



Pharmacological content of tablets sold as “ecstasy”: Results from an online testing service

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Abstract

Purpose: This study examined the pharmacological content of tablets sold as ecstasy, the variation of tablet content by geographic region, and change in tablet content between 1999 and 2005.

Methods: The sample was comprised of tablets anonymously submitted for laboratory testing between 1999 and 2005 ($n = 1214$). Tablet height, width, geographic region, and year of submission were all used to predict the pharmacological content of the tablets.

Results: Overall, 39% of the tablets were comprised of MDMA only, 46% only contained substances other than MDMA and 15% were mixtures of MDMA and other substances. Tablet height and width were inversely related to tablet purity. Ecstasy tablets from California and Florida had decreased likelihoods of containing non-MDMA substances. The purity of tablets decreased over time, which was largely a result of an increasing number of tablets comprised of MDMA along with other substances.

Conclusions: Ecstasy users may be putting themselves at increased risk of substance-induced anxiety, mood, and psychotic disorders by unknowingly ingesting substances other than MDMA. To decrease detrimental health effects, prevention programs should emphasize the impurity of ecstasy tablets and focus on the health impacts of these substances, particularly for populations at high-risk of substance-induced disorders.

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1. Introduction

Although the use of 3,4-methylenedioxymethamphetamine (MDMA) or “ecstasy” in the United States is stabilizing or declining, an estimated 2–4% of U.S. adolescents and young adults report annual use of MDMA (Johnston et al., 2005; Strote et al., 2002). Despite the low prevalence of MDMA use in the general population, MDMA is and remains popular as a “club drug” in the rave community. The few extant MDMA prevalence studies of U.S. rave attendees indicate that between 13 and 30% of sampled rave attendees report two-day ecstasy use (Arria et al., 2002; Yacoubian et al., 2003, 2004). MDMA use is also prevalent in Australia, Canada, and other European countries (Degenhardt et al., 2005; Gross et al., 2002; Landry, 2002), again, particularly for adolescents and young adults involved in the rave scene (Barrett et al., 2005; Engels and ter Bogt, 2004; Lenton et al., 1997; Wijngaart et al., 1999).

Given that many adolescents and young adults report lifetime as well as regular use of MDMA, it is no surprise that researchers have increasingly focused on the negative cognitive, psychological, and neurological effects of MDMA. There is great debate within the scientific community as to whether MDMA leads to long-term neurotoxicity in users (Morton, 2005), but evidence suggests that hyperthermia and hyponatraemia are potential acute adverse effects of ecstasy use (Gowing et al., 2002). In addition to the negative cognitive, psychological, and neurological effects of MDMA, another facet of ecstasy use that has important public health implications is the fact that many tablets sold as ecstasy contain a variety of substances in addition to or instead of MDMA (Cheng et al., 2003; Cole et al., 2002; Kalasinsky et al., 2004; Parrott, 2004). This is not to suggest that the detrimental health effects of MDMA are unimportant, but rather that they only comprise part of the risk associated with ecstasy use. For although users may be aware of the risks associated with MDMA (Gamma et al., 2005), they may be unaware of the risks associated with the other drugs they could be (unknowingly) ingesting. Ecstasy tablets may include substances such as caffeine that have few

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serious health repercussions in small doses (Daly and Fredholm, 1998), or substances such as ketamine, methamphetamine, or paramethoxyamphetamine that are unsafe alone or in combination with other drugs (Baggott et al., 2000; Renfro, 1986; Sherlock et al., 1999). Moreover, the contamination of ecstasy tablets is particularly troublesome for users with certain predisposing factors for addictions and/or psychiatric disorders (Chen et al., 2003). Given these public health implications, the systematic study of ecstasy tablets' pharmacological content provides valuable information for researchers and health professionals alike.

1.1. Ecstasy tablet purity

To date, several studies have empirically examined the pharmacological content of ecstasy tablets, relying primarily on samples of tablets from police seizures (Cheng et al., 2003; Cole et al., 2002), anonymous submissions by individuals (Baggott et al., 2000; Renfro, 1986; Spruit, 2001) or comparisons of self-reports to scalp hair analysis (Kalasinsky et al., 2004). However, given the variability in sampling methods, limited sample sizes, and limited heterogeneity of samples, the extant literature has yielded inconsistent findings regarding ecstasy tablet contamination.

For example, several empirical studies have reported considerable levels of ecstasy tablet contamination. One of the first empirical analyses of ecstasy tablet content was that of Renfro (1986), which reported the content of 101 tablets anonymously submitted between 1973 and 1985 to the U.S. drug testing service Analysis Anonymous. The results indicated that 58% of the alleged ecstasy tablets contained MDMA only, 24% contained MDMA as well as other drugs, 16% contained drugs other than MDMA, and 2% contained no identifiable substances; one of the primary adulterants in the ecstasy tablets was methylenedioxyamphetamine (MDA) (Renfro, 1986). Over a decade later, Baggott et al. (2000) analyzed the pharmacological content of 107 ecstasy tablets submitted anonymously to the U.S. organization DanceSafe between February 1999 and March 2000. The results indicated that 63% of the sample contained MDMA, 29% contained substances other than MDMA, and 8% contained no identifiable drugs; primary adulterants included dextromethorphan (DXM), caffeine, ephedrine, and pseudo-ephedrine (Baggott et al., 2000).

In another recent study, Cheng et al. (2003) identified the primary ingredients of ecstasy tablets seized in Hong Kong between 2000 and 2001. In a sample of 212 different types of ecstasy tablets, approximately 55% contained primarily MDMA, 40% contained primarily methamphetamine, 5% contained primarily MDA, and 5% contained primarily amphetamine. Moreover, the percentage of tablets comprised primarily of MDMA decreased significantly between 2000 and 2001, while the percentage of methamphetamine and MDA tablets significantly increased. Finally, although only 12% of the 2000 sample included tablets that were comprised of MDMA and ketamine, 42% of the 2001 sample included tablets that were a mixture of MDMA and ketamine—thus indicating increased tablet contamination between 2000 and 2001 (Cheng et al., 2003).

Other empirical studies, however, have reported lower levels of ecstasy tablet contamination, suggesting higher levels of purity. For example, Cole et al. (2002) analyzed the content of 80 ecstasy tablets sampled from a large police seizure of approximately 160,000 ecstasy tablets in the United Kingdom, as well as the content of ecstasy tablets analyzed by the Forensic Science Service in the United Kingdom. Interestingly, all of the tablets contained MDMA, although some tablets also contained portions of methylenedioxyamphetamine (MDEA). Despite the relative purity of the ecstasy tablets in this sample, the MDMA content of ecstasy tablets decreased over time, from 102 mg in 1991 to 73 mg in 2001 (Cole et al., 2002).

Using data from the Drug Information and Monitoring System (DIMS) in the Netherlands, Spruit (1999, 2001) analyzed over 10,000 ecstasy tablets submitted to DIMS for chemical analysis. The DIMS project was one of the first formal initiatives for harm reduction through pill testing, originating in 1992 with the support of the Dutch government. The DIMS sample of ecstasy tablets (submitted primarily by anonymous users) indicated that between 1993 and 1996 approximately 48–60% of the tablets were comprised of MDMA only, 7–13% were comprised of MDMA as well as other substances, and 2–7% were comprised of non-MDMA substances only (Spruit, 2001). Tablet purity decreased substantially in 1997, when 34% of tablets contained MDMA only and 14% contained MDMA as well as other substances (Spruit, 1999, 2001). Tablet purity rebounded in 1998 and 1999 however, when 75 and 81% of pills were comprised of MDMA, respectively (Spruit, 1999, 2001). So although purity levels were quite low in the early 1990s, they increased during the late 1990s.

In a more recent literature review, Parrott (2004) discussed the findings of numerous studies on ecstasy tablet purity ranging from the mid-1970s to the early 2000s. Parrott's (2004) comprehensive review summarized the results from the aforementioned studies, but also reviewed several smaller ($n < 100$) pharmacological analyses of ecstasy tablets, survey studies of ecstasy users' subjective reports of tablet purity, and toxicological analyses of ecstasy attributed deaths (e.g., Milroy et al., 1996; Saunders, 1995; Sherlock et al., 1999). Overall, Parrott (2004) reported that ecstasy tablets in the 1980s were of high quality and purity (90–98% containing MDMA), although a small amount of tablets did contain MDA. In the early 1990s, ecstasy tablet purity declined, and many tablets contained substances other than MDMA (50–80% containing MDMA). Finally, Parrott (2004) reported that the proportion of ecstasy tablets containing MDMA increased to 80–90% in the late 1990s, and increased to between 90 and 100% in the early 2000s.

Thus, the previous empirical literature suggests that ecstasy tablets often include substances other than MDMA, although estimates of tablet contamination have varied considerably across time and space. Unfortunately, previous studies have suffered common flaws that have left the need for more systematic research on the topic. For instance, due to limitations in data availability, many empirical studies' samples included tablets from a span of only one or two years, therefore precluding researchers' ability to analyze trends over time (with the notable exception of Spruit, 1999, 2001). Second, previous empirical

studies have also relied on largely homogeneous samples of ecstasy tablets (e.g., from police seizures), thus providing little information about variation in tablet purity. Moreover, the understandable reliance on small samples has limited researchers' ability to conduct multivariate analysis or analysis of trends in tablet purity across geographic regions. Finally, most recent empirical studies have relied on European tablet samples (see Parrott, 2004), thereby restricting generalizations to the purity of U.S. ecstasy tablets. The current study attempts to fill these gaps in the literature by analyzing a large sample of ecstasy tablets anonymously submitted to an online testing service in the United States over a span of six years.

2. Method

2.1. Sample

This study used publicly available information compiled from the website of DanceSafe (www.dancesafe.org), which is a U.S. non-profit organization that promotes harm reduction in the rave/nightclub community. In addition to onsite testing of ecstasy tablets at raves/nightclubs and distribution of tablet self-test kits, DanceSafe provides free laboratory analysis for ecstasy tablets submitted anonymously by mail. Due to the anonymous submission procedure, there is no way of knowing who is sending in the tablets, although it is probably a combination of users, drug dealers, club owners, or even concerned parents. DanceSafe encouraged submitters to mail tablets suspected to be fake or adulterated, so it is possible that the purity of tablets in this sample is lower than in the general population.

DanceSafe tested the submitted tablets using gas chromatography/mass spectrometry, which measures relative amounts of detected substances in each tablet by identifying compounds' unique fragmentation patterns (for more detailed information on the process of gas chromatography and mass spectrometry, see Bureau of Forensic Services, 2005). After laboratory analysis, DanceSafe posted the results on their publicly available website. The analytic sample was comprised of all tablets posted on the website between 1999 and July of 2005 ($n = 1214$).

It is possible that the sample may not be comprised of unique ecstasy tablets—for example, one person could have submitted several of the same tablet, or several people from the same area could have submitted the same tablets. There is no way to empirically test this, given that tablets with the same “brand” name originating from the same city could be derived from different manufactured batches of ecstasy tablets, even if they have the same pharmacological makeup. However, the data do indicate that only a very small percent of the tablets (less than 5%) have the same name, city, state, and pharmacological content; thus, any bias in variability introduced through repeated measures of tablets should be low.

2.2. Measures

The dependent variable of interest was the pharmacological content of ecstasy tablets. Although gas chromatography/mass spectrometry can only provide estimates of ratios of compounds

present in tablets, DanceSafe listed the laboratory results in terms of the percent of substances in each tablet (e.g., 100% MDMA, 20% MDA/80% MDMA). Because these listings were only crude estimates (at best) of the percent of substances in each tablet, the current study uses a three-category variable indicating the content of tablets as comprised of MDMA only, non-MDMA substances only, or a mixture of MDMA and non-MDMA substances. Overall, 39.0% ($n = 473$) of the tablets were comprised of MDMA only, 46.0% ($n = 558$) were comprised of substances other than MDMA, and 15.1% ($n = 183$) were comprised of a mixture of both MDMA and non-MDMA substances.

The independent variables of interest included tablet height, width, weight, geographic region, and year of submission. DanceSafe's laboratories recorded the height, width, and weight of tablets on the website. Height and width were coded in millimeters and weight was coded in milligrams. However, the DanceSafe listings for tablet weight included numerous data entry errors listing equivalent weights and heights (with average tablet weights of 260 mg, tablets weighing 9 mg were clearly data entry errors) and thus all tablets with equal weight and height listings were coded as missing weight information. Given the large proportion of tablets with missing weight information (see Table 1), tablet weight was not included in the multivariate analysis. Submitters indicated the geographic region from which the tablet originated, and geographic region was coded into dichotomous variables contrasting Northeast, South, Midwest, and West using U.S. Census region designations. Because a large number of tablets originated from California and Florida, the analysis also included two dummy variables indicating whether the tablets came from these two states so that 1 = yes. Because submitters anonymously provided geographic information, it is not possible to estimate the reliability of this measure; we can only assume that submitters provided accurate information given the anonymity that mail submission afforded them. Finally, the DanceSafe laboratories provided the year in which the tablet was received, which ranged from 1999 to 2005.

2.3. Statistical analysis

Section 3 presented relative risk ratios from multinomial logit regression models predicting pharmacological content of ecstasy tablets. This technique was appropriate given that the dependent variable – ecstasy tablet content – was categorized into three discrete and non-ordered categories (MDMA only,

Table 1
Descriptive statistics of ecstasy tablets: 1999–2005 DanceSafe postings

	<i>M</i>	S.D.	Range	Valid <i>n</i>
Width (mm)	4.5	1.7	1–26	1181
Height (mm)	8.5	1.4	1–20	1181
Weight (mg)	259.5	100.1	1–971	745
Midwest (1 = yes)	11.2%	.3	0–1	1202
Northeast (1 = yes)	18.4%	.4	0–1	1202
South (1 = yes)	27.9%	.5	0–1	1202
West (1 = yes)	42.2%	.5	0–1	1202
California (1 = yes)	30.0%	.5	0–1	1202
Florida (1 = yes)	10.7%	.3	0–1	1202

non-MDMA only, and MDMA and non-MDMA mixture). In Section 3, the MDMA only, or “pure” MDMA category of the dependent variable was specified as the comparison group, with the total number of categories in the dependent variable $j = 3$. Multinomial logit regression yields relative risk ratios (RRRs), which for continuous variables represent the expected change in the risk of being in category j versus the comparison group (i.e., MDMA only) for each one-unit increase in the independent variable. RRRs for dummy variables represent the relative risk of being in category j versus the comparison category for the group coded 1 on the dummy variable. Multinomial regression assumes the independence of irrelevant alternatives (IIA), or that the choice of one alternative over the other remains unaffected by the choice of the other alternative; the Hausman–McFadden test (Hausman and McFadden, 1984) indicated that the models did not violate the IIA assumption. All analyses were conducted using the statistical environment Stata 8.2.

3. Results

3.1. Descriptive statistics

Table 1 shows the means, standard deviations, ranges, and valid number of cases for the independent variables. On average, tablets were 4.5 mm × 8.5 mm in size and weighed 259 mg. Most of the tablets were sent in from the West (42%), followed by the South (28%), Northeast (18%), and Midwest (11%), respectively. Moreover, approximately 40% of tablets were sent in from the two states of California (30%) and Florida (11%), combined.

3.2. Pharmacological content of tablets

Table 2 lists the primary pharmacological components of the tablets, including the percentage of tablets that were comprised solely of each substance and the percentage of tablets that included each substance in addition to other substances. The names of the most commonly occurring substances appear in bold. As shown in Table 2, the tablets included a variety of substances other than MDMA, including methylenedioxyamphetamine (MDA), methylenedioxyethylamphetamine (MDE), caffeine, ketamine, and dextromethorphan (DXM). Over half of the tablets included MDMA in addition to other substances (54%), but only 39% of the tablets were comprised solely of MDMA. This means that 46% of the tablets contained no MDMA at all and 15% of the tablets were comprised of a mixture of MDMA and other drugs. Among contaminated tablets, the most common substances included MDA, methamphetamine, caffeine, DXM, and pseudo-ephedrine. Other potentially fatal drugs such as dimethoxyamphetamine (DOB), heroin, ketamine, phencyclidine (PCP), and paramethoxyamphetamine (PMA) appeared in only a small percentage of the tablets, but were nonetheless present in the sample.

3.3. Multivariate analyses

Table 3 presents relative risk ratios and 95% confidence intervals from a single multinomial logit regression model predicting

Table 2
Pharmacological content of ecstasy tablets: 1999–2005 DanceSafe postings

	Tablets with this ingredient only (%)	Tablets with this ingredient in part (%)
MDMA	38.96	54.04
5-MeO-DIPT	.66	.66
Acetaminophen	.58	1.73
Amitriptyline	.08	.08
Amphetamine	.25	.33
Aspirin	.16	.82
Benzylpiperazine	.16	1.48
Caffeine	2.14	16.56
Carisoprodol	.16	.25
Cocaine	.08	.33
Codeine	.08	.25
Dextromethorphan (DXM)	4.94	7.99
Diazepam	.33	.41
Diethylpropion	.08	.08
Diphenhydramine	.41	.66
Dimethoxyamphetamine (DOB)	.08	.08
Guaifenesin	.33	.91
Heroin	0	.08
Ketamine	.41	2.72
Lidocaine	.08	.16
Methylenedioxyamphetamine (MDA)	5.19	12.60
Methylenedioxyethylamphetamine (MDE)	.91	5.11
Metandienone	.08	.33
Methamphetamine	1.48	8.65
Methyl salicylate	.16	1.48
Phencyclidine (PCP)	.08	1.15
Paramethoxyamphetamine (PMA)	.16	.16
Pseudo-ephedrine	1.15	7.58
Trifluoromethylphenylpiperazine monohydrochloride	.08	1.32
Unknown	10.87	11.78
Zolpidem	.16	.16

the content of ecstasy tablets. Namely, tablet width, height, geographic region, and year are the independent variables predicting the risk of a tablet being comprised of non-MDMA substances only or MDMA and non-MDMA substances combined, relative to the risk of a tablet containing MDMA only (i.e., the reference or base category of the dependent variable). Similar to odds ratios, relative risk ratios (RRRs) greater than one are associated with increased risk, while RRRs between zero and one are associated with decreased risk. As shown in Table 3, there were significant associations between tablet width, height, and year of submission and non-MDMA tablet content. Namely, the relative risk of a tablet containing only non-MDMA substances increased significantly with tablet width and height. Moreover, each one-year increase in the year of submission was associated with an expected 39% increase in the risk of a tablet containing only non-MDMA substances (compared to MDMA only). The relative risk of a tablet containing non-MDMA substances was not significantly related to Census geographic region. Only year emerged as a significant predictor of tablet content for non-MDMA and MDMA mixtures, indicating that the risk of a tablet containing a mixture of non-MDMA and MDMA substances (versus MDMA only) significantly increased over time.

Table 3
Relative risk ratios from multinomial logit regression predicting ecstasy tablet content: 1999–2005 DanceSafe postings ($n = 1170$)^{a,b}

	Value of the categorical outcome variable		
	Non-MDMA only	MDMA and non-MDMA mix	MDMA only
Tablet width	1.29 (1.12–1.50) ^{***}	1.18 (.98–1.43)	Ref.
Tablet height	1.59 (1.42–1.78) ^{***}	1.14 (.96–1.34)	Ref.
Midwest (1 = yes)	1.20 (.75–1.91)	1.90 (.99–3.64)	Ref.
Northeast (1 = yes)	.75 (.51–1.11)	.73 (.40–1.34)	Ref.
South (1 = yes)	Ref.	Ref.	Ref.
West (1 = yes)	.82 (.59–1.13)	1.38 (.88–2.14)	Ref.
Year	1.39 (1.26–1.53) ^{***}	2.00 (1.75–2.27) ^{***}	Ref.

^a Relative risk ratios and 95% confidence intervals using multinomial logit regression predicting tablet content, with “pure” MDMA tablets as the reference group.

^b $\chi^2 = 240.96$ ^{***}, pseudo- $R^2 = .10$.

^{***} $p < .001$.

Table 4
Relative risk ratios from multinomial logit regression predicting ecstasy tablet content: 1999–2005 DanceSafe postings ($n = 1170$)^{a,b}

	Value of the categorical outcome variable		
	Non-MDMA only	MDMA and non-MDMA mix	MDMA only
Tablet width	1.31 (1.12–1.52) ^{***}	1.18 (.98–1.43)	Ref.
Tablet height	1.60 (1.43–1.80) ^{***}	1.15 (.97–1.36)	Ref.
California (1 = yes)	.68 (.50–.92) [*]	.85 (.57–1.28)	Ref.
Florida (1 = yes)	.59 (.38–.92) [*]	.29 (.14–.57) ^{***}	Ref.
Other state (1 = yes)	Ref.	Ref.	Ref.
Year	1.42 (1.29–1.57) ^{***}	2.08 (1.82–2.37) ^{***}	Ref.

^a Relative risk ratios and 95% confidence intervals using multinomial logit regression predicting tablet content, with “pure” MDMA tablets as the reference group.

^b $\chi^2 = 247.54$ ^{***}, pseudo- $R^2 = .10$.

^{*} $p < .05$.

^{***} $p < .001$.

Given that Census region failed to significantly predict ecstasy tablet content, Table 4 presents relative risk ratios and 95% confidence intervals from a multinomial logit model that includes dummy variables indicating whether a tablet was submitted from California, Florida, or another state. Again, the relative risk ratios represent the risk associated with being in the j th category of the dependent variable relative to being in the reference category of MDMA only. As shown in Table 4, tablet width and height were still associated with an increased risk of a tablet containing non-MDMA substances only. Moreover, the relative risk of a tablet containing (in part or in whole) adulterants other than MDMA significantly increased over time. Interestingly, compared to all other states, tablets submitted from the states of California or Florida had significantly decreased likelihoods of containing only non-MDMA substances. However, only tablets submitted from Florida had a significantly decreased risk of containing a mixture of MDMA and non-MDMA substances. Finally, these multivariate models only accounted for approximately 10% of the variance in tablets' pharmacological content, suggesting that there are other important predictor variables omitted from the model. These might include measures of both the availability of MDMA to tablet manufacturers (i.e., supply) and manufacturers' perceptions of ecstasy users' substance preference (i.e., demand).

To graphically illustrate the trend in ecstasy tablet content over time, Fig. 1 presents the percent of tablets that contained (1) MDMA only, (2) non-MDMA substances only, and (3) a

combination of MDMA and non-MDMA substances between 1999 and 2005. As shown in Fig. 1, the purity of ecstasy tablets decreased overall between 1999 and 2005. In 2004, the percent of pure MDMA tablets was at a low of 8.9%, but rebounded to 28% in 2005. The percent of ecstasy tablets containing only non-MDMA substances decreased slightly over time, but remained

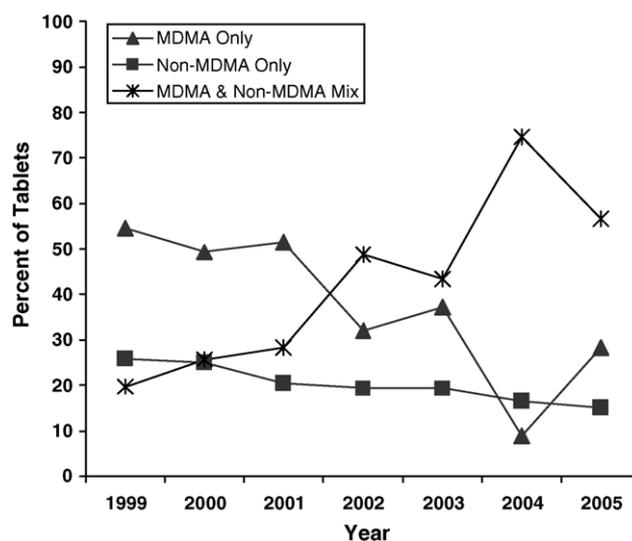


Fig. 1. Change in ecstasy tablet purity over time: 1999–2005 DanceSafe postings.

relatively stable at around 15–25%. Finally, between 1999 and 2005, tablets that were a mixture of MDMA and non-MDMA substances increased overall from 20 to 57%. However, the percentage of mixed substance tablets in 2005 (57%) was the result of a decrease from a high of 75% in 2004.

4. Discussion

This study has several limitations that should be acknowledged. First, given that DanceSafe encouraged the submission of pharmacologically suspect tablets, these estimates may overestimate the level of contamination in U.S. ecstasy tablets—which may explain why the findings are discrepant with a recent literature review of ecstasy tablet purity studies (Parrott, 2004). Second, although this sample of ecstasy tablets is national, it is not nationally representative of the population of U.S. ecstasy tablets. For instance, residents in California or Florida may have submitted a majority of the tablets because they were more aware of DanceSafe's tablet testing policies. Third, it is possible that submitters provided inaccurate information about tablets' geographic region of origin, thus conclusions about geographic trends in ecstasy purity are tentative. Finally, this sample is limited to the United States and therefore we cannot make any conclusions about the pharmacological content of ecstasy tablets in other countries.

Despite these limitations, this study is one of the first to analyze such a wide variety of ecstasy tablets available from across the United States over a period of six years. Data availability is limited, so many previous studies have understandably focused on tablets from police seizures—most often comprised of largely homogeneous tablet batches. Although the DanceSafe data are not nationally representative, they do provide information on a large heterogeneous sample of tablets that is currently unavailable elsewhere in the United States. Taking this study's findings along with those from studies using other data sources will allow researchers to gain a more comprehensive understanding of actual tablet purity in the population of the U.S. ecstasy market.

In general, the findings suggest that a large percentage of U.S. tablets sold as ecstasy between 1999 and 2005 contained substances in addition to or instead of MDMA. Some of the more common substances were MDA, methamphetamine, caffeine, and DXM. It is possible that manufacturers use certain contaminants (e.g., DXM, caffeine, or pseudo-ephedrine) because they are cheap and legal, and therefore may be more easily obtainable than MDMA. Indeed, as shown in Table 2, many of the adulterated tablets contained these cheap and legal alternatives. It is also possible that high retail and wholesale prices of ecstasy provide an economic incentive for manufacturers to make batches of tablets they can sell as ecstasy, even if they are comprised only of substances other than MDMA. For example, a recent report of the Community Epidemiology Work Group (2004, p. 70) suggests that retail prices for ecstasy tablets ranged from \$6 per tablet in Dallas or Washington, DC to \$35–40 per tablet in Philadelphia or San Francisco, with the most common retail price between \$15–20 per tablet. These high retail prices may thus provide an economic incentive for ecstasy manufacturers to

increase production by using cheaper and more easily available substances.

Overall, tablets from California and Florida were most likely to contain MDMA only, and tablet height and width were negatively related to tablet purity. The percent of pure ecstasy tablets decreased over time, largely due to an increase in tablets sold with mixtures of MDMA along with other substances. Given a lack of empirical research on the topic, we can only speculate as to why ecstasy tablet contamination has increased over the last six years. But again, it is possible that manufacturers' desires to maintain the supply of ecstasy tablets (and thereby rely on more cheap or legal contaminants) needed to meet consumer demand may have played a part in this emerging trend. Finally, although more lethal drugs such as dimethoxyamphetamine (DOB), heroin, ketamine, phencyclidine (PCP), and paramethoxyamphetamine (PMA) appeared in only a small percentage of the tablets, the fact remains that ecstasy users are at risk of ingesting potentially fatal drugs other than MDMA. Indeed, each tablet in this sample probably originated from a batch of pharmacologically similar tablets that was once available on the market.

The overwhelming presence of non-MDMA substances in ecstasy tablets is alarming and has important public health implications. First, many ecstasy users may be at increased risk of physical and/or psychological damage by unknowingly ingesting chemicals other than MDMA. Although some of the chemicals in ecstasy tablets may be less harmful than MDMA in small doses (e.g., caffeine), others may be more harmful and have potentially devastating long-term health effects. For instance, repeat users of ecstasy tablets with high doses of methamphetamine, pseudo-ephedrine, caffeine, cocaine, or opioids may be putting themselves at risk for such serious health problems as substance-induced anxiety, mood, or psychotic disorders as outlined in the DSM-IV (1994). Moreover, it is possible that users with pre-morbid schizoid/schizotypal personality traits may be unknowingly increasing their risk of psychosis (Chen et al., 2003).

The impurity of ecstasy tablets could also negatively effect users' health if they do not get the expected physical response from MDMA and intentionally increase the number of tablets they ingest (Schifano, 2004). Recent studies have indeed suggested that many ecstasy users often take several tablets simultaneously (Carlson et al., 2005; Schifano et al., 1998), and heavier users of ecstasy may be at increased risk of cognitive deficits associated with MDMA (Halpern et al., 2004), psychopathological disorders associated with MDMA (Schifano et al., 1998; Schifano, 2000; Singer et al., 2004), and/or harmful effects associated with non-MDMA substances. Thus, users of contaminated ecstasy tablets may be at greater risk of harm if they ingest more tablets in an attempt to get a desired physical response.

The presence of non-MDMA substances in ecstasy tablets also has important public health implications for counselors, treatment providers, and researchers alike. For example, knowing that users in treatment for MDMA abuse may be suffering from withdrawal symptoms associated with other drugs can improve the treatment and care that counselors and other public health professionals are able to provide to those in recovery.

Moreover, researchers attempting to link MDMA use with psychopathological or other health outcomes should be aware that users might be experiencing the simultaneous effects of other drugs. For example, a recent longitudinal study found evidence against neurotoxicity-related memory problems in ecstasy users, which is in contrast to previously published research (Gouzoulis-Mayfrank et al., 2005). It is possible that non-MDMA substances in ecstasy tablets, alone or in combination with MDMA may be partly responsible for these discrepant research findings.

Given this, more research is needed to investigate the potential harmful effects of interactions between drugs such as MDMA and methamphetamine that are often used together in ecstasy tablets. Research on laboratory rats indicates that the combination of MDMA and methamphetamine has more adverse effects than that of either drug alone (Clemens et al., 2004), but there is a dearth of similar empirical studies for humans. Given that ecstasy tablets contain such a wide variety of contaminants, more research is needed to investigate the threshold levels at which various contaminants contribute to and/or exacerbate the acute effects of MDMA. Indeed, more systematic research in this area will benefit public health professionals by providing useful information for educational programs aimed at preventing and/or reducing the harm of ecstasy use.

Although research suggests that most ecstasy users are aware of the drug's associated risks (Gamma et al., 2005), users may still be unaware of the risks they face from adulterated tablets. By educating potential users about the impurity of ecstasy tablets and the added health risks they bring, intervention and prevention programs may help users become aware of and better assess the risks associated with ecstasy use. As others researchers have suggested (Falck et al., 2004), developing network-based prevention programs that train users about the risks associated with ecstasy may be an effective method of reaching ecstasy users. More importantly, such prevention efforts should focus on reaching individuals with pre-morbid characteristics that put them at a high-risk of developing psychiatric disorders or drug addictions.

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