

Identification of Risk Factors in Rat Bite Incidents Involving Humans

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ABSTRACT. *Objective.* This study sought to assess the occurrence of rat bites within an urban population and examine the demographic characteristics to determine whether risk factors can be identified.

Methods. An observational epidemiologic study was used to collect rat bite data from 1974 to 1996 and plot the incidence of rat bites and factors relating to the characteristics of the victim, circumstances of the bite, and the environmental conditions present at the time and the location of the bite. Comparison between the first 10 years and the last 12 years was made to gauge changes in the incidence of rat bites.

Results. A total of 622 rat bite cases were confirmed, with incidence gradually decreasing each year. Rat bites primarily affected children 5 years of age and younger. The majority of bites were inflicted on the face and hands and occurred in the bedroom between midnight and 8 AM. Physical condition of the structure in which the bite occurred and adjoining structures were significant factors in rat bite incidents. Most bites occurred in the warmer months.

Conclusion. Risk factors for potential rat bite victims still exist and can be identified for additional planning of intervention and prevention strategies. *Pediatrics* 1999; 104(3). URL: <http://www.pediatrics.org/cgi/content/full/104/3/e35>; rat bite, risk factors, Philadelphia.

In many urban areas, the environmental distribution of the Norway rat is of considerable significance when taking into account its impact on human health and on the necessary measures to control it. The impact on human health is of primary importance here.

In urban areas, the Norway rat is found most commonly in residential dwelling units, cellars, stores, warehouses, food processing establishments (such as slaughterhouses), on docks, and in sewers.¹ In many cities and other urban areas, the primary site of the Norway rat is the sewer system. This characteristic is responsible for the Norway rat also being referred to as the sewer rat.

In Philadelphia, Pennsylvania, many existing sections of the city's 2900 miles of sewer lines were constructed early this century or even in the last century. Cracks and breaks occur in the sewer pipes either because of deterioration over time or as a result of increased loads of traffic on the street above. In its travels through the sections of sewer that are its habitat, the Norway rat will discover any breaks,

and, being a burrowing animal, will begin to tunnel outward.²

In Philadelphia, the sections of the city with the oldest sewers have the oldest housing stock. These houses usually are attached brick row houses with stone or cement foundations. When the rat emerges from the sewer onto the street level, it is confronted with a solid wall of brick houses with no front yards to burrow into and no alleyways between the houses through which to gain entrance to grassy plots in rear yards. Therefore, the rat is forced to seek shelter in the nearest dwelling, wherever a missing basement window pane or a large gap under the front door will allow its entrance. Rats also can enter through unplugged holes in the house soil lines.

Because the Norway rat is primarily dependent on humans for food and prefers to inhabit their dwellings, there is no incentive for it to move out once residence has been established in a house. Once inside the house, the Norway rat stays primarily in the basement and first floor, generally not going above these levels, although they are physically capable of doing so.² Therefore, as a consequence of the Norway rat's natural propensity toward living very closely with humans, and as a result of the type of housing found most commonly in many sections of Philadelphia that denies any viable exterior habitat to the rat, the environmental distribution of the Norway rat in Philadelphia is primarily in the kitchens and basements of the house.³

Over the centuries, rats have assumed a role of much greater significance than of mere pests that have moved uninvited into human dwellings and live on garbage thrown away by people. Rats have become of critical importance to public health because of their capacity to carry and transmit diseases and parasites to humans. Many diseases caused or carried by rodents had great public health significance. The greatest and most destructive pandemic ever to inflict humans was caused by bubonic plague that came out of Asia in 1347 and swept through the Middle East and Europe until 1350.² Murine typhus was once second only to the plague as a terrible scourge: "Typhus has ended more wars prematurely, lifted more sieges, and changed the general course of Western history by killing equally the populace and the warriors of opposing sides."² Leptospirosis, also known as Weil's disease or infectious jaundice, is caused by a spirochete, *Leptospira icterohemorrhagiae*, found in the rat's kidneys and excreted in the urine. Humans (such as children playing in puddles) contract the disease by coming in contact with infected water or by handling infected tissue. Rats become

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infected with *Trichinosis* by eating infected rat carcasses or discarded hog trimmings that are infected. Other animals become infected by eating contaminated rat carcasses or food contaminated with infected rat droppings.² Several types of salmonellosis are transmitted by rodents causing food borne illness in humans often with severe results. Foods and liquids consumed by humans become contaminated through contact with infected rat excrement. In addition, a variety of other diseases are spread by the rat including toxoplasmosis and Korean hemorrhagic fever with renal syndrome. Rats also have been associated with tetanus² and rat bite fever (Haverhill fever)² caused by *Clostridium tetani* and *Streptobacillus moniliformis*, respectively, found on the gums and teeth of many rats. Considering the fact that bites are far more common than the public may realize, the potential for disease transmittance is high.

The incidence of wound infection after a rat bite has been reported to be very low. A prospective study of 50 patients with uninfected rat bite wounds was conducted to determine the natural incidence of wound infection without prophylactic antibiotics.²⁰ All open wounds were cultured; bacterial isolates were cultured from 30% of wounds. Of bacterial isolates, 43% were *Staphylococcus epidermidis* and the remainder were *Bacillus subtilis*, diphtheroids, and α -hemolytic streptococcus. Only 1 patient (2%) developed an infection. The study's authors recommend treatment therapy to include good surgical management and avoidance of prophylactic antibiotics attributable to a low natural infection rate. If the wounds become infected, then a cephalosporin or penicillinase-resistant penicillin should be sufficient for treatment with appropriate surgical care of the wound.

A case report was published in 1994 describing how a physician was confronted by a patient with the recurrence of abscesses without any relevant medical history.²¹ The physician treated the patient with drainage and antibiotics only to discover that the cause was an unexpected source, a rat bite. A 24-year-old woman presented with fever and an abscess in her left antecubital fossa. General examination was otherwise unremarkable, but a β -hemolytic streptococcus and *Escherichia coli* were grown from the evacuated pus. An additional abscess appeared on the dorsum of the right foot 4 days after admission. Blood cultures were performed that eventually grew *E coli* and *Streptococcus milleri*. After 8 days, the number of abscesses continued to increase until it was discovered that the patient had been sleeping with her pet rat all the time while in the hospital; her friend brought the rat in the evening and removed it in the morning.

The multiple abscesses were thought to be caused by rat bites, and the patient was denied access to the rat that had been her pet since discovered in the wild some years before. Subsequently, no additional abscesses appeared, and the patient recovered fully.

Estimates from the Centers for Disease Control and Prevention state that large metropolitan areas experience rat bites at the rate of 10 per 100 000

people per year. Thus, the large cities account for ~3000 to 4000 rat bites per year. Many additional bites go unreported.⁴ Thus, when based on incidence, rat bites pose a significant public health problem. Because of this, it is paramount for public health professionals to investigate potential risk factors so that effective prevention programs may be developed.

Although interest in the study of animal bites can be traced back over 60 years, researchers point out that there are only a few studies in this area and that data are still scarce.^{5,6} The study of rat bites as a subdivision of the category of animal bites suffers from a similar scarcity of information.⁷ However, the problem of rat bites is ongoing, especially in urban areas, and increasingly more attention is being focused on it.⁸ The studies of animal bites to date have examined animals that most commonly bite humans, such as dogs and cats.⁹ Other studies have examined medical and economic factors associated with animal bites.¹⁰ Finally, several epidemiologic studies^{11,12} have examined the severity and location of dog bite wounds on victims, and a 13-year study conducted in Baltimore, Maryland, identified characteristics of dog bite victims.⁸ Borchelt et al¹³ examined animal bites involving predation on humans. They conducted behavioral examinations under controlled conditions on the dogs involved in the attacks and interviewed victims and their families, the dogs' owners, witnesses, and law enforcement officials who investigated the incidents.

An interesting fact revealed by the New York City human bite study was that the second most common cause of bite wounds (after humans) was rodents. In this category, rats accounted for the majority of bite wounds inflicted.⁹ Traditionally, animal bites have been studied because of the concern about rabies being transmitted as a result of the bite.¹⁴ Although the transmission of rabies to humans and other animals as a consequence of rodent bites has never been documented,¹⁸ the fear of rabies is so strong that it has long overshadowed the real significance of rat bites.

The bite itself is a significant medical, social, and emotional problem, even when rabies is not involved. One of the few in-depth studies on the problem of rat bites was conducted in Baltimore from 1939 through 1943.⁷ This study revealed that 60% of the victims were <1 year of age and that 62% of the victims were black. There was no differentiation of the sex of the victims, and most of the bites occurred in an area of substandard housing. This study also revealed that without exception all bites occurred while the victim was asleep. The parts of the body found to be bitten most often were the hands and arms (48%), followed by the face (20%) and the legs and feet (19%).

Another study,¹⁵ also conducted in Baltimore from 1948 through 1952 described conflicting results from the earlier Baltimore study. In the latter study, it was found that the major age group affected by rat bites were children <6 years of age, who accounted for 60.5% of victims. Infants <1 year of age accounted for 24.6%. Unlike the Richter study, Sallow¹⁵ found

that $\geq 20\%$ of the bites occurred while the victim was awake.

The Sallow study, unlike the previous study conducted by Richter, was conducted on a city-wide basis and each victim or victim's family was interviewed. In addition to the interviews, a check of the hospital records was conducted whenever possible.

The results of the Sallow study differed from those of the Richter survey. The researcher attributed this to the greater scope of the latter study.¹⁵

The latest published study of rat bites was conducted in New York City.¹⁶ From 1974 through 1978, rat bite reports were analyzed for person, place, and time characteristics. This study, along with an earlier study conducted in Tampa, Florida,¹⁷ revealed a seasonal trend in rat bite incidence depending on the geographic location of the area studied. The review of the literature revealed the need for much more research in the area of animal bites in general and rat bites specifically. Because the groundwork still is being established in this field, the findings of the earlier researchers suffer occasionally from the lack of a solid base of information on when, why, and where these bites occur. Consequently, the results of these initial research studies are contradictory to some degree and cannot always be replicated by later research. In addition, we could find no study in the past 2 decades that looked at 1) portions of the human population most at risk for an attack by rats, and 2) intervention strategies that can be implemented to protect the target population at risk.

This study involved the analysis of rat bite data over a period of 22 years. Rather than examining 22 years of data without the benefit of baseline information, we analyzed the first 10 years (1974–1984) of rat bites using 1980 census tract data and then the last 12 years (1985–1996) using 1990 census tract data. This procedure allowed the researchers to identify and compare risk factors between two periods of changing urban populations.

METHODS

Literature Review

A combination of bibliographic sources located studies for this review. They included computerized and manual searches of medical and social science; federal, state, and local health agencies' publications; allied health professional literature, dissertation abstracts, backward searches of reference lists in identified articles, and review of medical journals from the mid-1940s to present. Little has been published on the subject of rat bites. Most articles are anecdotal reports or have included a few patients with rodent bites in a larger series of animal bites of all types. No prospective study has determined the natural history of rat bites seen in the emergency department.

Source of Data

We conducted an observational epidemiologic study of the occurrence of rat bites within the population of Philadelphia from 1974 to 1996 and examined in detail the characteristics of person, place, and time to determine whether risk factors could be identified. In this article, we report on the number of rat bites, characteristics of the victim, circumstances of the bite, and the environmental conditions present at the time and the location of the bite.

Animal bites are reportable in Philadelphia under Title 6 (Health Code) of the Philadelphia Code. When the animal that caused the bite is reported to be a rat, an investigator is dispatched

immediately to visit the medical facility that reported the bite to confirm that the bite was caused by a rat and that the victim did receive appropriate medical treatment. Once the bite is confirmed, the investigator visits the victim and the victim's family. The purpose of the visit is to obtain more detailed information concerning the victim and the circumstance under which the bite occurred. In addition, the investigator conducts a complete environmental inspection of the premises in which the bite took place. The results of this inspection are used both to provide more information about the conditions under which the bite happened and to determine what assistance the victim will require to prevent any additional bites.

Investigation Form Content

The information obtained by the investigator is recorded on an official rat bite investigation form. This form contains spaces for specific information concerning person, place, and time characteristics. The files for all rat bite cases from 1974 to 1996 in Philadelphia were collected. In some cases, files could not be retrieved because of the length of time since the bite took place. In other instances, cases were not included in the study, because the investigator could not determine positively that the bite was inflicted by a rat or could not verify medical treatment. Once all the available files had been collected and reviewed for validity, the pertinent information about the bites was placed on specially prepared forms that would be used later for computer analysis. The information recorded on these forms was as follows: the day and date on which the bite occurred; the time of day the bite occurred; the age, sex, and race of the victim; the address and exact location where the bite took place; the area of the body bitten; the type of structure in which the bite took place; and finally, the physical and sanitary condition of the house, adjoining structures, and the neighborhood.

The population figures and information on socioeconomic status for Philadelphia for the years 1974 to 1984 is based on the US Census (population = 1 668 210) conducted in 1980. The population data from 1985 to 1996 is based on the 1990 US Census (population = 1 585 577). To correlate a relationship between the incidence of rat bites and the effectiveness of city rat control measures, risk factor characteristics were examined separately for the 1974–1984 data and the 1985–1996 data.

Statistical Analysis

Once the data had been gathered and encoded for computer tabulation, an enumeration was provided for each variable in each of the categories. Because being bitten is a discrete event and the population samples were sufficiently large, the χ^2 statistical test was used to determine statistical inferences, such as whether a variable occurred significantly more often than by chance, or the strength of an association between variables. Two-tailed P values were calculated, and a P value of $< .05$ was considered significant. In some instances, a statistical z test was used to calculate two-tailed P values for comparing incidence rates. In addition, a descriptive analysis was performed using the statistical function of Excel (Microsoft Corporation, Redmond, Washington).

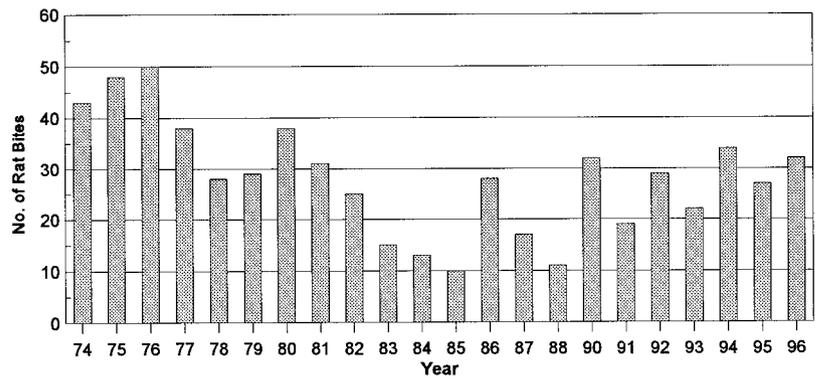
As a means of comparing RRs among host subcategories (for example, age groups), appropriate incidence rates were calculated using the following equation:

$$\text{Rate Bites/100 000} = \frac{\text{Number of bites in population at risk}}{\text{Population number at risk}} \times 100\,000.$$

RESULTS

There were 358 rat bite reports received by the Philadelphia Department of Public Health from 1974 through 1984, and 264 rat bites from 1985 through 1996 (including the first 4 months of 1997) analyzed for this study. Figure 1 shows the number of bites by the year in which they occurred. The total number of rat bite cases that occurred from January 1974 through April 1997 was 622. Comparison of the 1974–1984 and 1985–1996 periods indicates a 54% decrease in rat bites during the latter period. The

Fig 1. Confirmed rat bite cases by year in Philadelphia, Pennsylvania, 1974–1996. No data were available for 1989.



number of cases reported during the 12 months of 1996 and the first 4 months of 1997 indicates that this trend is continuing. There was a significantly lower ($P < .05$) incidence of rat bites the last period of the study (1.39 per 100 000 annually) compared with the first decade (2.12 per 100 000 annually).

We do not have a definitive explanation for the decrease in the incidence of rat bites between 1976 to 1985 and then the resurgence in the 1990s. There are a number of variables that may effect the incidence of rat bites: weather, food supply, vector control impact, and reporting methods by emergency department personnel.

The data concerning the characteristics of the victims revealed that during the 1974–1984 period, 52% of the rat bite victims were females, and 48% were males. During the 1985–1996 period, 56.5% of the victims were female, and 42.6% were male. A two-tailed z test shows that there is no significant difference in incidence rates for males versus females in both time periods ($P > .05$). An exception exists when comparing the number of bites within racial groups in which case black females did have a significantly higher number of bites than did black males, whereas white males had a higher number of bites than did white females ($P < .001$).

For the 1974–1996 period, the victims ranged in age from <5 years to >75 years. Figure 2 shows the

rate of bites by age groups of the victims for the 1974–1984 and 1985–1996 periods. The incidence rates have declined dramatically for all age groups comparing the last period with the first period of this study. During 1974–1984, the incidence rate for rat bites among victims <5 years old was 64.7 per 100 000 compared with the 1985–1996 incidence rate of 15.53 per 100 000, a significant decline comparing the two periods ($P < .0001$). The age group of 5- to 9-year-old children has shown similar improvement over the span of the study: for 1974–1984 the incidence rate was 56.7 per 100 000 and during 1985–1996 the incidence rate dropped to 14.4 per 100 000. A possible explanation for the decrease in the incidence rate for the <5- to 9-year-old age group may lie in the impact vector control services had during the second decade. However, no study has been conducted to prove this hypothesis. Smaller children are easier targets, sleep more often than do older children, and are subject to being bitten by rats more often. As vector control has become more technologically advanced, there may have been an impact on the rat population in much of the city’s aging housing.

The racial composition of the study population is divided into three groups: white, black, and other. Officially, those who are included in the other category are listed by the US Census as: American Indi-

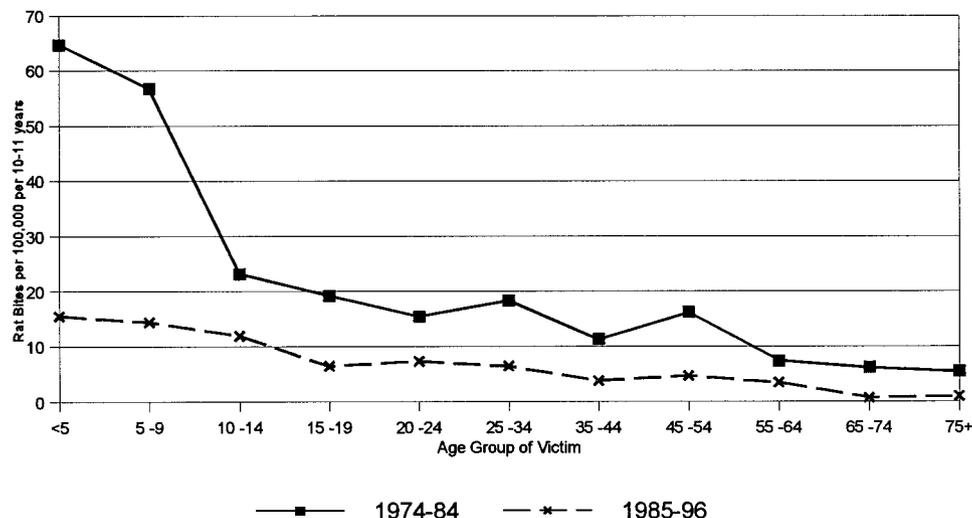


Fig 2. Incidence rate of rat bites by age group of victims in Philadelphia, Pennsylvania, 1974–1996. The incidence rates for 1974–1984 and 1985–1996 are based on 10 and 11 years of data, respectively.

ans, Eskimos and Aleuts, Asians and Pacific Islanders, and persons of Spanish origin. A review of the case files revealed that those in the other category of rat bite victims are entirely of Asian and Spanish origin. During the 1974 to 1996 period, the majority of rat bite victims were black. Overall, 50% of the rat bite victims are black, 28% are white, and 22% are described as other. Blacks and Hispanics are represented disproportionately as having a high risk of sustaining a rat bite.

The question of whether a rat will bite humans on subsequent nights was examined using the 1974 to 1984 data. (This variable could not be characterized using the 1985–1996 data because of the small sample size). The data revealed that of 316 cases in which such information was recorded, 33 cases (10.4%) experienced one bite in the same household during the previous year, and 6 cases (1.9%) experienced up to three bites among residents in the house during the previous 12 months. Most of the cases (87.7%) experienced no previous bites at the same address during the previous 12 months.

The type and physical condition of the buildings in which rat bites occurred also were considered. The majority of data on the physical condition of the building in which the bite occurred were available only for the 1974–1984 period. The 1985–1996 data sampling pertaining to the physical condition of the victim's dwelling is small compared with that for the 1974–1984 period. The results were that most of the bites occurred in single family dwellings: 67% compared with 25% of cases occurring in multiple family dwellings. The remaining 8% of the bites occurred in other structures such as research laboratories and schools. During 1985 to 1996, 88% (1974–1984; 86%) of the bites occurred inside the victim's house. During 1985 to 1996, 53% (1974–1984; 33%) of the rat bite victims lived in a residence that was rated poor in terms of its physical condition, the sanitation inside, the sanitation outside, the adjacent structure, or the block on which it was located. It is apparent from the data that a relationship does exist between the physical condition of the structure, the level of sanitation, and the number of rat bites that occur.

The month in which the bite occurred is also a significant risk factor. Figure 3 displays rat bite cases by the month of occurrence. The curve shows that most of the bites occurred from May through August

(48%). This observation is consistent with findings from the 1974 to 1984 study that showed a statistically greater increase in rat bites during warmer months ($P < .001$). In addition to the month, there seems to be a definite trend in the time of day in which a bite most likely will occur. The majority of the cases occurred between midnight and 6 AM (83%).

The area of the body where rat bites occurred was analyzed. Because of the small sampling of 1985–1996 data, the data from both periods were combined to calculate overall percentages. As a result, these data indicate that 48.3% of the victims were bitten on the hand; 19.6% were bitten on the head; 15% on the foot; and 9% on the leg. A review of the area of the body bitten revealed that three areas were attacked significantly more often than was expected based on body surface area ($P < .001$). The 1974–1984 data illustrate these areas to be the left hand and arm, the right hand and arm, and the face. The trunk sustained only 2% of the bites, which was not statistically significant. The 1985–1997 data substantiate the fact that the areas most commonly bitten are still the victim's hands and head.

The phenomenon of why certain areas of the body are bitten more or less often than are other areas can be explained by considering another victim-related variable: activity when bitten. The vast majority of victims, 86% of those whose activity was reported, were asleep when bitten. As shown previously^{7,15} in the Baltimore studies, most rat bites occurred at night when the victim was asleep. When bite victims are sleeping, the areas of the body usually not covered with apparel are the face, arms, and hands. The area of the body most likely to be clothed is the victim's trunk.

The location and room where the bite occurred also have a bearing on where and when the victim received a bite. The data show that 83% of the victims were at home when they were bitten. Not surprisingly, 84% were indoors at the time of the bite, and 60% were in the bedroom of their residence when bitten. (Room data were not available from 1985 to 1996. Statistic is based on 1974–1984 data). All the statistics noted above were found to be significant at $P < .001$.

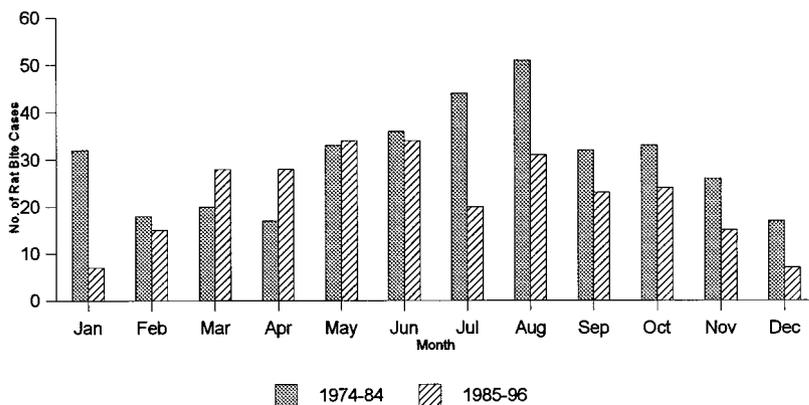


Fig 3. Rat bite cases by month for 1974–1984 and 1985–1996.

DISCUSSION

Thus, the victim profile found in the earlier years (1974–1984) of the Philadelphia study closely follows the patterns found in the New York City study and the Baltimore city studies mentioned previously. Typically, the victim of a rat bite in Philadelphia is most commonly a child of either gender, <5 years of age, and often nonwhite. Usually, the victim is bitten on the face or arms while asleep in the bedroom of his or her home sometime between midnight and 8 AM. The victim profile seems to have not changed over the 22-year span of this study. Although most rat bite victims are black, when ethnic population is taken into consideration, Hispanics have a four times higher incidence rate than do blacks. Still, one fact that has not changed over the 22-year span is that poor younger children are bitten by rats more often than are adults.

An examination of the data from 1974 through 1984 revealed that significantly more ($P < .001$) bites occurred in census tracts having the highest percent of families below the poverty level and the highest percentage of unemployed persons. These characteristics seem to be the same for the 1985–1996 data.

The reason most of the bites occurred in single family dwellings, 67% in comparison to 25% of cases occurring in multiple family dwellings, is not fully understood. Hirschhorn¹⁹ reports that no direct relationship exists between the number of people residing in a structure and the number of bites that occur.

Health districts 4, 6, and 8 were identified as having the highest percentage of rat bite cases for this period. These health districts, which are located in west and north Philadelphia have median household incomes as low as \$10 497 (1980 population census). Census tracts that experienced significantly fewer ($P < .001$) bites than would be expected also to have the lowest rates of unemployment and fewer families below the poverty level.^{9,11} All the rat bite studies cited previously have noted this connection between the distribution of rat bites and the areas of poverty. Despite the decrease in the incidence rate of rat bites during this 22-year study, there still is a close association between the incidence of rat bites and poverty.

CONCLUSION

Overall, the risk factors for rat bite victims from the 1985–1996 data are consistent throughout this 22-year study. Potential victims can be identified by age, race, location, and time of year. It is important to note that although there has been an overall decline in bite incidence over the past 20 years, the same risk factors persist. Of particular note, there still is a close association between the incidence of rat bites and

poverty. This connection is not surprising. The health districts identified in this study as having the greatest incidence of bites were also areas of the city in which the mean household income is low, unemployment is high, the number of children living in poverty is great, and the housing structures are old. Thus, urban deterioration, poverty, unemployment, rat infestations, and rat bites are related. If prevention programs are to be effective, they will need to target these high-risk populations. When taking into account the high probability of disease transmittance caused by rat bites as well as the economic and social impact, the potential remains for certain populations to be affected significantly by this scourge on the urban environment.

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