

Child Pedestrian Injury in an Urban Setting: Descriptive Epidemiology

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Abstract. **Objective:** To describe the epidemiology of pedestrian injuries to children and adolescents (ages <20 years) in an urban setting, providing analyses of environmental and pedestrian variables. **Methods:** Anonymous data were obtained for all motor vehicle crashes occurring in New York City over a seven-year period (1991–1997). **Results:** Among 693,283 crashes, 97,245 resulted in injuries to 100,261 pedestrians, of whom 32,578 were under the age of 20. Using census counts for the denominator, the overall incidence of pediatric pedestrian injuries was 246/100,000 per year, and the case fatality rate was 0.6%. Incidence rates peaked in the 6–14-year age group, and showed a modest annual decline dur-

ing the study period. Younger children were more likely to be struck mid-block and during daylight hours, whereas adolescents were more likely to be struck at intersections and at night. For younger children, there was a sharp peak in incidence during the summer months. Road and weather conditions did not appear to affect injury risk. **Conclusions:** These results help identify priorities for child pedestrian injury prevention and education, inform public health policy, and direct emergency medical health services resource allocation. **Key words:** injury; pedestrian; pediatric; epidemiology. *ACADEMIC EMERGENCY MEDICINE* 2002; 9:54–62

MOTOR vehicles pose a threat to the health of children. Pediatric pedestrians are particularly at risk of critical injury. In 1985, an estimated 50,000 children in the United States were struck by cars; 1,800 died.¹ This 3.6% case–fatality rate varied from a low of 1% for the oldest children to 9% for the youngest.¹

Although there has been a 43% decline in pedestrian death rates since 1975,² child pedestrian injury (CPI) continues to rank among the most serious childhood diseases. In New Zealand, pedestrian injuries kill twice as many children as leukemia and five times as many as all infectious diseases combined.³ In the United States in 1997 there were 2,098 motor vehicle-related deaths in children younger than 13 years old, of which 506 were pedestrian fatalities.

Emergency departments (EDs) bear the brunt of this onslaught of injury. In 1996 there were 163,000 ED visits for pedestrian injuries for all ages.⁴ In areas of New York City from 1989 to 1995,

an estimated 127/100,000 pediatric population suffered pedestrian injuries severe enough to result in hospital admission or death.⁵ Pedestrian injuries account for 61% of all pediatric trauma admissions to U.S. hospitals. They represent 34% of all pediatric critical care admissions.⁶ Younger children are at increased risk,⁷ with a peak between ages 6 and 9 years.⁸ Males are at increased risk for injury,^{1,9} and are twice as likely to be killed if injured.¹⁰

The aim of the following study is to describe the epidemiology of pediatric pedestrian injury in an urban setting. It includes analyses of environmental, pedestrian, and driver-related variables. The results are intended to help identify priorities for prevention and education, inform public health policy decisions, and direct emergency medical health services resource allocation.

METHODS

Study Design. A descriptive, population-based study of child pedestrian injury in New York City from 1991 to 1997 was undertaken. A database of all motor vehicle crashes involving pedestrians, based on forms MV-104AN, filed by the New York City Police Department with the New York State Department of Motor Vehicles was categorized by police precinct. New York State Vehicle and Traffic Law, sections 600 to 604, requires the police to investigate and report motor vehicle crashes resulting in death, personal injury, or property damage.

The “accident record file” is composed of a

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Received May 15, 2001; revision received September 10, 2001; accepted September 17, 2001.

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“header record” containing data common to the entire incident, such as date, location, and class of crash; a “vehicle trailer record” containing data on each individual vehicle involved in the crash; and an “occupant trailer record” containing data on the individuals involved in the crash, including drivers and pedestrians. Information on interpreting accident record files was obtained from the New York State Department of Motor Vehicles and the National Highway Traffic and Safety Administration.^{11,12} Approval for this study was obtained from the Columbia–Presbyterian Medical Center Institutional Review Board.

Study Setting and Population. The unit of analysis for the study was the individual child, based on a universe of child pedestrians in New York City during the study period. An injured child was defined as an individual under the age of 20 years who either resided in or visited New York City during the period under study and for whom a New York City Police Department form MV-104AN had been filed with the New York State Department of Motor Vehicles.

Study Protocol. The stages of data reduction began with the universe of 693,283 motor vehicle crashes in New York City between 1991 and 1997. Since several pedestrians may be involved in a single crash, separate person and incident files were examined and compared. A total of 97,245 pedestrian incidents involving 104,946 injured people were identified; 4,685 (4.5%) of the injuries were missing an entry for pedestrian age and were excluded from analysis. Of the remaining 100,261 injured people, 32,578 were under the age of 20 years. This constituted the study population. Pop-

TABLE 1. Age-specific Yearly Pediatric Pedestrian Injury, Fatality, and Case–Fatality Rates, New York City, 1991–1997

Age Group	Injury Rate (per 100,000)	Fatality Rate (per 100,000)	Case–Fatality (%)
<5 yr	92.9	0.9	1.0
5 to 9 yr	333.1	1.6	0.5
10 to 14 yr	355.2	1.3	0.4
15 to 19 yr	220.9	1.7	0.8
TOTAL (1 to 19 yr)	245.4	1.4	0.6

ulation counts used to compute incidence rates were obtained from the 1990 U.S. Census.

Measurements. Analyses are presented for the following four age categories: under 5 years old, 5 to 9 years old, 10 to 14 years old, and 15 to 19 years old. These conventional census age categories correspond to some extent with behavioral, anatomic, and physiologic differences observed across pediatric age groups.

Injury severity was based on the following State of New York Department of Motor Vehicles descriptions¹³:

1. “Fatal.”
2. “Severe” injuries include severe lacerations, broken or distorted limbs, skull fractures, crushed chest, internal injuries, unconsciousness when taken from the crash scene, inability to leave crash scene without assistance.
3. “Moderate” injuries include lump on the head, abrasions, and minor lacerations.
4. “Mild” or no injuries include momentary unconsciousness, limping, nausea, hysteria, and complaint of pain with no visible injury.

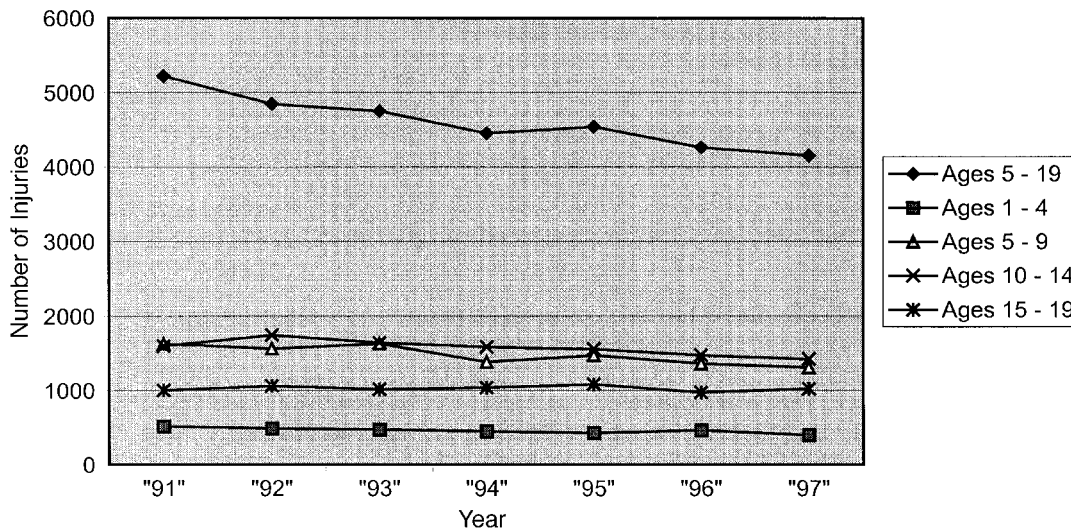


Figure 1. Yearly frequency of pediatric pedestrian injury by age group, New York City, 1991–1997.

TABLE 2. Number and Percentage of Injuries by Day of Week

Day of Week	1 to 4 Years Old		5 to 9 Years Old		10 to 14 Years Old		15 to 19 Years Old	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Sunday	420	12.7	1,115	10.6	1,015	9.1	686	9.1
Monday	331	10.0	1,325	12.6	1,524	13.6	1,021	13.5
Tuesday	344	10.4	1,349	12.9	1,718	15.3	1,058	14.0
Wednesday	287	8.6	1,390	13.3	1,650	14.7	1,011	13.4
Thursday	351	10.6	1,505	14.4	1,563	14.0	1,035	13.7
Friday	420	12.7	1,700	16.2	1,940	17.3	1,186	15.7
Saturday	464	14.0	1,444	13.8	1,232	11.0	913	12.1
Unknown	703	21.2	651	6.2	558	5.0	628	8.3

Investigating police officers make these assessments rather than medical personnel, although for severe and fatal injuries, the police assessments are informed by interviews with medical personnel.

Data Analysis. Chi-square for trend was conducted using Epi Info version 6.04.¹⁴ Other statistical analyses were carried out using SPSS version 9.0.¹⁵ Statistical significance was set at 5%. Average yearly incidence rates were calculated by dividing the total number of injuries or fatalities by 7 (the number of years in the study period) then dividing this number by the population of interest.

RESULTS

Incidence, Mortality, and Case-Fatality. The overall yearly injury rate of 245/100,000 varied from a low of 92.9 for the youngest pedestrians to a high of 333.1 for 5 to 9-year-olds. Fatality rates were highest for the 5 to 9-year-olds (1.6/100,000

population), but the case-fatality rate indicated that pedestrians under the age of 5 were at higher risk of death when injured (Table 1).

Trends. During the study period, there was a statistically significant decline in the absolute number of pediatric pedestrian injuries ($\chi^2_{trend} = 1396.154, p < 0.00001$). The 15 to 19-year-old subgroup showed little change. These trends are illustrated in Figure 1.

Seasonality. The total frequency of injuries in the 5 to 9-year-old group increased sharply in the summer months. There was a similar, but less marked, pattern for 10 to 14-year-olds (Fig. 2).

Day of the Week. As seen in Table 2, most pediatric pedestrian injuries occurred on Fridays. For all three age groups, injuries occurred less commonly on weekends, with Sunday less so than Saturday. This pattern was most prominent among the 10 to 14-year-olds.

While weekday injuries predominated, Figure

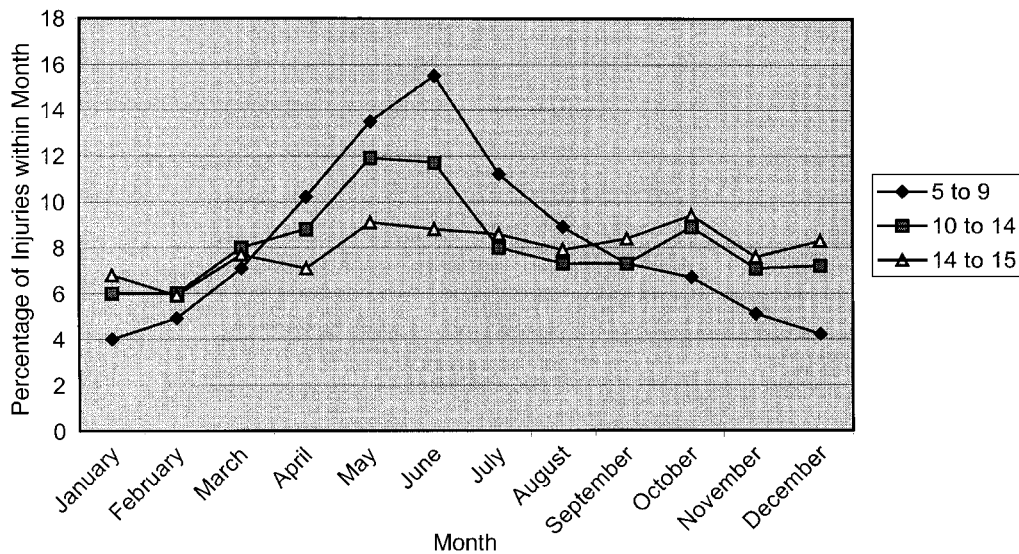


Figure 2. Percentage of pediatric pedestrian injuries by month and age group, New York City, 1991–1997.

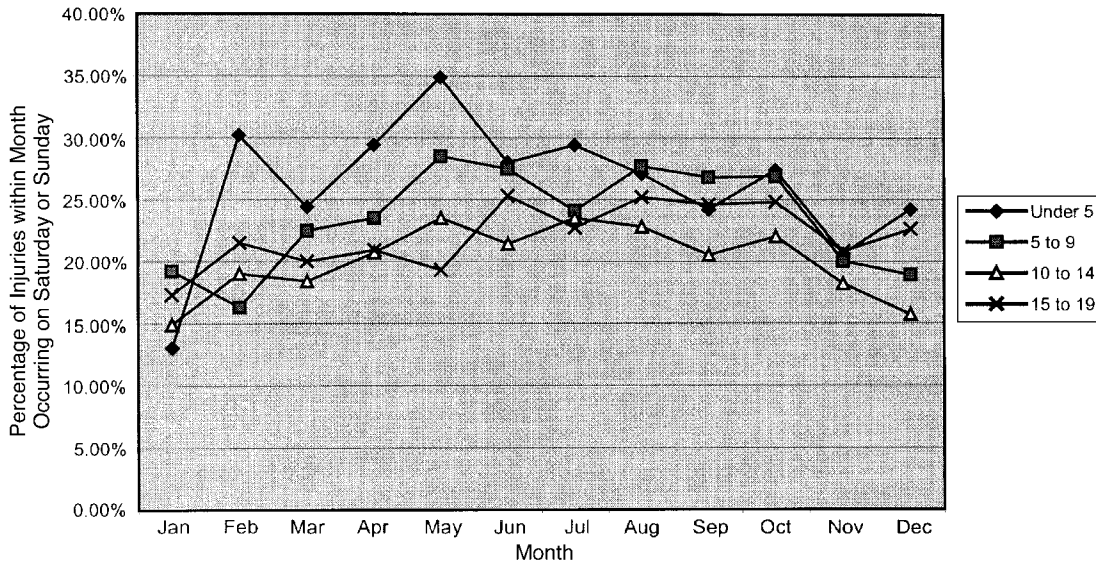


Figure 3. Monthly percentage of pediatric pedestrian injuries occurring on weekends by age group, New York City, 1991–1997.

3 illustrates that the proportion of injuries occurring on weekends increased during the summer months. By contrast, weekday injuries become more common during the school months. This pattern is more pronounced for younger pedestrians.

Light Conditions. Overall, 67.5% of the pediatric pedestrian crashes occurred during daylight hours and 17.1% occurred after dark on a lighted road. But, for the youngest pedestrians, 74.1% took place during daylight hours, and only 10.2% took place after dark. For the oldest pediatric population,

53.4% occurred during daylight hours, and 29.3% occurred after dark on a lighted road. Dark unlighted roads played little role for any age group, averaging about 0.7% of injuries. Few (1.2%) crashes occurred at dawn, and about 5% to 6% of injuries occurred at dusk. Again, these results were statistically significant ($\chi^2 = 1403.836$, $df = 10$, $p < 0.0001$).

Age and Gender. The age distribution for injured pediatric pedestrians shows a peak incidence in the 6–14-year age group (Fig. 4).

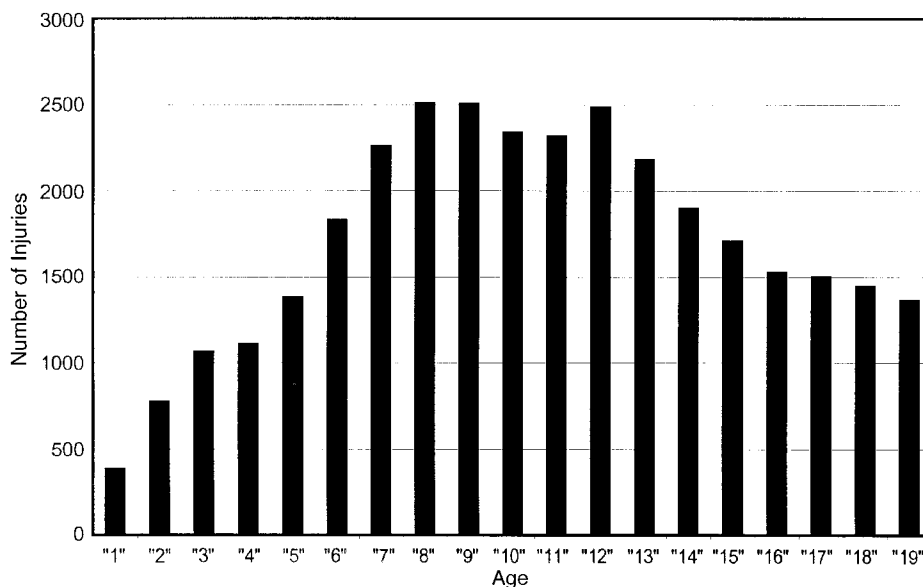


Figure 4. Age frequencies of injured pediatric pedestrians, New York City, 1991–1997.

TABLE 3. Pediatric Pedestrian Actions (Percent) Preceding Crashes, New York City, 1991–1997

	Age 5 to 9 Years	Age 10 to 14 Years	Age 15 to 19 Years
Crossing with signal	7.3	13.1	19.1
Crossing against signal	10.6	15.0	14.2
Crossing, no signal, marked crossway	5.6	5.6	5.5
Crossing, no signal or crosswalk	28.0	23.7	19.7
Walking along highway with traffic	0.2	0.7	1.4
Walking along highway against traffic	0.2	0.3	0.5
Emerging from in front of/behind parked vehicle	20.6	13.1	6.5
Going to or from stopped school bus	0.6	0.3	0.2
Getting on or off vehicle other than school bus	0.6	0.9	1.7
Pushing/working on car	0.0	0.1	0.1
Working in roadway	0.2	0.2	0.3
Playing in roadway	7.8	7.1	2.8
Other actions in roadway	5.0	6.3	7.8
Not in roadway	1.1	1.4	2.6
Unknown	12.2	12.3	17.4
TOTAL	100.0	100.0	100.0

Males predominated across all age categories, but the gender difference was the most pronounced among the youngest children (Fig. 5). These differences were statistically significant ($\chi^2 = 317.113$, $df = 2$, $p < 0.0001$).

Intersections, Traffic Controls, and Pedestrian Actions. Overall, most injuries occurred at intersections; but, for the younger pedestrians, intersections account for a minority of incidents. The older the child, the more likely the incident occurred at an intersection. These proportions, which are presented in Figure 6, were found to be statistically significant ($\chi^2 = 961.5$, $df = 4$, $p < 0.0001$).

Similarly, younger children were more likely to be struck at areas of the street where there were no traffic controls. Older children were more likely to be struck where traffic controls were present. These differences are presented in Figure 7, and were statistically significant ($\chi^2 = 1197.472$, $df = 6$, $p < 0.0001$).

There are, again, differences between the age groups in the importance of pedestrian actions that precede crashes. Table 3 shows the importance of emerging from between parked cars for the younger age group as well as greater reference to “playing in the roadway.” There was a notable lack of injuries occurring when exiting or entering school buses.

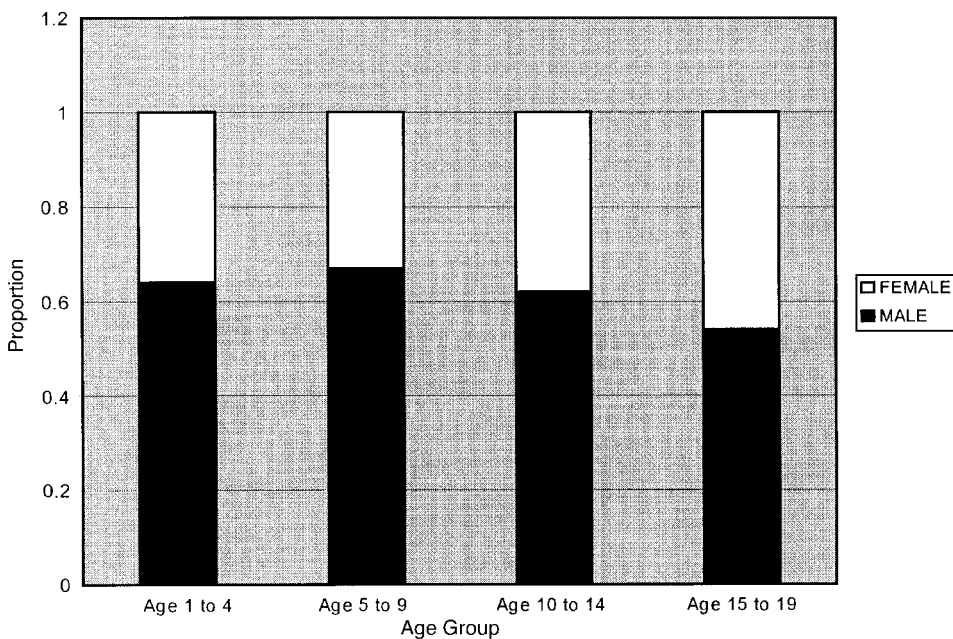


Figure 5. Proportion of pediatric pedestrian injuries by gender and age group, New York City, 1991–1997.

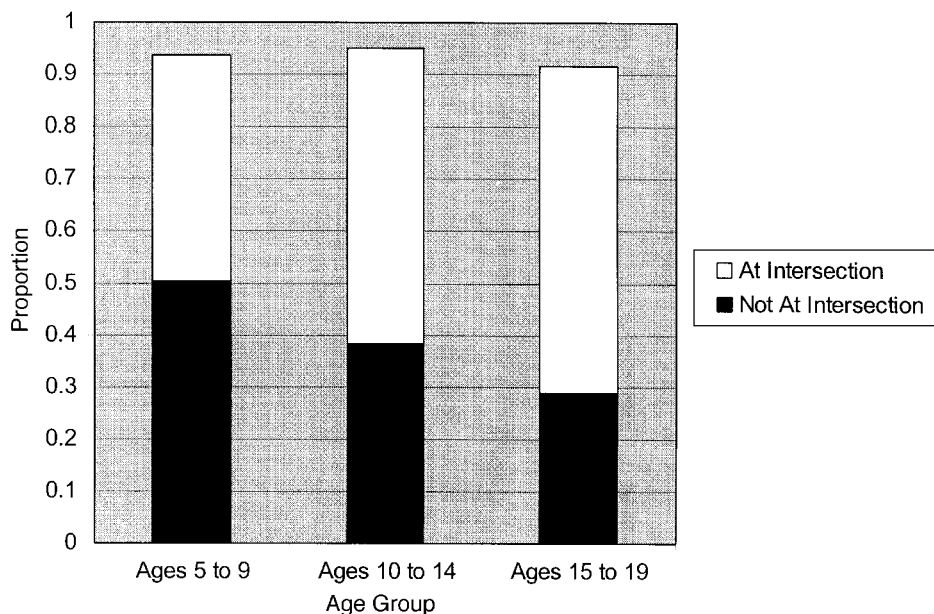


Figure 6. Proportion of pediatric pedestrian incidents occurring at intersections, New York City, 1991–1997.

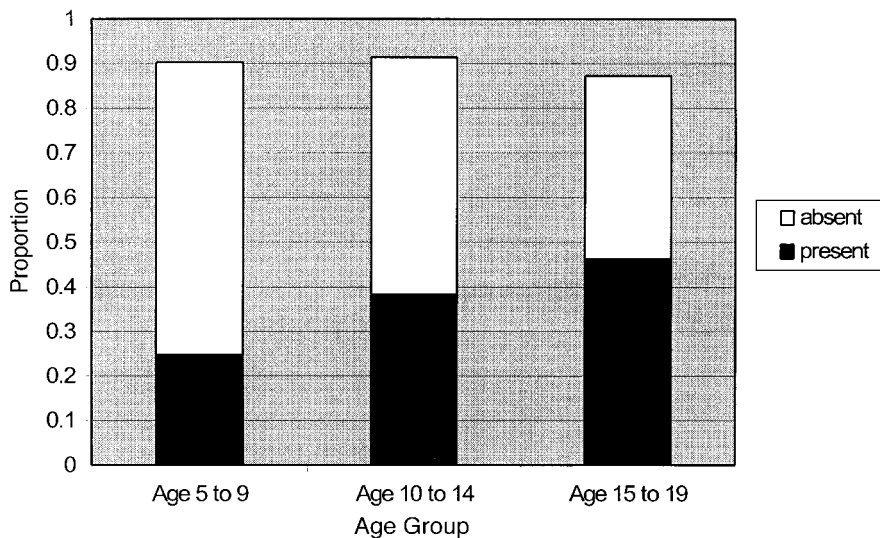


Figure 7. Proportion of pediatric pedestrian incidents occurring at sites with traffic controls, New York City, 1991–1997.

Road and Weather Conditions. The character of the road upon which pedestrian collisions occurred did not change appreciably across age groups. The majority of roads (85%) were level surfaces for all age groups. Only about 7% of incidents occurred on roads that had a grade or hill at the area of the crash. The road character was unknown for the remaining 8% of cases. Table 4 presents the proportion of incidents in which wet road surfaces were present. Table 5 presents weather conditions at the time of the crashes.

Driver Actions. The majority of crashes occurred as drivers were going straight on the road, although the oldest pediatric group was at a relatively larger risk of being struck while a driver was turning (particularly left turns) or backing/parking ($\chi^2 = 1016.459$, $df = 10$, $p < 0.0001$). These results may be found in Table 6.

Injury Severity. Injury severity, as ascertained by police personnel, was consistent across age groups. Overall, approximately one half of one percent of

TABLE 4. Road Surface Conditions (Percent) Preceding Pediatric Pedestrian Actions, New York City, 1991–1997

	Age 5 to 9 Years	Age 10 to 14 Years	Age 15 to 19 Years
Dry	81.5	79.3	73.2
Wet	11.2	14.4	16.7
Unknown	7.3	6.4	10.1

TABLE 5. Weather Conditions (Percent) at the Time of Pediatric Pedestrian Injury, New York City, 1991–1997

	Age 5 to 9 Years	Age 10 to 14 Years	Age 15 to 19 Years
Clear	74.1	71.5	66.2
Cloudy	12.4	13.2	11.7
Rain/snow/sleet/fog	6.2	9.0	12.1
Other/unknown	7.4	6.3	10.0

TABLE 6. Driver Actions (Percent) Preceding Pediatric Pedestrian Injury, New York City, 1991–1997

	Age 5 to 9 Years	Age 10 to 14 Years	Age 15 to 19 Years
Going straight	82.3	78.0	63.5
Right turn	1.9	3.0	5.5
Left turn	2.5	4.0	7.8
Backing/parking	2.1	3.0	5.4
Other	3.5	4.0	6.5
Unknown	7.8	7.0	11.2
TOTAL	100.0	100.0	100.0

injuries resulted in death. There was a slight but perceptible increase in proportion of fatalities and severe injuries among the oldest pedestrians (Table 7). These differences were statistically significant ($\chi^2 = 173.479$, $df = 6$, $p < 0.0001$). In Figure 8, fatalities are grouped with severely injured pedestrians. This categorization to test for the effect of age failed to achieve statistical significance.

DISCUSSION

The injury rate of 245/100,000 is higher than that reported by previous authors. In areas of New York City from 1989 to 1995, an estimated 127/100,000 pediatric population was reported to suffer severe pedestrian injury. A pediatric injury rate of 138/100,000 for pedestrians under the age of 14 years was reported in Memphis, Tennessee.¹⁶ The higher rate reported here reflects, in part, that the police data were more inclusive than those found in hospital-based studies, although it may also reflect that many of the injured children who make up the numerator of the rate may be tourists or other non-residents who are not included in the denominator.

The results, though, are similar to a 1991 Hartford, Connecticut, study of pediatric pedestrians under the age of 20 that reported a child pedestrian injury rate of 228/100,000.¹⁷

The case–fatality rates reported are lower than those cited by other authors.¹ Again, this reflects the comprehensive nature of the data. The inclusion of the many minor injuries documented by the police drives down the case–fatality rate.

The overall decline in the number of pedestrian injuries and fatalities in New York City during the study period mirrors the results of other investigators,¹⁸ although the decline was not so steep as previously reported. That the decline was limited to the 5 to 14-year-olds has not been reported. As Roberts has hypothesized, some of this decrease may be attributed to less walking¹⁸; perhaps 5 to 14-year-olds make greater use of public transportation, school buses, or rides from parents than the older pediatric group does.

The greater frequency of injuries occurring on weekdays is contrary to Baker et al.'s report¹⁹ that most injuries, including motor vehicle crashes, occur on weekends. That this increased risk was limited to months when school is usually in session prompts the hypothesis that the increased weekday risk is mediated by school-related travel. While there was some evidence that this is the case for 10 to 14-year-olds, this is an area for further analysis.

The occurrence of injuries at intersections is an interesting variable that highlights the differences between the younger and older pediatric pedestrians, differences that were seen across many variables. For example, while it has been reported that 78% of pedestrians struck in New York City were at intersection crosswalks,²⁰ for the youngest pedestrians in this study, most injuries occurred midblock. This may reflect the “dart and dash” type of injury described by Preusser.²¹

The results for “pedestrian action” again show the importance of midblock injuries for the youngest pedestrians as opposed to intersection-based injury occurrence for the oldest children. And, the results for driver maneuvers were generally consistent with midblock injuries among the youngest pedestrians. These results were consistent with the finding that the youngest children were also most sensitive to the lack of traffic controls (which are less likely to be found at midblock locations). In keeping with the urban nature of the study setting, few incidents involved a hill or road gradient contributing to injury occurrence; this variable was not closely analyzed.

It is intuitive to believe that wet road surfaces play an important role in the occurrence of pedestrian injuries, but the finding that more than 78% of incidents' road conditions were described as

TABLE 7. Number (Percent) Pediatric Pedestrian Injury Severity, New York City, 1991–1997

	Age 1 to 4 Years	Age 5 to 9 Years	Age 10 to 14 Years	Age 15 to 19 Years
Killed	32 (0.9%)	50 (0.5%)	43 (0.4%)	56 (0.7%)
Severe	466 (14.0%)	1,463 (14.0%)	1,639 (14.6%)	1,253 (16.6%)
Moderate	1,026 (30.9%)	3,034 (29.0%)	2,685 (24.0%)	1,591 (21.1%)
Mild or none	1,796 (54.0%)	5,932 (56.6%)	6,833 (61.0%)	4,638 (61.5%)
TOTAL	3,320 (100%)	10,479 (100%)	11,200 (100%)	7,538 (100%)

“dry” puts this to question. On average, New York City annually experiences 0.01 inches of precipitation on 121 (33%) days each year.²² There were therefore fewer than expected crashes during inclement weather.

Since older children were at increased risk of injury during inclement weather, perhaps the younger children are more likely to be at home or under greater supervision during bad weather. Also, while the proportion of injuries occurring when entering or exiting school buses is small, it remains a readily identifiable and important area for prevention.

The lack of difference in injury severity between the age groups is perhaps surprising given the differences found for other variables. Any statistical significance found in injury severity by age group was mostly a function of the large sample size. Given the large sample size, that the chi-square analysis of a dichotomized version of this variable (fatal/severe injuries vs. moderate/minor injuries) did not achieve statistical significance was notable.

The findings have implications for planning, prevention programs, and services. There are more pediatric pedestrian injuries in the summer. School-based prevention programs should not be limited to the school year. During these vacation months, EDs should assure adequate and appropriate staffing, such as Advanced Trauma Life Support–trained emergency physicians with pedi-

atric surgical consults on call. Emergency medical transportation services need to be apprised of those departments that are prepared to accept injured pediatric pedestrians.

That most 5 to 9-year-olds are injured in the middle of blocks indicates the role of street play in the occurrence of these injuries. Prevention programs should not only stress the dangers of street play, but also provide alternatives, such as organized activities in playgrounds. Trauma services, through the work of coordinators and clinicians, are ideal partners for community groups in addressing the needs of their communities in this respect.

LIMITATIONS AND FUTURE QUESTIONS

The denominator for the injury rates was based on census bureau figures. Certain areas of the city, particularly in Manhattan, have high transient populations of commuting workers and tourists. Not all the injured pedestrians included in the numerator of the rates may have been represented in the denominator. Some rate stabilization is to be expected over the course of seven years, and rates are presented only for the larger and more stable geographic area of the city as a whole, but the rates should be interpreted with this possible bias in mind.

Children under the age of 5 years posed a dif-

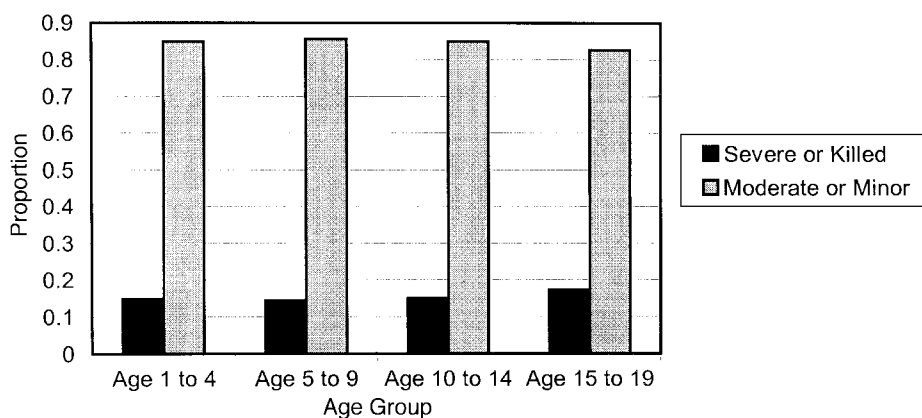


Figure 8. Dichotomized injury severity, pediatric pedestrian injuries, New York City, 1991–1997.

ficulty in this study. These children are frequently injured in so-called "rollovers" that occur on private driveways.²³ The data are limited to pedestrian injuries on public roadways and do not include private driveways. These results probably underestimate injuries to small children and toddlers. Adding to the difficulty, some variables for this age group were missing entries for nearly 30% of cases. No results were reported for those variables.

Ratings of injury severity in this study must be interpreted cautiously. Nonmedical personnel made the determinations. The accuracy of police assessments has been called into question.²³ Cosmetically impressive but non-life-threatening wounds such as "severe lacerations" might be included in the "severe" category, while a less apparent solid viscous injury might be placed in a lesser category. The designations are useful as an estimate of injury severity, but are far from precise assessments. Linkage to hospital records would be necessary to achieve a truly valid measurement of injury severity.

Fatalities may also be misleading. Determinations of fatality were based on assessments performed at the scene of the crash. They do not capture subsequent deaths in the ED or after hospitalization. It should be expected that some percentage of those categorized as severely injured would subsequently succumb to their injuries. The case-fatality rate is in all likelihood an underestimate. It was hoped that categorizing into fatal/severe injuries would group together fatalities with some of the subsequent deaths as well as with those injuries that were potentially life-threatening.

Despite these limitations, these results complement those based on medically treated or fatal injuries by capturing the full range of pedestrian injuries. They help present a more complete picture of pediatric pedestrian injury occurrence in an urban setting.

The results also raise questions for future research. Such routinely gathered, governmental sources of data constitute an important resource for researchers. Governmental-academic collaborations to analyze this type of data should be encouraged. Studies of the accuracy and completeness of police recording of injury severity and the circumstances surrounding the occurrence of injury would be necessary. Linkage of police reports to clinical data sources such as trauma registries would perhaps be the best approach to improving the quality of data. Geographic information systems would be an excellent means of presenting data and analyzing results. The role of drivers, vehicle factors, and pedestrian behaviors all deserve attention.

CONCLUSIONS

This descriptive study illustrates how the epidemiology of pediatric pedestrian injury varies by age group and fluctuates temporally. These results indicate that different behaviors are at play as well as different exposure opportunities. The youngest pedestrians appear to be more sensitive to risks posed by their environment as measured by such variables as presence or absence of traffic controls and pedestrian actions prior to injury. One methodologic lesson from this study is the importance of making investigations or interventions into pediatric pedestrian injuries age-specific. Another lesson is the use to which routinely collected data can be put to describe patterns of injury.

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