Ambient Temperature and Mortality From Unintentional Cocaine Overdose

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Context.—Hot weather taxes cardiovascular function and is associated with increased deaths from heart disease. Cocaine can cause hypertension, tachycardia, coronary vasospasm, arrhythmias, and increased core temperature.

Objective.—To determine the association between mortality from cocaine overdose and hot weather.

Setting.—New York, NY.

Design.—Retrospective review of medical examiner cases from 1990 through 1995.

Subjects.—All fatal unintentional cocaine overdoses from 1990 through 1992 (n = 1382) and all hyperthermia deaths of cocaine users (n = 10) were used to identify a maximum daily temperature threshold above which mortality from cocaine intoxication increased. The study population consisted of all fatal unintentional cocaine overdoses from 1993 through 1995 (n = 2008) and 4 contemporaneous comparison groups that included fatal unintentional opiate overdoses (n = 793), all other fatal unintentional overdoses (n = 85), and a subset of homicides (n = 4638) and fatalities from motor vehicle crashes (n = 815).

Main Outcome Measures.—The number of overdose deaths and the proportion of homicides and traffic fatalities with a positive cocaine toxicology test result on days with a maximum temperature above or below the temperature threshold.

Results.—A threshold temperature of 31.1°C (88°F) was identified, above which the mean daily number of fatal cocaine overdoses increased steadily. On days with a maximum daily temperature of 31.1°C (88°F) or higher ("hot days"), the mean daily number of cocaine overdose deaths was 2.34 (SD = 1.68), which was 33% higher than the mean on days with a maximum temperature of less than 31.1°C (88°F) (mean = 1.76 [SD=1.37] ($P<.001$). In contrast, the mean number of opiate overdose deaths per day was 0.81 (SD = 0.94) on hot days and 0.71 (SD = 0.86) on other days ($P = .28$). For other drug overdose deaths, the mean number of deaths per day was 0.08 (SD = 0.28) on hot days and 0.08 (SD = 0.28) on other days ($P = .69$). Among homicides, the proportion with a positive cocaine toxicology test result was 18.9% on hot days and 19.5% on other days ($P = .69$), and among traffic fatalities, the proportions with positive cocaine toxicology test results were 9.5% on hot days and 10.3% on other days ($P = .91$).

Conclusions.—High ambient temperature is associated with a significant increase in mortality from cocaine overdose. Based on our comparison groups, the increase is not explained by changes in cocaine use among the general population. Although cocaine use is dangerous on all days, it appears to be even more dangerous on hot days.

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COCAINE-RELATED morbidity and mortality constitute a significant public health problem.[1] Approximately 8000 drug abuse deaths occur in the United States each year, about half of which involve cocaine use.[2] In addition, there are more than 400 000 emergency department visits for drug abuse, many of which involve cocaine.[3]

Cocaine use can result in serious toxic effects and death, in part because of hyperthermia.[4,5-7] However, even relatively low doses of cocaine can result in elevated core temperatures that are below those seen in extreme hyperthermia, but nonetheless tax cardiac reserve.[5,8] In addition, as a sympathomimetic agent, cocaine can produce tachycardia, hypertension, coronary vasospasm, and arrhythmias.[7-9] The association between cardiovascular deaths and hot weather is well documented.[10-13] Thus, the number of deaths from cocaine intoxication might be greater on days with high ambient temperature because of the effects of cocaine on cardiovascular function or its thermogenic properties.

For editorial comment see p 1828.

To investigate this hypothesis, we conducted a medical examiner surveillance study in New York City to assess the association of hot weather with mortality from unintentional cocaine overdoses. To rule out the possibility that a generalized increase of overdose deaths occurred on hot days, we also assessed the association of ambient temperature with fatal overdoses due to drugs other than cocaine, such as opiates, that do not have sympathomimetic or thermogenic properties.

The exact number of individuals who used cocaine on specific dates is unknown. Excess mortality from cocaine overdoses may occur on hot days, not because of the cardiovascular or thermogenic effects of the drug, but because more cocaine users may take the drug on such days. To examine this possibility, we also assessed the relationship between temperature and the presence of cocaine in 2 comparison groups, homicides and traffic fatalities.

METHODS

Fatal Unintentional Drug Overdoses

All cases of fatal unintentional drug overdoses in New York City from 1990 through 1995 were identified through manual review of all medical files at the Office of Chief Medical Examiner of New

York. This office has the responsibility for assessing all cases of persons believed to have died in an unnatural manner, including drug overdoses. To be classified as a subject, a person had to be certified as having died of an unintentional overdose caused by 1 or more drugs. Cases certified as suicidal or homicidal overdoses were excluded.

In the attribution of the cause and manner of death, the medical examiner uses the decedent's medical history, the circumstances and environment of the fatality, autopsy findings, and supporting laboratory data. A diagnosis of death caused by intoxication by 1 or more drugs requires that the toxicological data be within the range customarily encountered in such fatalities, that the history and circumstances be consistent with a fatal intoxication, and that the autopsy fail to disclose a disease or physical injury that has an extent or severity inconsistent with continued life. For instance, in the findings of a disease inconsistent with life, a concurrent intoxication would be regarded as incidental and unrelated to the cause of death.

In deaths determined to be caused by drug intoxication, when toxicology results reveal the presence of more than 1 drug in concentrations greater than trace amounts, it is customary to include all of the identified drugs in the cause of death. An exception occurs when 1 drug is present in extremely high concentrations and the others are present in concentrations commonly encountered in persons who die from other unequivocal causes, such as firearm injuries.

For purposes of data analysis, all fatal unintentional overdoses were divided into the following 3 hierarchical, mutually exclusive groups: (1) those in whom cocaine was, on the basis of history, circumstances, autopsy, and toxicological testing, causative of death; (2) those in whom opiates were causative of death, but in whom cocaine or its metabolite either were not detected or were detected in clinically insignificant amounts at toxicological testing; and (3) the remaining overdoses caused by substances other than cocaine or opiates.

For each case of fatal unintentional drug overdoses, demographic data, time, date, location of injury and death, cause and manner of death, and toxicology data were abstracted from the files. In a practical sense, the time of injury and of death differ by minutes to hours in almost all such cases.

Comparison Groups

We used 2 comparison groups of fatal injuries that occurred in the city from 1993 through 1995. Homicides were chosen as a comparison group because, on the whole, they have similar demographic characteristics to those dying of unintentional overdoses in New York City. Moreover, persons dying of homicide or unintentional drug overdoses generally reside in the same communities of the city that have high rates of drug use.[14] We also used a group composed of persons between the ages of 15 and 54 years who had died in a motor vehicle crash (as a driver, a passenger, or a pedestrian). This sample was restricted to this age group because 95% of cocaine overdoses occur among persons in this age range. In the same manner as in unintentional overdoses, for each homicide and traffic fatality, demographic data, time, date, location, cause and manner of death, and toxicology data were abstracted from the files.

Toxicologic Procedures

Urine and blood specimens collected at autopsy were stored at 4°C until they were assayed. A single toxicologic laboratory at the medical examiner's office performed all assays. Benzoylecgonine, the principal metabolite of cocaine, was initially screened for in urine by enzyme immunoassay. A specimen was considered positive if the concentration of benzoylecgonine was at least 0.3 mg/L. If urine was not readily available at autopsy, benzoylecgonine was screened for in blood by radioimmunoassay. A blood specimen was considered positive if the concentration of benzoylecgonine was at least 0.1 mg/L. Positive immunoassay findings were substantiated by radioimmunoassay in another tissue.

Blood was screened for cocaine by gas chromatography involving a nitrogen-phosphorus detector. A specimen was considered positive if the concentration of cocaine was equal to or exceeded 0.1 mg/L. All positive findings were confirmed by gas chromatography and mass spectrometry.

Opiates were screened for in urine by enzyme immunoassay or, if urine was not available, by radioimmunoassay in blood. Specimens that contained a concentration of at least 0.3 mg/L in urine or 0.1 mg in blood were considered positive, and were substantiated by radioimmunoassay in another tissue.

Head space chromatography was used to perform ethanol analysis. Other drugs were screened for and their presence confirmed by a variety of analytic methods, including enzyme immunoassay, thin-layer and high-performance liquid chromatography, and gas chromatography–mass spectrometry.

Temperature Data

We obtained hourly temperatures from the National Weather Service for Central Park Station in Manhattan, New York City, for each day from January 1, 1990, through December 31, 1995, and determined the daily maximum temperature in a 24-hour period. We hypothesized that the number of fatal overdoses involving cocaine would be higher on those days on which the ambient temperature exceeded an as yet undefined threshold temperature. Because we are unaware of any literature that has identified a temperature threshold for cocaine-related mortality, we sought to identify a threshold using our own data. As there is no single conventional method for determining such a threshold, we used the following strategy.

Sample of Hyperthermia Deaths That Involved Cocaine.—We identified all medical examiner cases from 1990 through 1995 that the medical examiner certified as due to hyperthermia (n = 48), but were not classified as unintentional drug overdoses. From this group, we identified all such cases in which benzoylecgonine was detected at autopsy (n = 10). The daily maximum temperatures for the 10 dates of death ranged from 17.2°C (63°F) to 39.4°C (103°F) (mean = 29.6°C [85.3°F], SD = 6.1°C [10.9°F], median = 30.9°C [87.5°F]).

Index Sample of Fatal Cocaine Overdoses.—Analyses of heat-related deaths often use a 1-day lag phase, which involves the comparison of mortality on days that exceed the threshold and the *next* day, with mortality on all other days.[15] For instance, a person who had died of an overdose may not have been found dead until the next day, or the date of pronounced death might have been recorded as the next day, especially if the death occurred just before midnight. We then examined the bivariate plot of the maximum daily temperature (x-axis) by the mean number of cocaine overdose deaths (y-axis) that occurred on days when the temperature was greater than or equal to a given temperature (Figure 1). For each temperature value, we determined the mean number of cocaine deaths occurring on days that had a maximum temperature that was greater than or equal to this specified temperature value. We plotted these data for the 1096 days from January 1, 1990, through December 31, 1992, which we refer to as the "index sample" and included all 1382 cases of fatal cocaine overdoses during this period (n = 1382). The plot shows a relatively flat relationship until 27.8°C (82°F), then a gradual increase, which accelerates more markedly at 31.1°C (88°F) (Figure 1).

Establishment of the Threshold Temperature.—Based on the median of the maximum temperature for the dates of deaths from the sample of hyperther-

mia cases involving cocaine and the plot of the index sample of fatal cocaine overdoses, we chose 31.1°C (88°F) as the threshold temperature. For purposes of analysis, we considered a day "hot" if the maximum hourly temperature was greater than or equal to 31.1°C (88°F), or if the maximum hourly temperature of the preceding day was greater than or equal to 31.1°C (88°F).

We considered reporting the results of analyses based on the heat index, which is a function of the temperature in degrees Fahrenheit and the relative humidity. However, for most persons the temperature is a more readily interpretable variable. Because temperature is a fundamental component of the heat index, the Pearson correlation between the daily maximum heat index and the daily maximum temperature in New York City during the study period was 0.986 ($P<.001$).

Statistical Analysis

All subsequent statistical analyses were performed using fatal unintentional overdoses that occurred during the next 3-year period, January 1, 1993, through December 31, 1995 (ie, the "cross-validation sample"). This split-sample approach to data analysis was used so that our hypothesis could be tested on a sample that was distinct from the index sample (1990-1992), which had been used to establish the threshold temperature.

Separate analyses were conducted for the 3 types of overdoses described earlier, deaths caused by cocaine; deaths caused by opiates, but not cocaine; and deaths caused by other drugs. The Mann-Whitney test was used to compare "hot" and "other" days with regard to the number of deaths from a particular type of overdose. Day was the unit of analysis. We also assessed the Pearson correlation coefficient for autocorrelation, which incorporated our 1-day lag phase.

We further examined whether cocaine use was increased on hot days among other causes of death during the same period, 1993 through 1995. For that reason, we compared the proportion of homicides and traffic-related fatalities with a positive cocaine toxicology on "hot" days with the respective proportions with a positive cocaine toxicology test result on "other" days. Using χ^2 tests, person was the unit of analysis.

For all analyses, 2-tailed α levels of .05 were considered statistically significant.

RESULTS
Deaths Due to Hyperthermia

During the 6-year period there were 48 deaths in New York City attributed to hyperthermia, including 34 males
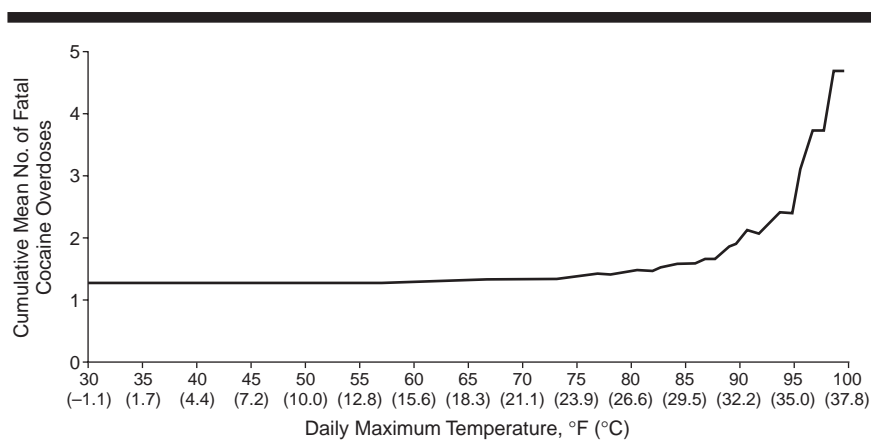

Figure 1.—Index sample. Mean number of fatal unintentional cocaine overdoses in New York City that occurred from 1990 through 1992 on days during which the maximum temperature was greater than or equal to each given temperature.

Table 1.—Number of Unintentional Deaths Due to Drug Overdoses, by Type of Day, Based on the Maximum Daily Temperature in New York City, January 1, 1993, Through December 31, 1995

Cause of Death	Type of Day*	No. of Deaths	Mean Daily No. of Deaths	SD	z†	P
Cocaine overdose (n = 2008)	Hot	341	2.34	1.68	3.98	<.001
	Other	1667	1.76	1.37		
Opiate overdose (n = 793)	Hot	118	0.81	0.94	1.08	.28
	Other	675	0.71	0.86		
Overdoses caused by drugs other than cocaine or opiates (n = 85)	Hot	12	0.08	0.28	0.39	.69
	Other	73	0.08	0.28		

*A day was considered "hot" if the maximum hourly temperature for that day or the preceding day was greater than or equal to 31.1°C (88°F). In the 3-year period, there were 1095 days, of which 146 days were considered hot and 949 days were below the temperature threshold of 31.1°C (88°F) (other).
†The z score from the normal approximation to the Mann-Whitney test.

(70.8%) and 14 females (29.2%). Three (6.3%) of these deaths were among infants younger than 1 year, 29 (60.4%) were among those aged 15 through 54 years, and 16 (33.3%) were among those older than 54 years.

Among the 48 deaths, 40 (83.3%) were screened for benzoylecgonine and cocaine. Among these 40, benzoylecgonine was detected in 10 (25% of those screened, 21% of the total sample) and cocaine was detected in 7 (17.5% of those screened, 14.6% of the sample). In contrast, opiates were detected in only 1 case (2.5%) of the 40 screened. Ethanol was detected in only 5 (12.2%) of 41 cases screened.

When the sample of hyperthermia deaths was restricted to the age group that is most likely to have used cocaine (ie, those aged 15-54 years, n = 27), the percentages that were positive for benzoylecgonine and cocaine were 37.0% and 25.9%, respectively.

Fatal Unintentional Cocaine Overdoses

There were 1095 days during the cross-validation period (1993-1995). Of these, 146 days (13.3%) were considered hot and 30 days were considered extremely hot, with maximum temperatures reaching 35°C (95°F) or higher. The hottest days of the period were July

15 and 16, 1995, when the maximum temperature was 39.4°C (103°F).

During this period, there were 2008 fatal unintentional cocaine overdoses. Complete autopsies were performed on 93% of these cases. The mean age of this group was 39.0 years (SD = 8.8 years), and 94.9% were aged 15 to 54 years. There were 1569 men (78.1%) and 439 women (21.9%), and 505 non-Hispanic whites (25.2%), 884 non-Hispanic blacks (44.0%), 605 Hispanics (30.1%), and 14 Asian or others (0.6%).

Significantly more deaths were due to cocaine overdoses on hot days (n = 146 hot days, mean = 2.34, SD = 1.68), than other days (n = 949 other days, mean = 1.76, SD = 1.37) (by Mann-Whitney, $z = 3.98$, $P<.001$) (Table 1). This difference represents a 33% increase in mean mortality on hot days. Mean daily mortality began to increase when the maximum temperature equalled or exceeded 31.1°C (88°F) (Figure 2). The 2 days with the highest number of cocaine overdose deaths (n = 9) were July 10 and 13, 1993, when the maximum temperatures were 37.2°C (99°F) and 33.3°C (92°F), respectively. There were no significant differences by age, race, gender, or location of death between subjects who had died on a hot day and those who had died on another day. The autocorrelation coefficient for cocaine overdose deaths was 0.12
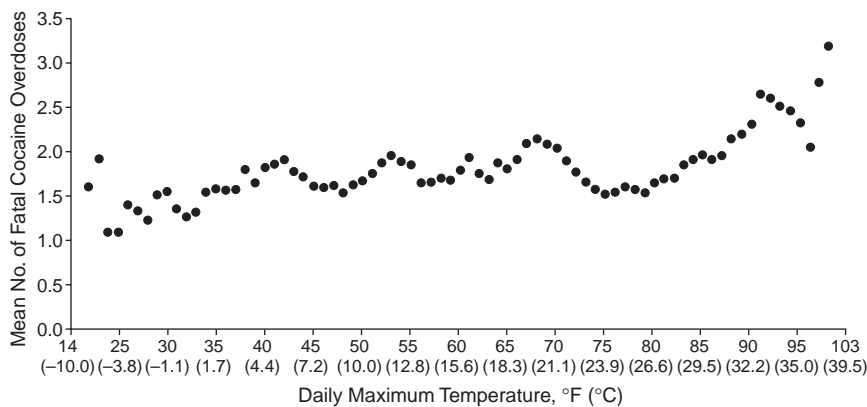
Figure 2.—Cross-validation sample. Mean number of fatal unintentional cocaine overdoses in New York City from 1993 through 1995 by the daily maximum temperature. The mean number of cocaine overdose deaths for a given temperature is plotted using centered moving averages spanning 5 degrees. (See the "Methods" section for more details about the use of a 1-day lag phase.)

Table 2.—Proportion of Fatal Cocaine Overdoses With a Positive Toxicology Result for Drugs Commonly Associated With a Risk of Hyperthermia*

Drug Type†	Cocaine Overdoses by Type of Day, % Positive	
	Hot (n = 341)	Other (n = 1667)
Antipsychotic medications‡	2.1	2.1
Antidepressant medications§	12.1	10.4
Antiparkinsonian and antihistaminic medications‖	5.0	9.7
Psychostimulants and sympathomimetic drugs¶	0.0	0.1
Phencyclidine	1.8	1.4
Any drug from above types	20.3	22.0

*In determining the percentage, an individual who had more than 1 drug of a given type detected (eg, an individual who had taken several different antidepressant medications) was counted only once for that drug type.
†Naming of the drug types reflects only the most common clinical indications for these classes of drugs.
‡Includes phenothiazines, thioxanthenes, dibenzodiazepines, butyrophenones, indolones, and diphenylbutylpiperidines.
§Includes tricyclic antidepressants and monoamine oxidase inhibitors.
‖Includes benztropine mesylate, biperiden, trihexyphenidyl hydrochloride, diphenhydramine hydrochloride, and chlorpheniramine maleate.
¶Includes amphetamines, methylphenidate hydrochloride, ephedrine, and phenylpropanolamine.

(P<.001), which indicates that the number of cocaine overdoses on a prior day accounted for only 1.4% of the variance in cocaine overdose deaths.

Of the 341 subjects who died of cocaine overdoses on hot days, the proportion that had positive toxicology test results for ethanol was 42.9%, compared with 41.4% for the 1667 subjects who died on other days. Likewise, the proportions with positive toxicology test results for benzodiazepines, barbiturates, or salicylates on hot days were 10.3%, 1.2%, and 0.9%, respectively, compared with similar proportions as those who died on other days, which were 11.5% (benzodiazepines), 1.4% (barbiturates), and 1.3% (salicylates). Opiates were detected in 57.1% of cocaine overdose cases on hot days compared with 61.7% of such cases on other days.

Some drugs, including tricyclic antidepressants, antipsychotic medications, or psychostimulants, can affect heat regulation by central mechanisms, by increasing heat production through muscular activity, or by impairing heat dissipation. Many of these drugs have anticholinergic or sympathomimetic effects. Overall, only 20% of the individuals who died of cocaine overdoses had a positive toxicology test result for at least 1 of these drugs (Table 2), and the proportion of cocaine overdose deaths that had a positive toxicology test result for these agents on hot days was nearly identical to the proportion with a positive toxicology test result of those who died on other days (Table 2).

Fatal Unintentional Overdoses of Opiates and Other Drugs

During the cross-validation period, there were 793 fatal unintentional overdoses of opiates and 85 fatal overdoses that tested positive for neither cocaine nor opiates. There were no significant differences in the number of deaths on hot days and the number on other days for either of these drug-death groups (Table 1). Figure 3 and Figure 4 show no discernible change in the mean number of such deaths at any temperature.

Comparison Groups

During the cross-validation period, there were 4793 homicides in New York City, of which 4638 (96.8%) were assessed for the presence of cocaine in blood. Among these 4638 homicides, 902 homicides had a positive toxicology test result for cocaine. The demographic characteristics of the homicides that were positive for cocaine were similar to the cocaine overdose group (mean [SD] age = 32.9 [9.0] years; 97.5% between the ages of 15 and 54 years; 83.6% men; and 8.0% non-Hispanic white, 53.4% non-Hispanic black, 37.9% Hispanic, and 0.6% Asian or others). Of the 719 homicides that occurred on "hot" days, 136 (18.9%) had a positive toxicology test result for cocaine. Of the 3919 homicides that occurred on "other" days, 766 (19.5%) had a positive toxicology test result for cocaine ($\chi^2 = 0.11$; $df = 1$, $P = .69$).

During the cross-validation period, there were 921 traffic-related fatalities among persons between the ages of 15 and 54 years in New York City, of which 815 (88.5%) were assessed for cocaine in blood. Among these 815 fatalities, 83 had a positive toxicology test result for cocaine. The demographic characteristics of these 83 cases were similar to the cocaine overdose group (mean [SD] age = 34.4 [8.5] years; 79.5% men; and 14.5% non-Hispanic white, 44.5% non-Hispanic black, 39.8% Hispanic, and 1.2% Asian or others). Of the 126 traffic fatalities that occurred on "hot" days, 12 (9.5%) had a positive toxicology test result for cocaine. Of the 689 traffic fatalities that occurred on "other" days, 71 (10.3%) had a positive toxicology test result for cocaine ($\chi^2 = 0.01$, $df = 1$, $P = .91$).

COMMENT

This study demonstrates several main findings. First, a quarter of all individuals younger than 55 years who died from hyperthermia in New York City had used cocaine immediately prior to their deaths. Second, the mean number of deaths from cocaine overdoses on days in which the temperature was equal to or greater than 31.1°C (88°F) was 33% higher than the mean on days with lower maximum temperatures. On days with temperatures higher than 31.1°C (88°F), daily mortality from cocaine overdoses increased steadily. Third, the association of ambient temperature with drug overdose mortality appears specific to cocaine, and not to other major drugs of abuse, such as opiates. Although the number of deaths from cocaine overdose was increased on hot days, only 10% of days in a year on average reach a temperature of 31.1°C (88°F) in New York City. Thus, the temperature effect we

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found does not have a major influence on the annual mortality from cocaine overdoses.

The exact reason for an association between high ambient temperature with mortality from cocaine overdose is not known. Increased temperature places considerable demands on the cardiovascular system to increase cardiac output and to decrease systemic vascular resistance.[16] The immediate effects of cocaine use include increases in mean arterial pressure, heart rate, and cardiac output.[17] Moreover, cocaine use has been associated with cardiac abnormalities including coronary artery occlusion, malignant arrhythmias, and myocarditis.[9] Thus, cocaine use during hot weather may further tax cardiovascular capacity and increase the risk of mortality.

Another explanation is that the excess of such deaths on hot days may, in some cases, be due to the thermogenic effects of cocaine. These effects have been postulated to result from the propensity of cocaine to cause increased muscular activity and peripheral vasoconstriction, or its direct effect on dopamine-modulated, heat-regulatory centers in the hypothalamus.[18-20] For instance, several case reports have documented fatal hyperthermia with and without rhabdomyolosis in cocaine users.[21-23] Dogs administered intravenous cocaine experienced a significant increase in core temperatures, which proved fatal.[24,25] Moreover, above an ambient temperature of 11.5°C (52.7°F) the increase in core body temperature in canines was positively correlated with the ambient temperature at which the cocaine had been administered.[25]

Hyperthermia is a clinical diagnosis, rather than a diagnosis established by pathologic findings. Therefore, the number of deaths classified with this cause is quite limited. Persons who overdose on cocaine may not be discovered for hours after death, long after it would have been possible to determine if a clinical hyperthermia syndrome had preceded their deaths. Although we cannot determine from our database whether many of the fatal cocaine overdoses on hot days were attributable to hyperthermia, at least 1 in 4 deaths in New York known to have resulted from hyperthermia had a positive cocaine toxicology test result. This prevalence is considerably greater than the 1.3% prevalence of recent cocaine use (in the past 30 days) reported in general population household surveys of drug use in New York.[26] Moreover, most cocaine-related hyperthermia deaths occurred on warm or hot days. It is possible that some of the deaths from acute cocaine intoxication may have been cases of undetected hyperthermia.
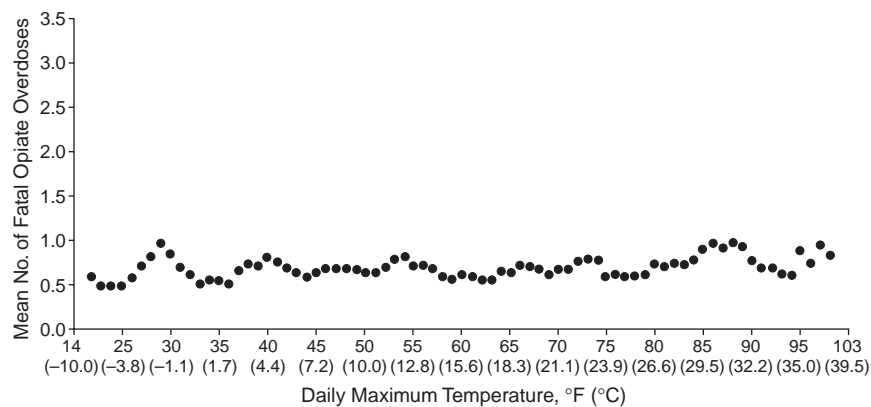

Figure 3.—Mean number of fatal unintentional opiate overdoses (not caused by cocaine) by the maximum daily temperature for the cross-validation period, 1993 through 1995, in New York City. The mean number of opiate overdose deaths for a given temperature is plotted using centered moving averages spanning 5 degrees. (See the "Methods" section for more details about the use of a 1-day lag phase.)
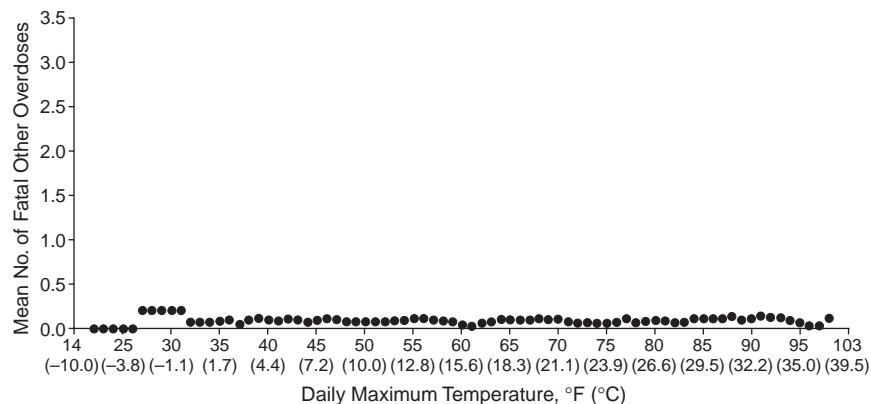

Figure 4.—Mean number of fatal unintentional overdoses caused by drugs other than cocaine or opiates by the maximum daily temperature for the cross-validation period, 1992 through 1995, in New York City. The mean number of overdose deaths caused by drugs other than cocaine or opiates for a given temperature is plotted using centered moving averages spanning 5 degrees. (See the "Methods" section for more details about the use of a 1-day lag phase.)

Drug overdose deaths that involve a single agent are uncommon. Many cocaine users concurrently administer opiates, ethanol, and other sedative drugs. However, only about 20% of cocaine overdose cases had a positive toxicology test result for other drugs that are commonly associated with a risk of hyperthermia. Moreover, the proportions of cocaine overdose deaths with a toxicology test result positive for at least 1 of these drugs was virtually the same for those who died on hot days vs other days. Thus, our findings cannot be attributed exclusively to the presence of other drugs that impair heat regulation. It is probable that individuals who had administered cocaine along with anticholinergic or sympathomimetic agents may have enhanced their risk of heat-related mortality.

Our findings cannot be explained by a generalized increase in the number of overdose deaths on hot days as we observed no association of ambient temperature with overdoses caused by opiates or by other drugs. It is also unlikely that our findings can be explained by an increase in cocaine use in the New York City population on hot days. Among homicides, which have similar demographic characteristics and reside in similar neighborhoods as cocaine overdose cases, and among persons involved in motor vehicle crashes, we found that cocaine was detected in virtually identical proportions among those dying on hot days or on other days. Rates of screening for drugs also are not influenced by hot weather in New York City.

It is likely that our findings from New York would apply to other cities in the United States. Ambient temperatures in cities are often higher than other regions because of increased heat production from crowds, cars, and factories; re-

tention of heat by buildings and pavements; and diminished heat loss because of low wind speed.[27,28] Socioeconomic factors also may contribute to heat-related mortality, as city residents are likely to be older and poorer, and more likely to live in substandard housing without air conditioning, showers, or baths, than suburban or rural residents.[29] In an earlier study, we found that many drug overdose deaths occur in poor neighborhoods,[14] which are likely to include few homes with air conditioners.

Cities in the Northeast and on the Pacific Coast have the lowest threshold temperatures above which general mortality increases.[30] People who reside in higher latitudes or near oceans experience fewer hot days, but have a harder time adjusting to sudden changes in temperature, particularly in early summer.[10,27] Thus, the threshold of 31.1°C (88°F) that we found in New York may vary somewhat in other locations.

Typically, periods of high humidity and warm nighttime temperatures, which reflect persistent, high heat exposure and diminished cooling from evaporative loss, have been associated with increased general mortality, rather than transient daytime peaks in temperature.[31] However, the models that best account for variability in general mortality in New York City involve dry, hot conditions (ie, a threshold of 33.3°C [92°F], a low dew point, and a 1-day lag phase in mortality).[30] Our analyses using the heat index yielded similar results, which is not surprising given that during the study period the maximum daily heat index was so highly correlated with the maximum daily temperature.

Several methodologic issues in our study warrant comment. First, it is not possible to know the dose of cocaine that an individual had used prior to death. Thus, the relationship between dose of cocaine and ambient temperature is unknown. Second, we do not know the exact ambient temperature to which the subjects were exposed when they used cocaine. However, even nighttime low temperatures on very hot days in New York remain in the 70s. Third, the threshold temperature of 31.1°C (88°F)

was established for a group and not for individuals. Some individuals may have higher or lower thresholds at which their mortality risk from cocaine use changes. Fourth, we do not know whether the individuals who died were occasional cocaine users or long-term, heavy users.

Although it is not possible to prove that high ambient temperature results in a direct, increased risk of death from cocaine use, our data suggest that the increased mortality from cocaine overdoses on hot days is not explained by changes in cocaine use in the general population on such days. Cocaine use is dangerous on all days. Our findings suggest that the risk of death associated with cocaine increases further during hot weather.

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