

Opiates, cocaine and alcohol combinations in accidental drug overdose deaths in New York City, 1990–98

Phillip O. Coffin¹, Sandro Galea¹, Jennifer Ahern¹, Andrew C. Leon², David Vlahov¹ & Kenneth Tardiff²

Center for Urban Epidemiologic Studies, New York Academy of Medicine, New York,¹ and Department of Psychiatry, Weill Medical College of Cornell University, New York, USA²

Correspondence to:

Sandro Galea

Center for Urban Epidemiologic Studies

New York Academy of Medicine

1216 Fifth Avenue

New York, NY 10029

USA

Tel: +1 212 987 2560

Fax: +1 212 876 6220

E-mail: sgalea@nyam.org

Submitted 5 September 2002;

initial review completed 4 November 2002;

final version accepted 6 January 2003

ABSTRACT

Aims Accidental drug overdose contributes substantially to mortality among drug users. Multi-drug use has been documented as a key risk factor in overdose and overdose mortality in several studies. This study investigated the contribution of multiple drug combinations to overdose mortality trends.

Design We collected data on all overdose deaths in New York City between 1990 and 1998 using records from the Office of the Chief Medical Examiner (OCME). We standardized yearly overdose death rates by age, sex and race to the 1990 census population for NYC to enable comparability between years relevant to this analysis.

Findings Opiates, cocaine and alcohol were the three drugs most commonly attributed as the cause of accidental overdose death by the OCME, accounting for 97.6% of all deaths; 57.8% of those deaths were attributed to two or more of these three drugs in combination. Accidental overdose deaths increased in 1990–93 and subsequently declined slightly in 1993–98. Changes in the rate of multi-drug combination deaths accounted for most of the change in overdose death rates, whereas single drug overdose death rates remained relatively stable. Trends in accidental overdose death rates within gender and racial/ethnic strata varied by drug combination suggesting different patterns of multi-drug use among different subpopulations.

Conclusions These data suggest that interventions to prevent accidental overdose mortality should address the use of drugs such as heroin, cocaine and alcohol in combination.

KEYWORDS Alcohol, cocaine, multi-drug, opiates, overdose, polydrug.

INTRODUCTION

Mortality rates among illicit drug users are many times those in the general population. Mortality among drug users has been calculated as 6.9 times that of the general population in the United States (Joe & Simpson 1987), 10.10 in Rome, Italy (Perucci *et al.* 1991), 11.9 in London, United Kingdom (Oppenheimer *et al.* 1994) and 22.0 in Glasgow, United Kingdom (Frischer *et al.* 1997). A meta-analysis found a mortality rate among illicit opiate users 13 times that of the general population (Hulse

et al. 1999). Authors of each of these studies attributed the majority of excess mortality to accidental drug overdose.

Simultaneous use of multiple drugs has been shown to contribute substantially to overdose mortality. In a study of 329 heroin users in Sydney, Australia, 68% had overdosed in their life-time and 62% of recent overdoses had involved heroin with other depressants (Darke *et al.* 1996). Among respondents in an Australian survey of heroin users, 52% reported using heroin with other depressants at the time of overdose, principally benzodi-

azepines (33%) and alcohol (22%) (McGregor *et al.* 1998). A toxicological analysis of 87 drug-related deaths among recently released prisoners in Scotland found that 71% of decedents showed evidence of multi-drug use just prior to death (Seymour *et al.* 2000). In a study of 1018 injection drug users (IDUs) in Glasgow, Scotland, 27% reported at least one overdose requiring medical attention in the past year; 19% (57) of those who injected one drug and 40% (29) of those who reported injecting six or more drugs reported such an overdose (Taylor *et al.* 1996). Among 124 young IDUs in San Francisco, 48% of respondents had overdosed, and speedball (cocaine and heroin) injectors were 2.6 times more likely to report an overdose (Ochoa *et al.* 2001). In a study of 55 witnessed fatal overdoses, respondents identified multiple drugs in 58% of cases (Strang *et al.* 1999).

Simultaneous use of illicit drugs with alcohol also is known to be a major contributor to opiate overdose and subsequent mortality. In most studies, 50% or more of opiate overdose decedents also used alcohol just prior to death (Baselt *et al.* 1975; Brandt 1996; Zador *et al.* 1996; Poletti *et al.* 1999). Analysis of drug overdose deaths in Halifax, Canada in the early 1990s found ethanol present in 47.8% of 42 deaths (Poulin *et al.* 1998). A toxicological comparison of heroin-related decedents with current heroin users found ethanol present in 51% of decedents, compared to only 1% of current users. An inverse relationship was found between the amount of alcohol and the amount of morphine metabolites present in decedents, suggesting that alcohol use decreased the amount of heroin required to induce a fatal overdose (Darke *et al.* 1997). In a study of 438 heroin users in London, 30% of respondents said that using alcohol in combination with other drugs was the main reason for their most recent overdose (Gossop *et al.* 1996). These data suggest that drug combinations involving opiates, cocaine and/or alcohol may account for a substantial proportion of non-fatal and fatal accidental drug overdose episodes.

Although this evidence suggests the importance of understanding multi-drug overdose trends and their relation to overdose mortality, there are limited data that explore specifically changing trends of multi-drug use among overdose decedents. The study of changing overdose patterns can both suggest avenues for effective intervention and assist in predicting overdose rates in coming years. In this study we examined records on all overdose decedents in New York City (NYC) to (i) determine how accidental drug overdose deaths changed in NYC between 1990 and 1998, and (ii) examine multi-drug use among accidental overdose decedents over time. For the purposes of this paper, 'multi-drug' is defined as the use of multiple drugs together or during the same session of drug use.

METHODS

All cases of accidental drug overdose deaths in NYC from 1990 to 1998 were identified through manual review of medical files at the Office of the Chief Medical Examiner of New York (OCME). The OCME is responsible for assessing all deaths of people believed to have died in an unnatural manner. Thus, all accidental overdose deaths in NYC are reviewed by the OCME and would be included in this chart extraction. Data regarding demographics, cause of death, race/ethnicity, circumstance of death and toxicology were collected from the OCME files. The OCME investigators used the decedent's medical history, the circumstances and environment of the fatality, autopsy findings and laboratory data to attribute cause of death to each case reviewed.

Rates of autopsy vary by manner of death. During 1990–98, 99.8% of homicides, 85.6% of suicides, 79.4% of accidents and 88.2% of manner undetermined deaths underwent complete autopsy. All autopsied cases undergo toxicological screening. In some cases in which an autopsy was not performed, specimens were still submitted for toxicological analysis. The reader is referred to previous studies for further details on this data collection methodology and toxicological measurement of drugs involved in these cases (Tardiff *et al.* 1994; Tardiff *et al.* 1996).

Analyses were carried out on all accidental drug overdose deaths. We first described demographic characteristics of all accidental drug overdose deaths in NYC between 1990 and 1998; demographic characteristics considered include age, race, gender, manner of death, borough of death, place of death and drugs detected. In these analyses, we limited our observations to cocaine, opiates and alcohol, the principal drugs that appear in positive drug toxicology and cause of death. Drug categories in these analyses were not mutually exclusive, i.e. cause of death could be attributed to several of these drugs in the same decedent.

We calculated the total overdose death rate and overdose death rate caused by specific drugs in NYC for each year from 1990 to 1998. All population denominators for rate determination were obtained from US census data (Bureau of the Census 1990). We obtained census population counts for NYC for 1990 and 2000 and carried out a linear interpolation of the census population counts to obtain population denominators for the intervening years. All rates were expressed per 100 000 person-years. We subsequently directly standardized overall rates by age, sex and race to the 1990 census population for NYC to enable comparability between years relevant to this analysis. We determined best-fit models for the overall overdose death rates, for multiple drug overdose death rates and for single drug overdose death rates using log-likelihood testing.

We calculated accidental drug overdose death rates in NYC between 1990 and 1998 stratified by race and sex. We limited this part of the analysis to the three largest racial/ethnic groups in NYC: white, black, and Latino. Thus, we calculated the rate of overdose deaths caused by cocaine, opiates or alcohol within each of six racial/gender strata: white male, white female, black male, black female, Latino male, Latina female. We calculated the relative risks for overdose death comparing blacks and Latinos to whites within strata of gender.

RESULTS

There were 7451 accidental drug overdose deaths extracted from OCME files in NYC between 1990 and 1998. A plurality (43.4%) of decedents were 35–44 years old and the majority (79.5%) were men. Almost 33% (32.8%) of decedents were white, 36.3% were black and 30.0% were Latino. Death was attributed to opiates in 71.1% of all decedents, cocaine in 69.5% and alcohol in 40.4%. A plurality of deaths occurred in the borough of Manhattan (32.8%), with Brooklyn (24.6%) being the second most common borough of death. The majority of deaths (62.5%) occurred in the decedents' residence.

Table 1 shows detailed counts and adjusted rates of accidental overdose death between 1990 and 1998. The total number of accidental drug overdose deaths per year increased from 537 in 1990 to 1025 in 1993, then declined steadily to 752 in 1998. The accidental drug overdose death rate in 1990 was 7.33 per 100 000 person-years and comparable age-, race- and sex-adjusted drug overdose death rate was 13.89 per 100 000 person-years in 1993 and 11.13 in 1998. The proportion of accidental drug overdose deaths caused by opiates, cocaine or

alcohol was 97.6% overall and remained similar from 1990 (95.0%) to 1998 (97.9%). Opiates or cocaine were cited as cause of death in 99.3% of these deaths. For opiates, cocaine and alcohol, as well as for all drugs combined, overdose deaths peaked in 1993.

Figure 1 shows overall trends in overdose death rates. The relative contribution of opiates and cocaine to cause of death among accidental overdose decedents throughout the time interval is shown in the graphic trend. Overall, 57.8% of opiate, cocaine or alcohol overdose deaths were attributed to more than one of these drugs. Table 2 presents detailed counts and standardized rates for combinations of opiates, cocaine and alcohol. The most frequently observed drug combination in overdose deaths was opiates with cocaine (2.19 per 100 000 person-years in 1990, peaking at 4.36 in 1994 and 3.11 in 1998). The rate of deaths attributed to more than one of these drugs rose substantially from 3.85 per 100 000 person-years in 1990 to 8.76 per 100 000 person-years in 1993, then declined slowly to 5.88 per 100 000 person-years in 1998, mirroring the overall trend in overdose death rates. The trends in overall overdose death rates and in multi-drug overdose death rates were described best by quadratic models ($P < 0.001$ for both) while the trend in single drug death rates was best described by a linear model ($P = 0.007$).

Among accidental drug overdose deaths attributed to one drug alone, as shown in Table 2, those positive for cocaine only were most common from 1990 (1.93 per 100 000 person-years) to 1996 (2.76 per 100 000 person-years). Deaths positive for opiates only were most common in 1997 (2.71 per 100 000 person-years) and 1998 (2.62 per 100 000 person-years). The rate of single drug deaths increased substantially from 1990 (3.11 per 100 000 person-years) to 1991 (4.41 per 100 000

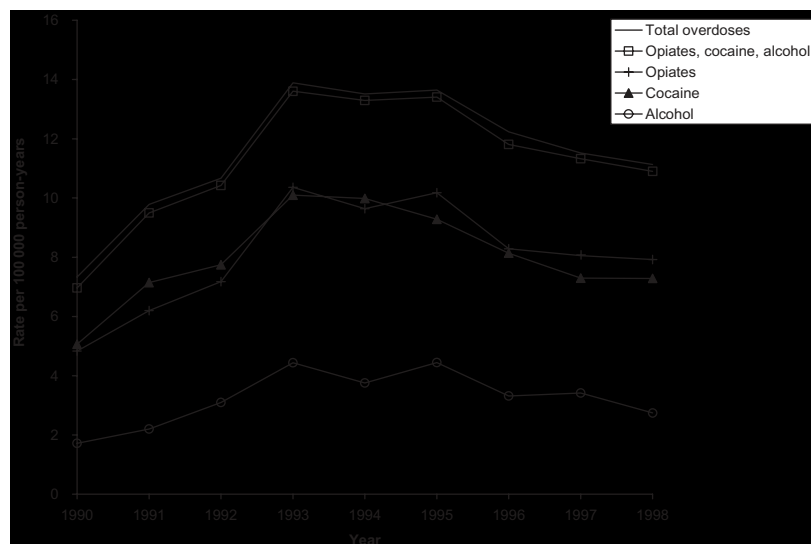


Figure 1 Standardized overdose death rates with drugs in decedents, New York City 1990–98

Table 1 Total overdose deaths and drugs in decedents, New York City 1990–98. Rate directly standardized by age, sex and race to 1990 census population for New York City.

	1990		1991		1992		1993		1994		1995		1996		1997		1998	
	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate
Total	537	7.33	722	9.78	788	10.66	1025	13.88	981	13.51	982	13.64	856	12.22	808	11.52	752	11.12
Opiates, cocaine or alcohol	510	6.96	701	9.49	770	10.42	1003	13.60	966	13.28	964	13.40	824	11.80	794	11.32	738	10.89
Opiates	371	5.06	528	7.14	573	7.75	741	10.09	727	9.98	666	9.28	567	8.14	509	7.30	499	7.29
Cocaine	354	4.83	458	6.20	532	7.18	768	10.35	703	9.64	734	10.17	583	8.29	575	8.05	537	7.92
Alcohol	126	1.72	162	2.20	229	3.09	324	4.44	272	3.76	322	4.45	234	3.32	238	3.42	187	2.74

Table 2 Overdose deaths by opiates, cocaine and alcohol combinations, New York City 1990–98. Rate directly standardized by age, sex and race to 1990 census population for New York City.

Op ^a	Coc ^b	Alc ^c	1990		1991		1992		1993		1994		1995		1996		1997		1998	
			n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate
+	+	+	59	0.81	63	0.87	122	1.66	189	2.59	145	2.02	165	2.30	107	1.52	110	1.58	89	1.30
+	+	- ^c	160	2.19	232	3.15	222	3.01	319	4.31	321	4.36	275	3.83	224	3.17	187	2.57	214	3.11
+	-	+	52	0.71	57	0.81	69	0.98	96	1.33	86	1.20	113	1.55	73	1.06	89	1.25	60	0.98
-	+	+	11	0.15	32	0.47	29	0.42	37	0.54	39	0.54	40	0.61	49	0.76	32	0.55	33	0.49
+	-	-	83	1.13	106	1.48	119	1.64	164	2.19	151	2.11	181	2.55	179	2.60	189	2.71	174	2.62
-	+	-	141	1.93	201	2.73	200	2.74	196	2.73	222	3.10	186	2.62	187	2.76	180	2.68	163	2.46
>1 drug ^d			282	3.85	384	5.31	442	6.06	641	8.76	591	8.13	593	8.28	453	6.51	418	5.95	396	5.88
1 drug alone ^e			228	3.11	317	4.41	328	4.60	362	5.04	375	5.32	371	5.29	371	5.49	376	5.55	342	5.21

^aOp: opiates; Coc: cocaine; Alc: alcohol. ^bDeath attributed to this drug. ^cDeath not attributed to this drug. ^dDeath attributed to more than one drug. ^eDeath attributed to one drug alone.

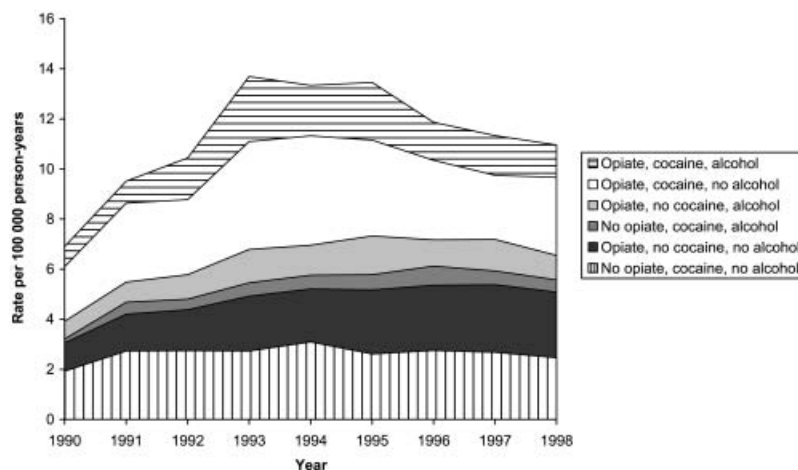


Figure 2 Stacked standardized rates of overdose deaths by drug combinations, New York City 1990-98

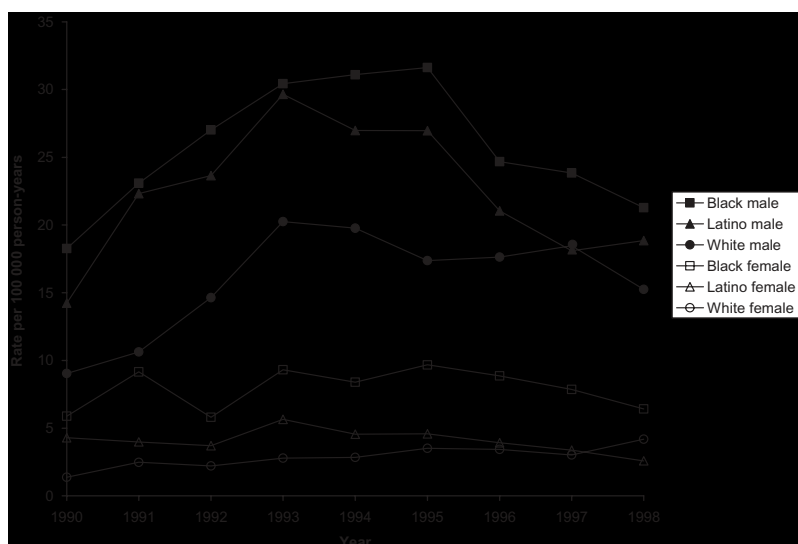


Figure 3 Overdose death rates by race and sex, New York City 1990-98

person-years), then rose slowly until 1997 (5.55 per 100 000 person-years) and declined slightly in 1998 (5.21 per 100 000 person-years). Figure 2 shows the relative contributions of different drug combinations of opiates, cocaine and alcohol to overdose deaths from 1990 to 1998.

Table 3 shows detailed rates of accidental overdose death by drug combinations detected in the six gender and racial/ethnic strata studied. Overdose death rates were highest among black men and second-highest among Latino men compared to all other strata throughout the time period studied. In 1990, there were 18.27 overdose deaths per 100 000 person-years among black men, 14.23 per 100 000 person-years among Latino men and 9.04 per 100 000 person-years among white men; these rates peaked at 31.63 deaths per 100 000 person-years among black men in 1995, 29.65 per 100 000 person-years among Latino men in 1993, and 20.25 per 100 000 person-years among white men in

1993. By 1998, the rates had declined to 21.28 deaths per 100 000 person-years among black men, 18.85 per 100 000 person-years among Latino men and 15.25 per 100 000 person-years among white men.

Overdose death rates among black women were consistently higher than rates among Latina and white women throughout the time period. In 1990, there were 5.88 overdose deaths per 100 000 person-years among black women, 4.29 per 100 000 person-years among Latina women and 1.38 per 100 000 person-years among white women. In 1998, there were 6.42 deaths per 100 000 person-years among black women, 2.59 per 100 000 person-years among Latina women and 4.19 per 100 000 person-years among white women. Figure 3 shows trends in overdose death rates by sex and race between 1990 and 1998; death rates among men mirror the overall pattern of overdose deaths. The risk of overdose death was significantly higher among blacks than whites throughout the time period studied and ranged

Table 3 Overdose death rates by race and sex for each major drug and combination, New York City, 1990–98. Rate directly standardized by age, sex and race to 1990 census population for New York City.

Race and sex	Opiates	Cocaine	Alcohol	1990	1991	1992	1993	1994	1995	1996	1997	1998
Black male	+ ^a	+	+	1.94	2.04	3.47	5.47	5.20	4.70	2.81	3.60	2.78
	+	+	– ^b	3.99	6.74	6.82	8.44	8.75	8.23	6.43	4.88	5.20
	+	–	+	1.33	1.08	2.03	1.66	2.13	2.70	1.17	2.33	1.50
	–	+	+	0.36	1.20	1.20	1.43	1.66	1.76	1.29	1.74	0.93
	+	–	–	2.54	2.65	2.15	3.69	3.55	5.06	4.68	4.19	3.58
Latino male	–	+	–	7.38	8.66	10.52	8.80	9.22	8.94	8.07	6.86	7.29
	+	+	+	2.00	2.76	4.50	7.49	4.10	4.44	3.01	3.56	2.59
	+	+	–	4.59	7.13	6.64	8.82	8.42	6.77	5.60	4.07	4.79
	+	–	+	2.12	2.88	3.26	3.20	2.59	4.44	2.49	2.34	2.19
	–	+	+	0.24	1.27	0.90	0.99	0.76	1.06	1.76	0.31	0.70
White male	+	–	–	2.23	3.57	3.71	5.62	5.18	6.35	3.11	4.37	5.09
	–	+	–	2.71	3.91	3.94	3.42	5.72	3.28	3.84	2.85	2.99
	+	+	+	9.04	10.63	14.63	20.25	19.77	17.37	17.63	18.47	15.25
	+	+	–	1.07	0.74	2.87	3.32	3.63	3.95	2.43	2.09	2.04
	+	–	+	2.95	3.52	4.58	7.05	6.78	5.30	4.35	4.26	4.60
Black female	–	+	+	1.27	1.29	1.23	2.70	2.24	2.61	2.36	2.67	1.39
	+	–	–	0.13	0.20	0.34	0.62	0.70	0.56	0.57	0.87	0.66
	–	+	–	1.88	2.30	3.01	3.52	3.63	2.97	4.92	5.34	3.72
	+	+	+	0.29	0.49	0.29	1.25	0.48	1.33	0.75	0.47	0.56
	+	+	–	1.47	2.53	1.35	2.59	3.53	3.04	2.36	1.87	1.86
Latina female	+	–	+	0.39	0.10	0.19	0.38	0.19	0.09	0.09	0.37	0.00
	–	+	+	0.10	0.49	0.19	0.29	0.19	0.57	0.94	0.19	0.47
	+	–	–	0.49	0.68	0.97	0.96	0.67	1.23	1.23	1.31	1.30
	–	+	–	2.55	4.19	2.71	3.56	3.06	3.42	2.92	3.56	2.23
	+	+	+	0.54	0.32	0.52	0.81	0.30	0.58	0.57	0.56	0.00
White female	+	+	–	1.93	1.68	1.03	1.62	1.79	1.27	1.34	0.94	1.11
	+	–	+	0.00	0.21	0.31	0.40	0.50	0.49	0.19	0.09	0.00
	–	+	+	0.21	0.11	0.21	0.20	0.20	0.10	0.10	0.00	0.00
	+	–	–	0.54	0.32	0.82	1.21	0.89	0.88	0.96	0.56	0.74
	–	+	–	0.75	1.16	0.82	1.31	0.89	1.07	0.67	1.13	0.74
White female	+	+	+	0.06	0.12	0.12	0.37	0.19	0.38	0.39	0.26	0.27
	+	+	–	0.60	1.09	0.74	1.24	1.01	1.21	0.84	0.98	1.60
	+	–	+	0.00	0.06	0.00	0.31	0.32	0.26	0.13	0.26	0.33
	–	+	+	0.00	0.12	0.12	0.12	0.19	0.00	0.13	0.00	0.20
	+	–	–	0.12	0.55	0.37	0.37	0.32	0.83	1.10	0.92	1.00
–	+	–	0.18	0.42	0.68	0.31	0.63	0.51	0.32	0.52	0.40	

^aDeath attributed to this drug. ^bDeath not attributed to this drug.

from a relative risk of 2.17 (95% confidence interval (CI) = 1.76–2.68) in 1991 to 1.29 (95% CI = 1.07–1.56) in 1997 among men. The risk of overdose death was significantly higher among blacks than whites throughout the period and ranged from a relative risk of 4.27 (95% CI = 2.64–6.91) in 1990 to 1.53 (95% CI = 1.09–2.16) in 1998 among women. The risk of overdose death was significantly higher among Latino men than among white men throughout the period studied except in 1997 (relative risk = 0.99, 95% CI = 0.81–1.19). There were no significant differences in risk of overdose death between Latina women and white women during the period 1995–98 (relative risks ranged from 3.11, 95% CI = 1.86–5.20 in 1990, to 1.31, 95% CI = 0.88–1.92 in 1995, to 0.62, 95% CI = 0.40–0.96 in 1998).

Among black men overdose deaths attributed to cocaine alone were more common than any other drug combination throughout the time period studied. Among Latino and white men deaths attributed to opiate and cocaine together were most common in most years studied. In all three groups, the trend in deaths attributed to opiates and cocaine together closely mirrored the overall trend in overdose deaths. Figure 4 shows the overdose death rates among black males by drug combinations throughout the period studied.

Among blacks the proportion of overdose deaths attributed to one drug alone decreased during the time period studied (from 56.8% in 1990 to a low of 41.9% in 1994 and 51.1% in 1998). Among Latinos and whites the proportion of overdose deaths that involved one drug

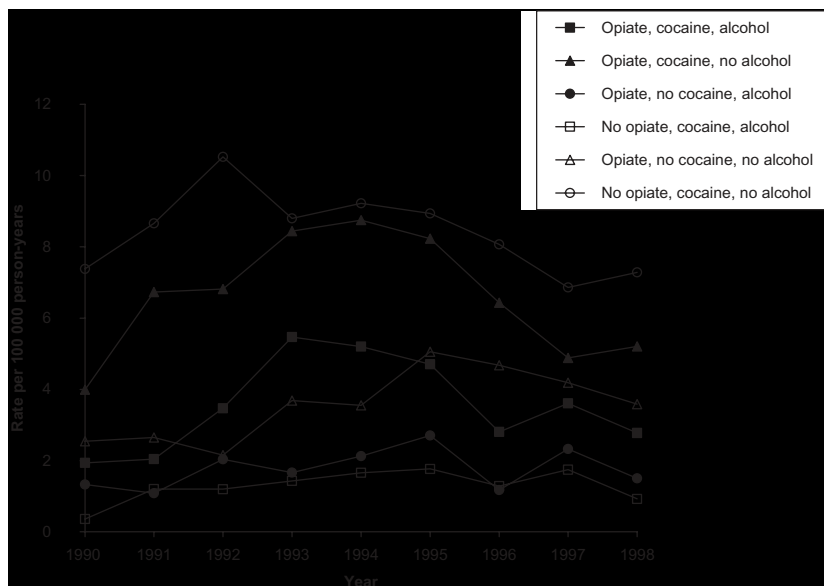


Figure 4 Overdose death rates among black males by drug combinations, New York City 1990-98

alone increased slightly during the time period studied (for Latinos: from 36.1% in 1990 to a low of 30.6% in 1993 and a peak of 44.6% in 1998; for whites: from 36.2% in 1990 to a low of 26.7% in 1995 and 41.4% in 1998).

DISCUSSION

We documented an increase in accidental overdose deaths in NYC between 1990 and 1993 and then a slight decline from 1993 through 1998. The rate of overdose deaths positive for either opiates or cocaine alone increased slightly during the study period but the majority of the variation in overdose death rates was observed among the rate of overdose deaths attributed to drug combinations of opiates, cocaine and alcohol. We also demonstrated that the patterns of drugs among accidental overdose deaths varied by racial/ethnic group.

Our finding that most overdose deaths were positive for multiple drugs is congruent with work in the United States and other countries that has demonstrated an association of multi-drug use with overdose death. In a seminal report, Brecher (1972) showed that in NYC, when street doses of heroin were far more pure than they have been recently, drug overdoses were practically unknown, suggesting that it was use of drugs in combination with other drugs (or impurities) that were primarily responsible for overdose fatality. Recent US data from the Drug Abuse Warning Network showed that three of every four drug abuse deaths reported by Medical Examiners nationally involved more than one drug (USDHHS 1999). The role of multiple drugs in drug overdose has been confirmed in several European countries in the

1990s. Risser showed that single drug intoxication was responsible for only 30% of overdose deaths in Vienna (Risser & Schneider 1994) and suggested more recently that an observed increase in drug-related deaths in Vienna was due to a significant increase in 'polydrug heroin-related deaths' (Risser *et al.* 2000). Up to 90% of overdoses presenting to an emergency department in Switzerland were shown to be positive for multiple drugs (Cook *et al.* 1998) and 84% of cocaine overdose deaths in Spain also involved heroin (Lora-Tamayo *et al.* 1994). Similarly, toxicological analysis of 152 heroin-related fatalities in New South Wales, Australia, found more than one drug in 71% of cases (Zador *et al.* 1996). In our data we found that while the proportion of overdose deaths attributed to a single drug remained relatively stable over time, the overdoses attributed to drug combinations, in particular opiates with cocaine, varied considerably and were the principal contributors to the variability in overall mortality rate. This suggests that changes in overdose mortality rates in NYC from 1990 to 1998 were largely the result of changes in the prevalence of multi-drug use, in particular the use of opiates with cocaine. This is consistent with findings (Ochoa *et al.* 2001) of an association between use of speedball injections (opiates with cocaine) and increased risk of non-fatal overdose and with findings from Darke *et al.*, who found that in Australia, where there was relatively little cocaine use, the majority of heroin overdoses occurred in circumstances where there was simultaneous use of other opioids or alcohol (Darke *et al.* 1996).

National US monitoring data on drug abuse deaths has shown an increase in deaths in the last few years with the increase concentrated particularly among Latinos (USDHHS 1999). We found that whereas opiates were the

most common cause of overdose deaths among Latino and white men more overdose deaths are caused by cocaine among black men. Harlow (1990) documented higher rates of cocaine overdose in Texas among blacks compared to whites and Latinos. It is unclear whether our data and previous findings reflected higher rates of cocaine use among black men or other factors that may place black men who use cocaine at higher risk of overdose mortality than white or Latino men who use cocaine. Research suggests that overdose rates are influenced by a variety of behavioral and structural factors (Strang *et al.* 1999) which should be investigated further to explain these observations (Galea *et al.* 2003).

Fatal overdose is an extreme consequence of drug use behavior. Non-fatal overdoses are probably more common among persons who use drugs. One recent study in Austria suggested that non-fatal overdoses are up to seven times more prevalent than fatal overdoses (Seidler *et al.* 2000). It is worth noting that different factors may determine fatal and non-fatal overdoses and, as such, the role of multi-drug use in overall overdose may differ from its role in fatal overdoses. For example, emergency medical system response may be a more important determinant of the outcome of more severe, potentially multi-drug, overdose. To explore fully the role of multi-drug use in overdose deaths, it would be necessary to compare multi-drug use with accidental drug overdose deaths over time in a particular locality. Such an analysis would permit the quantification of the greater likelihood of fatality of overdoses with multiple drugs present. It is also possible that other drug-using circumstances (e.g. differential drug use patterns whereby people using drug combinations are more or less likely to use drugs in the presence of others) are more powerful predictors of overdose mortality than the use of multiple drugs in combination.

In this study we were limited by OCME determinations of cause of death. OCME determinations of cause of death are based on several factors including but not limited to toxicology and may underestimate the role of multiple drugs in overdose deaths. Further study is warranted to determine the extent to which OCME determinations of causes of overdose death are accurate in assessing all drugs responsible for accidental overdose mortality.

Changes in overall drug use and in drug use patterns can be influenced by a variety of factors and changing social circumstances. For example, changes in the availability of drugs, locations of use, and different drug use patterns among habitual users in the 1990s may have been affected by shifting mores of drug users, growth in the national economy, increased availability of mobile phones and pagers leading to 'drug delivery services' (Dixon & Coffin 1999), and changes in policing (Kelling & Coles 1996; Bowling 1999) While a study of overdose decedents in isolation cannot determine the reasons for

changing trends in overdose fatalities, the observation that it is changing patterns of multiple drug positive overdoses that underlie overall overdose changes has substantial implications for public health prevention efforts.

While some risk reduction efforts have emphasized the role of multiple drugs in overdose fatality, most state-sanctioned public health interventions focus on reducing drug use without a discussion of the increased risk of using drugs in combination. This study suggests that public health efforts addressing the use of drugs in combination may have a greater effect on overall overdose mortality than efforts aimed at reducing use of single drugs. Furthermore, our findings demonstrate that overdose death rates involving different drug combinations varied between racial/ethnic strata, emphasizing the importance of understanding multi-drug use patterns among subpopulations that are at risk of accidental drug overdose death. Further research needs to examine the relationship between multi-drug use and risk of overdose fatality and to assess interventions that address the use of drugs in combination.

In summary, our analysis demonstrates that trends in overall overdose mortality reflected changing patterns in overdose mortality due to multi-drug combinations in NYC in 1990–98 while single-drug overdose rates were relatively unchanged. In addition, these trends varied among different gender and racial/ethnic strata with overdoses among blacks due primarily to cocaine and among Latinos and whites due to opiates with cocaine. These results build on previous research demonstrating the association between multi-drug use and overdose death and suggest that changing multi-drug use patterns may be the principal contributors to changing overdose death rates in NYC. These findings suggest that measuring single drug use prevalence is insufficient to guide public health interventions aiming to minimize morbidity and mortality related to drug use. In addition, multi-drug use has been shown to have a role in blood-borne pathogen transmission (Paone *et al.* 1999). Because syringe exchange programs have proved effective at reducing HIV risk behaviors among injection drug users, similar risk reduction modalities may be effective in encouraging reductions in multi-drug use. Finally, studies have documented a positive association between early onset of licit or illicit drug use and adult multi-drug use (Galaif & Newcomb 1999) suggesting that a long-term strategy to reduce multi-drug use may involve efforts to delay initiation into drug use.

ACKNOWLEDGEMENTS

This work was funded partly by grants DA-06534 and DA-12801-S1 from the National Institute on Drug Abuse.

REFERENCES

- Baselt, R. C., Allison, D. J., Wright, J. A., Scannell, J. R. & Stephens, B. G. (1975) Acute heroin fatalities in San Francisco. Demographic and toxicologic characteristics. *Western Journal of Medicine*, **122**, 455–458.
- Bowling, B. (1999) The rise and fall of New York murder: zero tolerance or crack's decline? *British Journal of Criminology*, **39**, 531–554.
- Brandt, M. D. (1996) *Opening the Casket: an Analysis of Alcohol and Heroin Overdoses: Myths, Misattributions and Misunderstandings*. Ann Arbor, MI: UMI Dissertation Services.
- Brecher, E. M. (1972) *The consumers' union report—licit and illicit drugs* [WWW document]. URL <http://www.druglibrary.org/schaffer/Library/studies/cu/cumenu.htm>.
- Bureau of the Census (1990) *Census Summary Tape, File 3A (STF3A)*. Washington, DC: US Department of Commerce. Available from http://www.census.gov/ftp/pub/population/www/estimates/co_crh.html.
- Cook, S., Moeschler, O., Michaud, K. & Yersin, B. (1998) Acute opiate overdose: characteristics of 190 consecutive cases. *Addiction*, **93**, 1559–1565.
- Darke, S., Ross, J. & Hall, W. (1996) Overdose among heroin users in Sydney, Australia: I. prevalence and correlates of non-fatal overdose. *Addiction*, **91**, 405–411.
- Darke, S., Sunjic, S., Zador, D. & Prolov, T. (1997) A comparison of blood toxicology of heroin-related deaths and current heroin users in Sydney, Australia. *Drug and Alcohol Dependence*, **47**, 45–53.
- Dixon, D. & Coffin, P. (1999) Zero tolerance policing of illegal drug markets. *Drug and Alcohol Review*, **18**, 477–486.
- Frischer, M., Goldberg, D., Rahman, M. & Berney, L. (1997) Mortality and survival among a cohort of drug injectors in Glasgow, 1982–94. *Addiction*, **92**, 419–427.
- Galaif, E. R. & Newcomb, M. D. (1999) Predictors of polydrug use among four ethnic groups: a 12-year longitudinal study. *Addictive Behaviors*, **24**, 607–631.
- Galea, S., Coffin, P. O., Tardiff, K. J., Ahern, J., Leon, A. C., Fuller, C. & Vlahov, D. (2003) Neighborhood characteristics and risk of fatal drug overdose in New York City. *Drug and Alcohol Dependence*, in press.
- Gossop, M., Griffiths, P., Powis, B., Williamson, S. & Strang, J. (1996) Frequency of non-fatal heroin overdose: survey of heroin users recruited in non-clinical settings. *British Medical Journal*, **313**, 402.
- Harlow, K. C. (1990) Patterns of rates of mortality from narcotics and cocaine overdose in Texas, 1976–87. *Public Health Reports*, **105**, 455–462.
- Hulse, G. K., English, D. R., Milne, E. & Holman, C. D. J. (1999) The quantification of mortality resulting from the regular use of illicit opiates. *Addiction*, **94**, 221–229.
- Joe, G. W. & Simpson, D. D. (1987) Mortality rates among opioid addicts in a longitudinal study. *American Journal of Public Health*, **77**, 347–348.
- Kelling, G. L. & Coles, C. M. (1996) *Fixing Broken Windows: Restoring Order and Reducing Crime in Our Communities*. New York: Touchstone.
- Lora-Tamayo, C., Tena, T. & Rodriguez, A. (1994) Cocaine-related deaths. *Journal of Chromatography A*, **15**, 217–224.
- McGregor, C., Darke, S., Ali, R. L. & Christie, P. (1998) Experience of non-fatal overdose among heroin users in Adelaide, Australia: circumstances and risk perceptions. *Addiction*, **93**, 701–711.
- Ochoa, K. C., Hahn, J. A., Seal, K. H. & Moss, A. R. (2001) Overdosing among young injection drug users in San Francisco. *Addictive Behaviors*, **26**, 453–460.
- Oppenheimer, E., Tobutt, C., Taylor, C. & Andrew, T. (1994) Death and survival in a cohort of heroin addicts from London clinics: a 22-year follow-up study. *Addiction*, **89**, 1299–1308.
- Paone, D., Cooper, H., Alperen, J., Shi, Q. & des Jarlais, D. C. (1999) HIV risk behaviours of current sex workers attending syringe exchange: the experiences of women in five US cities. *AIDS Care*, **11**, 269–280.
- Perucci, C. A., Davoli, M., Rapiiti, E., Abeni, D. D. & Forastiere, F. (1991) Mortality of intravenous drug users in Rome: a cohort study. *American Journal of Public Health*, **81**, 1307–1310.
- Poletti, A., Groppi, A. & Montagna, M. (1999) The role of alcohol abuse in the etiology of heroin-related deaths: evidence for pharmacokinetic interactions between heroin and alcohol. *Journal of Analytical Toxicology*, **23**, 570–576.
- Poulin, C., Stein, J. & Butt, J. (1998) Surveillance of drug overdose deaths using medical examiner data. *Chronic Diseases in Canada*, **19**, 177–182.
- Risser, D. & Schneider, B. (1994) Drug-related deaths between 1985 and 1992 examined at the Institute of Forensic Medicine in Vienna. *Austria Addiction*, **89**, 851–857.
- Risser, D., Uhl, A., Stichenwirth, M., Honigschnabl, S., Hirz, W., Schneider, B., Stellwag-Carion, C., Klupp, N., Vycudilik, W. & Bauer, G. (2000) Quality of heroin and heroin-related deaths from 1987 to 1995 in Vienna, Austria. *Addiction*, **95**, 375–382.
- Seidler, D., Schmeiser-Rieder, A., Schlarp, O. & Laggner, A. N. (2000) Heroin and opiate emergencies in Vienna: analysis at the municipal ambulance service. *Journal of Clinical Epidemiology*, **53**, 734–741.
- Seymour, A., Oliver, J. S. & Black, M. (2000) Drug-related deaths among recently released prisoners in the Strathclyde Region of Scotland. *Journal of Forensic Sciences*, **45**, 649–654.
- Strang, J., Griffiths, P., Powis, B., Fountain, J., Williamson, S. & Gossop, M. (1999) Which drugs cause overdose among opiate misusers? Study of personal and witnessed overdoses. *Drug and Alcohol Review*, **18**, 253–261.
- Tardiff, K., Marzuk, P. M., Leon, A. C., Hirsch, C. S., Stajic, M., Portera, L. & Hartwell, N. (1994) Homicide in New York City: cocaine use and firearms. *Journal of the American Medical Association*, **272**, 43–46.
- Tardiff, K., Marzuk, P. M., Leon, A. C., Portera, L., Hartwell, N., Hirsch, C. S. & Stajic, M. (1996) Accidental fatal drug overdoses in New York City: 1990–92. *American Journal of Drug and Alcohol Abuse*, **22**, 135–146.
- Taylor, A., Frischer, M. & Goldberg, D. (1996) Non-fatal overdosing is related to polydrug use in Glasgow. *British Medical Journal*, **313**, 1400–1401.
- US Department of Health and Human Services (USDHHS) (1999) *Annual Medical Examiner Data*. Drug Abuse Warning Network (DAWN). Washington, DC: Substance Abuse and Mental Health Services Administration.
- Zador, D., Sunjic, S. & Darke, S. (1996) Heroin-related deaths in New South Wales, 1992: toxicological findings and circumstances. *Medical Journal of Australia*, **164**, 204–207.