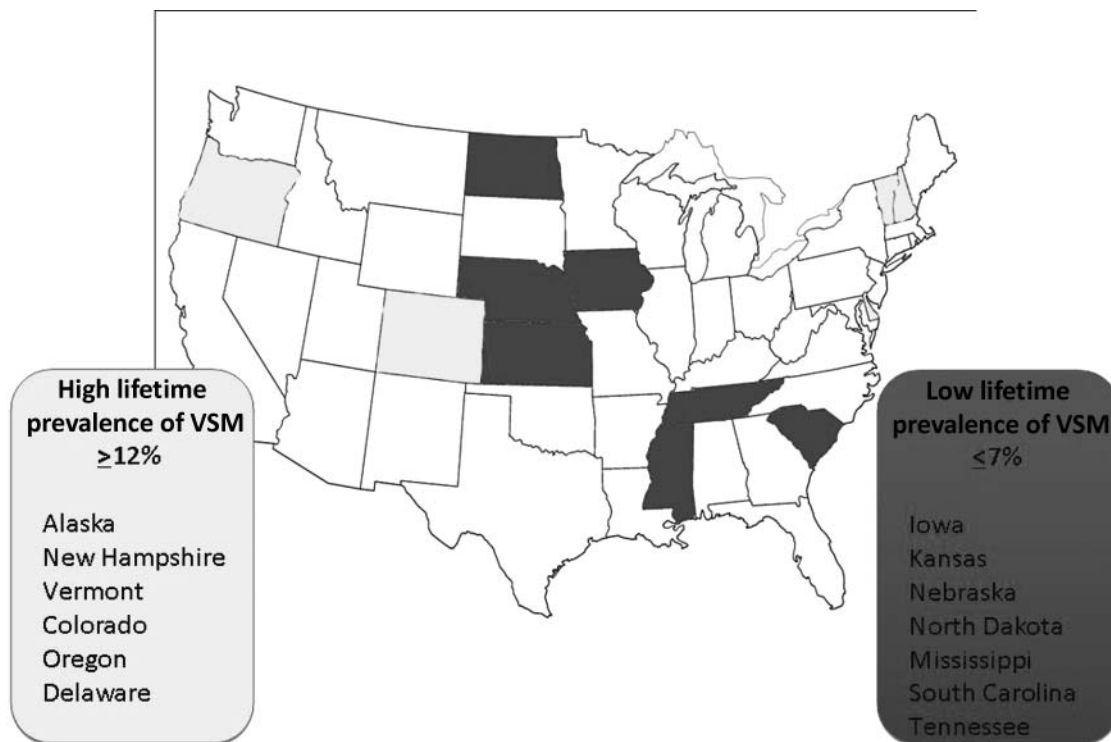


FIGURE 1. The NSDUH-derived map of States with high ($\geq 12\%$) and low ($\leq 7\%$) lifetime prevalence of VSM.

Studies of Specific Volatile Agents

Studies of the prevalence, effects, and consequences of specific misused volatile substances are needed (Balster, Cruz, Howard, Dell, & Cottler, 2009). Unfortunately, VSM has traditionally been assessed in surveys using a single omnibus item listing a number of substances with different structural and pharmacological properties. Recent reports have examined misuse of asthma inhalers (Perron & Howard, 2008b), nitrites (Hall & Howard, 2009), nitrous oxide (Garland, Howard, & Perron, 2009), computer “duster” spray (Garland & Howard, 2010b), and prevalence of use and subjective intoxication in relation to more than 50 specific volatile substances (Howard, Balster, Cottler, Wu, & Vaughn, 2008). Garland and Howard (2010a) recently examined the phenomenology of adolescent VSM intoxication, noting that the prevalence of various hedonic and aversive reactions varied across different volatile substances and by frequency of VSM, suggesting that agents with different physiochemical properties have distinct cognitive, affective, and somatic effects, and that the psychological sequelae of chronic VSM may differ significantly from those stemming from casual VSM (see Table 4).

Prevalence of Inhalant Use Disorders

The lifetime risk for inhalant abuse and dependence disorders among volatile substance misusers is unclear. High liability for abuse and dependence was reported by Ridenour, Bray, and Cottler (2007) who studied a community-based sample of 162 adolescent and young adult volatile substance misusers in St. Louis, reporting that 46.9% (34.6% abuse; 12.3% dependence) developed

DSM-IV inhalant use disorders (*note*: DSM-IV “inhalant use disorders” do not include those related to nitrite or nitrous oxide use). Howard and Perron (2009) also found that 46.9% (18.6% abuse; 28.3% dependence) of the Missouri adolescent volatile solvent misusers they examined presented with evidence of inhalant use disorders. Sakai, Hall, Mikulich-Gilbertson, and Crowley (2004) reported that 18.3% of the adolescent volatile substance misusers they assessed who were in treatment for substance use or behavioral problems evidenced DSM-IV inhalant use disorders, a percentage similar to that reported by Wu and Howard (2007a) for a nationally representative sample of US adult volatile substance misusers. Prior studies have indicated that comparatively few volatile substance misusers developed the formal DSM-IV disorders of inhalant abuse or dependence (Anthony, Warner, & Kessler, 1994); however, recent findings suggest that the abuse liability of some volatile substances may be greater than appreciated previously.

Summary

Volatile substance misuse is prevalent in the United States. Relatively high levels of use are characteristic of the rural western region of the United States and West Virginia, whereas lower rates are observed in the Midwestern and southern regions of the nation. Trends in VSM indicate that significant fluctuations in VSM do occur over time, as between 10% and 20% of adolescents surveyed annually over the past 30 years reporting a history of VSM. Recent investigations suggest that the abuse liability of volatile substances may be greater than recognized previously and there is some evidence that dependence on

TABLE 1. State-specific estimates for number of lifetime volatile substance misusers (VSMs) and lifetime prevalence of volatile substance misuse (VSM) for respondents participating in the 2002–2004 administrations of the national survey on drug use and health and the 2007 youth behavior risk survey

State	Estimated number of lifetime VSMs	Lifetime prevalence of VSM (%)		State	Estimated number of lifetime VSMs	Lifetime prevalence of VSM (%)	
		NSDUH	YRBS			NSDUH	YRBS
1. Alabama	276,000	7.4	X	27. Montana	84,000	10.9	16.2
2. Alaska	70,000	13.8	14.4	28. Nebraska	93,000	6.6	12.9
3. Arizona	512,000	11.4	14.6	29. Nevada	200,000	11.0	X
4. Arkansas	201,000	9.1	15.3	30. New Hampshire	133,000	12.3	12.8
5. California	2,854,000	10.0	X	31. New Jersey	662,000	9.3	X
6. Colorado	451,000	12.2	X	32. New Mexico	182,000	11.9	X
7. Connecticut	328,000	11.4	11.2	33. New York	1,573,000	11.9	11.9
8. Delaware	81,000	12.0	12.9	34. North Carolina	589,000	8.8	13.8
9. District of Columbia ^a	53,000	11.1	X	35. North Dakota	36,000	6.9	11.1
10. Florida	1,458,000	10.3	10.8	36. Ohio	992,000	10.5	X
11. GA	616,000	8.9	11.4	37. Oklahoma	243,000	8.5	11.7
12. Hawaii	115,000	11.5	11.4	38. Oregon	358,000	12.1	X
13. Idaho	120,000	10.9	18.1	39. Pennsylvania	1,070,000	10.3	X
14. Illinois	977,000	9.5	11.8	40. Rhode Island	106,000	11.8	9.9
15. Indiana	471,000	9.3	15.8	41. South Carolina	254,000	7.5	12.6
16. Iowa	175,000	7.2	9.8	42. South Dakota	52,000	8.3	13.7
17. Kansas	163,000	7.4	12.5	43. Tennessee	370,000	7.7	13.7
18. Kentucky	305,000	9.0	14.2	44. Texas	1,413,000	8.1	12.9
19. Louisiana	298,000	8.2	X	45. Utah	196,000	10.7	12.7
20. Maine	114,000	10.2		46. Vermont	65,000	12.3	
21. Maryland	364,000	8.1		47. Virginia	600,000	10.1	
22. Massachusetts	564,000	10.5		48. Washington	579,000	11.5	
23. Michigan	813,000	10.5	12.0	49. West Virginia	135,000	8.8	19.2
24. Minnesota	390,000	9.3		50. Wisconsin	452,000	9.7	
25. Mississippi	156,000	6.7	12.6	51. Wyoming	48,000	11.4	16.7
26. Missouri	477,000	10.2					

^aWashington, DC.

X = No prevalence reported.

volatile substances may be associated with a withdrawal syndrome (Perron, Howard, Vaughn, & Jarman, 2009).

SUBPOPULATIONS AT A HIGH RISK FOR VOLATILE SUBSTANCE MISUSE

Investigations of juvenile justice and treatment samples have identified high levels of VSM. Howard et al. (2008) reported that 36.9% of 723 Missouri adolescents in residential care for antisocial conduct were volatile substance misusers; a substantial majority of this group consisted of polyinhalant users. Similarly, Howard and Jenson (1999) found that 34.3% of Utah juvenile probationers ($N = 475$) evidenced histories of VSM. Earlier age at initiation of VSM was associated with significantly greater frequency of VSM. Volatile substance misusers evidenced notable levels of psychiatric and psychosocial dysfunction. Sakai et al. (2004) found that nearly one in five adolescents ($N = 847$) in treatment for drug abuse or conduct problems had inhaled volatile substances. Compton et al. (1994) reported that 10% of adults in treatment for substance use disorders had inhaled volatile substances for more than

five times and that their average age at initiation of VSM was 14.7 years.

Summary

Numerous US studies suggest that juvenile and criminal justice populations and persons in treatment for substance use problems are at high risk for VSM. Additional subgroups at high risk for VSM are identified below in the discussion of correlates of VSM.

CORRELATES AND CONSEQUENCES OF VOLATILE SUBSTANCE MISUSE

Volatile substance misuse is associated with a range of sociodemographic and psychosocial factors that may provide some clues as to the causal origins and potential consequences of the behavior (Vaughn, Perron, & Howard, 2007). Findings related to age, gender, race/ethnicity, mental health, and psychosocial characteristics are reviewed below.

TABLE 2. Trends in the prevalence of inhalant and other illegal drug use: Youth Risk Behavior Survey (YRBS) findings for 1991–2007

1991	1993	1995	1997	1999	2001	2003	2005	2007	Changes from 1991–2007 ^a	Changes from 1991–2007 ^b
Lifetime marijuana use (used marijuana one or more times during their life) (%)										
31.3 (28.4–34.4) ^c	32.8 (29.6–36.2)	42.4 (44.1–50.1)	47.1 (44.7–49.7)	47.2 (40.5–54.3)	42.4 (40.5–44.3)	40.2 (37.4–43.1)	38.4 (35.9–41.0)	38.1 (35.5–40.7)	Increased, 1991–1999 Decreased, 1999–2007	No change
Current marijuana use (used marijuana one or more times during the 30 days before the survey) (%)										
14.7 (12.6–17.0)	17.7 (15.3–20.3)	25.3 (23.5–27.3)	26.2 (24.0–28.5)	26.7 (24.2–29.4)	23.9 (22.3–25.5)	22.4 (20.2–24.6)	20.2 (18.6–22.0)	19.7 (17.8–21.8)	Increased, 1991–1999 Decreased, 1999–2007	No change
Lifetime cocaine use (used any form of cocaine, including power, crack, or freebased one or more times during the life) (%)										
5.9 (5.1–6.9)	4.9 (4.1–5.8)	7.0 (5.9–8.3)	8.2 (7.2–9.4)	9.5 (8.2–11.1)	9.4 (8.2–10.7)	8.7 (7.6–9.9)	7.6 (6.7–8.7)	7.2 (6.2–8.2)	Increased, 1991–1999 Decreased, 1999–2007	No change
Lifetime methamphetamine use (used methamphetamines [also called speed, crystal, crank, or ice] one or more times during their life) (%)										
NA ^d	NA	NA	NA	9.1 (7.9–10.5)	9.8 (8.3–11.5)	7.6 (6.7–8.7)	6.2 (5.3–7.2)	4.4 (3.7–5.3)	No change, 1999–2001 Decreased, 2001–2007	Decreased
Lifetime inhalant use (sniffed glue, breathed the contents of aerosol spray cans, or inhaled any points or sprays to get high one or more times during their life) (%)										
NA	NA	20.3 (18.3–22.5)	16.0 (14.7–17.3)	14.6 (12.9–16.5)	14.7 (13.1–16.6)	12.1 (10.9–13.4)	12.4 (11.1–13.8)	13.3 (12.1–14.6)	Decreased, 1995–2003 No change, 2003–2007	No change
Lifetime illegal steroid use (took steroid pills or shots without a doctor's prescription one or more times during their life) (%)										
2.7 (2.3–3.2)	2.2 (1.7–2.8)	3.7 (3.1–4.3)	3.1 (2.7–3.6)	3.7 (3.1–4.5)	5.0 (4.4–5.5)	6.1 (4.7–7.8)	4.0 (3.5–4.6)	3.9 (3.4–4.6)	Increased, 1991–2003 Decreased, 2003–2007	No change

^aBased on trend analyses using logistic regression model controlling for sex, race/ethnicity, and grade.

^bBased on *t*-test analyses, *p* < .05.

^c95% confidence interval.

^dNot available.

Age

Volatile substance misuse typically is of early onset and evidences a high discontinuation rate (Crocetti, 2008). Past-year VSM was reported by 3.4% and 4.8% of 12- and 13-year-olds, 5.3% and 5.1% of 14- and 15-year-olds, and 4.2% and 3.9% of 16- and 17-year-olds in the NSDUH (SAMHSA, 2008c). Thus, past-year VSM was most prevalent among 14-year-olds. Siqueira and Crandall (2006) in their study of more than 60,000 Floridian 6th–12th graders found that VSM was most prevalent among 14-year-olds.

Early-onset VSM is associated with various deleterious outcomes. Perron and Howard (2008b) found that adolescent volatile substance misusers who were younger, with prior problems with VSM, or who had friends and/or siblings who were volatile substance misusers were significantly more likely to report intentions to use volatile substances in the future in comparison to their counterparts. Wu, Pilowsky, and Schlenger (2004) observed that initiation of VSM by age 14 (versus initiation between ages 15 and 17 years) was associated with a five- to six-fold increase in risk for inhalant dependence in their study of more than 1,300 adolescent volatile substance misusers. Relationships between early-onset VSM and subsequent

heroin and injection drug use, antisocial behavior, and other psychoactive drug use have also been established (SAMHSA, 2005; Storr, Westergaard, & Anthony, 2005; Wu & Howard, 2007b).¹

Many VSM initiates discontinue use relatively quickly. Results of the 2006 MTF survey indicated that 44%, 52%, and 59% of 8th-, 10th-, and 12th-grade lifetime volatile substance misusers, respectively, had not engaged in VSM in the past year (Johnston, O'Malley, Bachman, & Schulenberg, 2007). However, youth at the highest risk for continuing VSM may drop out of school at disproportionately high rates; thus, VSM discontinuance rates may be upwardly biased. Few studies of volatile substance misusers' reasons for quitting their misuse of volatile substances have been published. Garland and Howard (in press) identified four classes of adolescent volatile substance misusers that differed clinically and in their reported reasons for ultimately desisting from VSM.

¹The reader is referred to Hills' (1965) criteria, which were developed in order to help assist researchers and clinicians determine if *risk factors* were causes of a particular disease or outcomes, or merely associated. Editor's note

TABLE 3. Long-term trends in lifetime prevalence of inhalant and other drug use among 12th graders participating in the Monitoring the Future (MTF) survey: 1975–2008

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Approximate weighted (N)	9,400	15,400	17,100	17,800	15,500	15,900	17,500	17,700	16,300	15,900
Any illicit drug (%)	55.2	58.3	61.6	64.1	65.1	65.4	65.6	64.4	62.9	61.6
Any illicit drug other than marijuana (%)	36.2	35.4	35.8	36.5	39.4	38.7	42.8	41.1	40.4	40.3
Marijuana/hashish (%)	47.3	52.8	56.4	59.2	60.4	60.3	59.5	58.7	57.0	54.9
Inhalants (%)	–	10.3	11.1	12.0	12.7	11.9	12.3	12.8	13.6	14.4
Inhalants, adjusted (%)	–	–	–	–	18.2	17.3	17.2	17.7	18.2	18.0
Amyl/butyl nitrites (%)	–	–	–	–	11.1	11.1	10.1	9.8	8.4	8.1
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Approximate weighted (N)	16,000	15,200	16,300	16,300	16,700	15,200	15,000	15,800	16,300	15,400
Any illicit drug (%)	60.6	57.6	56.6	53.9	50.9	47.9	44.1	40.7	42.9	45.6
Any illicit drug other than marijuana (%)	39.7	37.7	35.8	32.5	31.4	29.5	26.9	25.1	26.7	27.6
Marijuana/hashish (%)	54.2	50.9	50.2	47.2	43.7	40.7	36.7	32.6	35.3	38.2
Inhalants (%)	15.4	15.9	17.0	16.7	17.6	18.0	17.6	16.6	17.4	17.7
Inhalants, adjusted (%)	18.1	20.1	18.6	17.5	18.6	18.5	18.0	17.0	17.7	18.3
Amyl/butyl nitrites (%)	7.9	8.6	4.7	3.2	3.3	2.1	1.6	1.5	1.4	1.7
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Approximate weighted (N)	15,400	14,300	15,400	15,200	13,600	12,800	12,800	12,900	14,600	14,600
Any illicit drug (%)	48.4	50.8	54.3	54.1	54.7	54.0	53.9	53.0	51.1	51.1
Any illicit drug other than marijuana (%)	28.1	28.5	30.0	29.4	29.4	29.0	30.7	29.5	27.7	28.7
Marijuana/hashish (%)	41.7	44.9	49.6	49.1	49.7	48.8	49.0	47.8	46.1	45.7
Inhalants (%)	17.4	16.6	16.1	15.2	15.4	14.2	13.0	11.7	11.2	45.7
Inhalants, adjusted (%)	17.8	17.5	16.9	16.5	16.0	14.6	13.8	12.4	12.2	10.9
Amyl/butyl nitrites (%)	1.5	1.8	2.0	2.7	1.7	0.8	1.9	1.5	1.6	1.3
	2005	2006	2007	2008	2007–2008 change					
Approximate weighted (N)	14,700	14,200	14,500	1,400						
Any illicit drug (%)	50.4	48.2	46.8	47.4	+0.6					
Any illicit drug other than marijuana (%)	27.4	26.9	25.5	24.9	–0.6					
Marijuana/hashish (%)	44.8	42.3	41.8	42.6	+0.8					
Inhalants (%)	11.4	11.1	10.5	9.9	–0.6					
Inhalants, adjusted (%)	11.9	11.5	11.0	10.1	–0.9					
Amyl/butyl nitrites (%)	1.1	1.2	1.2	0.6	–0.7					

Gender Differences

The 2006 MTF survey indicated that lifetime VSM was more prevalent among girls than boys in 8th (17.4% versus 14.7%) and 10th (14.3% versus 12.4%) grades, but less prevalent among girls than boys in 12th grade (10.3% versus 12.0%) (Johnston et al., 2007). A possible explanation for the reversal in magnitude of lifetime prevalence figures for VSM in girls and boys between 8th/10th and 12th grades is that girls who used volatile substances in earlier grades may drop out of school at higher rates than boys who are volatile substance misusers.

The NSDUH findings underscore the general absence of significant gender differences in the prevalence of

adolescent VSM. Between 2002 and 2004, an average of nearly 600,000 adolescents annually initiated VSM. Whereas 48.9% of total respondents to the survey in ages 12–17 years were girls, 50.5% of past-year VSM initiates over this interval were girls (SAMHSA, 2006). Wu et al. (2004) identified nonsignificant gender differences for lifetime VSM among 36,859 12- to 17-year-old participants in the National Household Survey on Drug Abuse (NHSDA, a precursor to NSDUH). Lifetime VSM prevalence rates for girls and boys were 8.8% and 8.7%, respectively. Neumark, Delva, and Anthony (1998) also observed nonsignificant gender differences in lifetime prevalence of VSM in adolescent respondents to the

TABLE 4. Cognitive, affective, and somatic effects of volatile substances that are significantly more likely to be experienced by moderate and/or high frequency inhalant users compared to low frequency users (Garland & Howard, 2010a)

Effect	Elevated odds of experiencing effect for moderate frequency users compared to low frequency users	Elevated odds of experiencing effect for high frequency users compared to low frequency users
Euphoria		+
Relaxation	+	+
Vertigo	+	
Headache		+
Rapid heartbeat		+
Talkativeness		+
Decreased appetite		+
Amnesia	+	+
Slurred speech	+	+
Irritability		+
Aggressiveness		+
Fatigue		+
Burning in eyes or throat		+
Grandiosity		+
Chest pain	+	+
Increased appetite		+
Depressed mood	+	+
Sexual arousal	+	
Suicidal ideation		+

+ denotes a statistically significant increase in the odds of experiencing a given phenomenological effect during acute volatile substance intoxication for high- or moderate frequency VSMs relative to low frequency VSMs.

NHSDA between 1990 and 1995. Studies of criminal justice and clinical samples have also infrequently identified significant gender differences in the prevalence of VSM (Howard et al., 2008; Sakai et al., 2004).

Race/Ethnicity

Significant racial/ethnicity differences are observed in the United States with respect to VSM. Wu and Ringwalt (2006) examined 73,396 adults participating in the NS-DUH and identified comparatively high levels of lifetime VSM in American Indians/Alaska Natives (12.9%), Caucasians (11.5%), and persons of more than one race (11.4%), whereas low levels of use were identified in African-American (3.5%), Asian/Pacific Islander (4.5%), and Hispanic (6.1%) respondents. Similar findings were reported by Wu, Pilowsky, and Schlenger (2004) for 36,859 adolescents: 13.2%, 9.5%, and 11.2% of American Indian/Alaska Native, Caucasians, and bi/multi-racial youth reported lifetime VSM use, respectively, compared with 5.3%, 6.5%, and 9.0% of African-American, Asian/Pacific Islander, and Hispanic youth, respectively.

Caucasian and Hispanic 8th-, 10th-, and 12th-graders had similar levels of lifetime VSM in the MTF sur-

vey, whereas African-American youth had lifetime VSM prevalence rates approximately half of those of Caucasian and Hispanic youth (Johnston et al., 2007).

Studies of specific ethnic populations, such as Cuban immigrants (Szapocznik, Daruna, Scopetta, & De Los Angeles Aranalde, 1977), Alaskan Eskimo youth (Zebrowski & Gregory, 1996), reservation-residing American Indian youth (Beauvais, Oetting, & Edwards, 1985), and residents of urban Barrio areas (Bachrach & Sandler, 1985) have often identified high prevalence of VSM and associated etiological factors (Howard, Walker, Walker, Cottler, & Compton, 1999).

Psychiatric Correlates

Numerous studies have identified strong associations between VSM and mental health problems, although the causal nature of these relationships remains unclear. Suicidal ideation is commonly observed among adolescent (Freedenthal, Vaughn, Jenson, & Howard, 2007) and adult (Howard et al., 2010) VSM users, especially among women and persons manifesting formal diagnoses of VSM abuse and dependence disorders. Exorbitantly elevated risks for mood, anxiety, personality, and substance use disorders were identified in a nationally representative sample of US adults (Wu & Howard, 2007a; Wu, Howard, & Pilowsky, 2008). Nearly half of all adult volatile substance misusers met criteria for a mood (48%) or personality (45%) disorder, and most met criteria for an alcohol use (87%) or other substance use (96%) disorder. VSM in adolescence, as noted above, is also a risk for later intravenous drug use (Wu & Howard, 2007b).

Behavioral problems are also commonly observed in samples of volatile substance misusers. One recent nationally representative study concluded that volatile substance misusers, particularly those engaged in more severe use, evidenced pervasively elevated levels of antisocial behavior, especially interpersonal violence and early-onset conduct problems (Howard, Perron, Vaughn, Bender, & Garland, 2010). Surveys of adolescent volatile substance misusers indicate that they tend to behave more impulsively and fearlessly, and report more substance use than non-volatile substance misusers (Howard et al., 2008; Perron & Howard, 2009). The antisocial behaviors and traits exhibited by volatile substance misusers may be linked with the general higher rates of lifetime trauma (Howard et al., 2008), and lower levels of self-esteem, family support, and family cohesiveness observed among volatile substance misusers relative to non-volatile substance misusers (Howard & Jenson, 1999).

Elevated levels of psychiatric dysfunction in volatile substance misusers appear to be of significant clinical importance. Perron, Howard, Maitra, and Vaughn (2009) noted that the presence of a mood, anxiety, and/or alcohol use disorder antedating onset of VSM powerfully predicted subsequent risk for the development of a VSM abuse disorder. Antisocial youth with histories of VSM were significantly more likely to report intentions to misuse volatile substances in the future if they reported elevated levels of current psychiatric distress (Perron &

Howard, 2008b). Although the nexus of causal relations between mental health dysfunction and VSM remains to be elucidated, recent studies suggest that one subgroup of volatile substance misusers use these substances to medicate negative emotional states (Perron, Vaughn, & Howard, 2008), and such self-medication motives significantly predict adverse psychosocial consequences of VSM (Garland & Howard, 2010a). Further, comparatively more severe psychiatric dysfunction appears to predict greater frequency of lifetime VSM (Howard et al., 2008) and the use of potentially toxic combinations of volatile substances (Garland et al., 2009).

In sum, an abundance of data from nationally representative surveys and studies of high-risk populations indicate that significant levels of co-occurring mental health and substance use-related problems are commonly observed among adolescent and adult volatile substance misusers.

Psychosocial Correlates

In addition to substance use and psychiatric problems, volatile substance misusers often experience significant psychosocial challenges. Wu and Ringwalt (2006) reported that lifetime VSM was significantly more prevalent among adults who were polydrug users, manifested alcohol use disorders, who never married, and who were arrested or had received mental health treatment in the prior year. Wu et al. (2004) found relatively high rates of VSM among adolescents with a history of foster care placement, incarceration, frequent delinquent conduct, mental health care utilization, and alcohol and drug use. Low levels of parental education and plans not to complete college were significant correlates of adolescent VSM in the MTF survey (Johnston et al., 2009).

Psychosocial Consequences

In spite of the robust associations between VSM, psychiatric disorders, polydrug use, and antisocial behavior, it remains unclear to what extent, if any, VSM contributes directly or indirectly to the psychosocial problems commonly observed in misusers. Due to the cross-sectional nature of most epidemiological and clinical studies on VSM, it has been difficult thus far to tease apart the antecedents, concomitants, and outcomes of VSM. In one of the first systematic attempts to characterize the psychosocial consequences of acute volatile substance intoxication, Garland and Howard (2010b) examined the nature and prevalence of self-reported adverse outcomes and high-risk behaviors occurring during episodes of acute volatile substance intoxication among low-, moderate-, and high-frequency adolescent volatile substance misusers. A substantial proportion of volatile substance misusers reported use of alcohol and marijuana, getting in fist fights, committing property crimes, taking dangerous risks, and driving a motor vehicle under acute volatile substance intoxication. High-frequency volatile substance misusers were significantly more likely than moderate- and low-frequency misusers to experience adverse outcomes. Certain risky behaviors and consequences, such as engaging

in unprotected sex, committing acts of physical violence, or attempting suicide while intoxicated on volatile substances, were multiplicatively more common among high-frequency than low-frequency users. Youth with more extensive trauma histories and those who tended to use volatile substances to self-medicate negative emotional states reported greater numbers of adverse consequences and high-risk behaviors during acute volatile substance intoxication. Although this research provides suggestive evidence regarding the psychosocial impact of acute VSM, causal linkages between adverse outcomes and VSM cannot be established due to the reliance on retrospective reports. In order to more accurately detail the psychosocial consequences of VSM, there is a need for prospective observational studies that use multiple data sources (e.g., collateral reports of family members and peers, law enforcement records, formal psychiatric evaluation) to triangulate self-reports with more objective forms of evidence.

Summary

Volatile substance misuse is associated with a wide range of serious mental health problems and psychosocial challenges. Volatile substance misusers are often raised in socially disadvantaged families and discouraging or traumatic social contexts that increase risk of early involvement with substance misuse and antisocial behavior. Thus, it is not surprising that in the United States volatile substance misusers are disproportionately found in the criminal justice, mental health, and chemical dependency treatment systems. Unfortunately, VSM is rarely screened for and detected given the lack of affordable and readily available biological assays, as well as the fact that volatile substances can be easily used in covert fashion while eluding detection by family members, authority figures, and law enforcement. Surveillance and treatment systems for VSM are inadequately funded because VSM is a "hidden epidemic," a highly stigmatized practice that disproportionately affects marginalized persons and to which few societal resources are allocated.

ETIOLOGICAL AND CONTEXTUAL CONSIDERATIONS OF VOLATILE SUBSTANCE MISUSE

Little is known about why individuals engage in VSM. Some researchers have suggested that family instability, parental substance use, dysfunctional parent/child interactions, and child abuse are precursors of VSM (e.g., Fendrich, Mackesy-Amiti, Wislar, & Goldstein, 1997; Oetting & Webb, 1992; Pack et al., 2005), yet most of the VSM literature relies on retrospective reports and cross-sectional data that cannot establish causality. Recent research indicates that having a more extensive history of exposure to traumatic violence predicts VSM frequency, self-medication with volatile substances, and the adverse consequences of VSM (Garland & Howard, 2010b). Furthermore, the influence of intra-individual variables, such as trauma and psychiatric dysfunction, on the etiology of VSM may be compounded by the forces of socioeconomic

and geographic marginalization (Dinwiddie, 1994). Given that many volatile substance misusers live in rural, impoverished, or marginalized communities, economic stress coupled with geographic and/or social isolation may render volatile substance misusers especially prone to seek intoxication via volatile substances, which are inexpensive and ubiquitous in the physical environment. Individuals with genetic loading toward impulsivity and emotional dysregulation and who are raised in impoverished social environments characterized by high rates of familial/peer violence and substance use are more likely to exhibit psychological distress and engage in a range of high-risk behaviors, including the misuse of psychoactive substances (Enoch, 2010). Thus, it is plausible that the etiology of VSM may be traced back to pathogenic gene-environment interactions and early experiences of adversity.

From the consideration of the foregoing epidemiological data, intentional misuse of volatile substances appears to be an act of desperation committed by troubled individuals in dire circumstances, rather than an act of pleasure-seeking (MacLean, 2008). This view is bolstered by the extreme stigma associated with VSM (Oetting, Edwards, & Beauvais, 1988). Yet, subjective accounts of experiences associated with VSM suggest that the inhalation of volatile substances produces an intensely pleasurable form of intoxication (e.g., Beckman, Zacny, & Walker, 2006; Garland & Howard, 2010a; MacLean, 2008). Contextual theories, which suggest that VSM may be in part determined by one's position within a socially stratified and hierarchical society (MacLean, 2005), may reconcile these views of VSM as a desperate act and a sought-after source of pleasure. For marginalized individuals who typically seek intoxication via volatile substances, VSM may provide an "opportunity for a temporary escape" (MacLean, 2005, p. 311) and "feelings of personal power and autonomy" (MacLean, 2005, p. 312). In other words, VSM may provide a form of pleasure that is particularly appealing to individuals who have limited access to alternative means of gratification (MacLean, 2008). This perspective, in contradistinction to etiological theories focused on intra-individual pathology, raises the question: "Do volatile substance misusers need psychotherapeutic treatment, socioeconomic advocacy, or alternate ways to achieve meaning, pleasure, and social integration?" Hence, to be effective, future VSM intervention development efforts must take into account these apparently discrepant yet potentially complementary etiological considerations.

CONCLUSION

Volatile substance misuse is prevalent in the United States, with more than 22 million persons reporting a history of VSM. VSM is endemic among population subgroups and prevalence rates differ notably across regions of the country and various sociodemographic subgroups.

Serious mental health and substance use problems commonly co-occur with VSM. Nationally representative survey findings based on face-to-face structured psychi-

atric interviews indicate that the typical misuser of volatile substances is polydrug-dependent, afflicted with multiple comorbid psychiatric disorders, and exhibits antisocial traits and behaviors. These challenging conditions are further complicated by the disadvantageous and traumatic social circumstances that characterize the lives of many volatile substance misusers.

Given the long history of VSM in the United States, it is lamentable and to some degree mystifying that the deleterious social and health consequences of VSM have been publicly recognized only recently. Scant research on the assessment, prevention, and treatment of VSM has been conducted in the United States, and potentially effective policy measures have rarely been the subject of social or political discussion (Perron, Vaughn, Howard, Bohnert, & Guerrero, 2010) despite the fact that the World Health Organization (WHO) and United Nations Office on Drugs and Crime published reports on the problem more than a decade ago (Flanagan, Streete, & Ramsey, 1997; WHO, 1999). VSM has been characterized as "a stepchild in the war on drugs," and formerly was not considered as serious of a public health threat as drugs such as cocaine, heroin, and alcohol (National Institute on Drug Abuse [NIDA], 1994). Recently, NIDA delineated a needed program of VSM research and set aside funds for this research, resulting in significant advances in knowledge of VSM over the past decade. Additional research is needed to identify effective prevention and treatment approaches for VSM. In addition to increased research monies, greater funding of VSM prevention and treatment programs in school and service (e.g., juvenile justice) settings is needed to reduce the considerable toll exacted by VSM—costs that are typically borne by some of the most vulnerable citizens of the United States.

The present review has a number of implications for policymakers and clinicians alike. First, the magnitude and long-standing history of VSM in the United States warrant the deployment of specific policies designed to facilitate effective VSM intervention development and implementation. Given epidemiological data identifying subgroups at elevated risk for engaging in VSM, policymakers should target these distinct populations with intervention policies tailored to address the unique needs of each subset of volatile substance misusers. For example, rural areas should be allocated a greater proportion of state funds to prevent and intervene with VSM. Prevention efforts should commence in elementary school, as volatile substances are typical among the first "drugs of abuse"² used by youth and often are of particularly early onset in antisocial youth. Similarly, clinicians working in treatment systems where volatile substance

²The reader is asked to consider that the often used nosology "drugs of abuse" is both unscientific and misleading in that (a) it mystifies and empowers selected active chemicals into a category whose underpinnings are neither theoretically anchored nor evidence-informed and which is based upon "principles of faith" held and transmitted by a range of stakeholders representing a myriad of agendas and goals, and (b) active chemical substances of any types—"drugs"—are used or misused; living organisms can be and are all-too-often abused. Editor's note

misusers are more likely to be encountered (e.g., adolescent correctional or psychiatric institutions) should be trained to have a high index of awareness for VSM and to integrate volatile-substance-related screening questions into routine intake procedures. In light of the strong associations between self-medication tendencies, traumatic experiences, and VSM, clinicians should be trained to focus VSM assessment and intervention efforts on individuals with mood symptoms and more extensive trauma histories.

Given the dearth of extant VSM prevention and treatment interventions, there is a need to establish viable criteria with which to assess the process and outcomes of such interventions. Fortunately, the well-established methodologies utilized in clinical research for other psychoactive substances (e.g., randomized controlled trials, comparative effectiveness studies, etc.) may be adapted to VSM intervention research. Estimates of VSM frequency and quantity could serve as primary study outcomes, and secondary outcomes might include factors as diverse as readiness/motivation to change, reduction of associated high-risk and antisocial behaviors, decreased psychological distress, and increased academic or occupational involvement. As VSM is unlikely to result in court-mandated treatment, detention, or institutionalization requiring complete abstinence from volatile substances, clinical research on VSM interventions would most profitably follow harm reduction assessment methods (Des Jarlais, 1995; Marlatt, 1996) with emphasis on outcomes related to social integration and the moderation of VSM-related health problems.

Ultimately, research on VSM should be conducted with an eye toward the ethical issues inherent in collecting data from individuals who are not likely to benefit directly from their participation in research (Kleinig & Einstein, 2006). For instance, in the conduct of basic psychological and sociological research on VSM, participants may reveal sensitive information about involvement in illicit activities that, should confidentiality be breached, might expose them to risk of legal or occupational ramifications. For the individual, the potential costs of participating in such research may outweigh the social benefits. Yet, while epidemiological and basic science research on VSM may not directly benefit the individuals who participate in such investigations, these forms of research lay the foundation for the future development of effective and culturally appropriate interventions. For example, knowing what factors motivate individuals to engage in (Perron et al., 2008) and desist from VSM (Garland & Howard, 2010b) is a key step in developing interventions that can capitalize on natural recovery processes (Orford, 2001). Given the vulnerable and marginalized nature of many volatile substance misusers (some of whom have been historically exploited), studies should be planned and implemented with a focus on the relevance of such research for the ultimate aim of intervening with this serious threat to public health. Consideration of community-based research methodologies may be a notable starting point.

Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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GLOSSARY

Barrio: A Spanish word for district or neighborhood.

DSM-IV: Diagnostic and Statistical Manual of Mental Disorders, 4th edition.

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