ORIGINAL ARTICLE

Exposure to traffic among urban children injured as pedestrians

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Objectives: To explore the immediate pre-crash activities and the routine traffic exposure (street crossing and play) in a sample of urban children struck by automobiles. In particular, the traffic exposure of children who were struck while playing was compared with that of those struck while crossing streets.
Design: Cross sectional survey.
Setting: Urban pediatric emergency department.
Patients: A total of 139 children ages 4–15 years evaluated for acute injuries resulting from pedestrian-motor vehicle collisions during a 14 month period.
Main outcome measures: Sites of outdoor play, daily time in outdoor play, weekly number of street crossings, pre-crash circumstance (play *v* walking).
Results: Altogether 39% of the children routinely used the street and 64% routinely used the sidewalks as play areas. The median number of street crossings per week per child was 27. There were no differences in exposures for the 29% who were hit while playing compared with the 71% who were hit while walking. Although 84% of the children walked to or from school at least one day per week, only 15% of the children were struck while on the school walking trip. The remainder were injured either while playing outdoors or while walking to other places.
Conclusions: Urban children who are victims of pedestrian crashes have a high level of traffic exposure from a variety of circumstances related to their routine outdoor playing and street crossing activities. The distributions of traffic exposures were similar across the sample, indicating that the sample as a whole had high traffic exposure, regardless of the children's activity preceding the crash. Future pedestrian injury programs should address the pervasive nature of children's exposure to traffic during their routine outdoor activities.

Pedestrian-motor vehicle collisions remain a major cause of pediatric morbidity and mortality despite decades of research. In 1999, 840 US children (ages 0–20) were killed and an additional 35 000 children were injured as a result of pedestrian-motor vehicle crashes.[1] Previous investigations have clearly identified child, environmental, and driver risk factors for pediatric pedestrian injury events.[2–8] Yet pedestrian injury prevention programs have shown variable success.[9]

A child's risk for pedestrian injury is likely related to his overall exposure to traffic. Recently, investigators have recognized the difficulties associated with the determination of the appropriate measurement of exposure for pedestrians.[10 11] Macpherson *et al*,[11] Roberts *et al*,[12 13] and Carlin *et al*[14] have utilized "number of streets crossed" in their work. However, urban children participate in other activities in addition to street crossing that expose them to traffic and therefore place them at risk for traffic related injuries.

It is possible that some previous intervention studies have shown limited effectiveness because all "pedestrian injury events" have been considered a single category of events. However, we felt that these events appear to be comprised of two potentially distinct subgroups based on the immediate pre-crash activity of the child: events that occur while a child is at play and events that occur during destination based walking. We hypothesized that injured children struck while at play would have greater exposure to traffic with regard to their routine play activities than those who are struck during destination based walking. Conversely, we hypothesized that children struck during destination based walking would have greater exposure via their routine street crossing exposure. If this were true, the delineation of two distinct groups would influence the way in which pedestrian injury events are studied in future investigations and instruct us in specific prevention efforts that address these pre-injury circumstances.

The principal objective of this study was to explore the immediate pre-crash activities and the routine outdoor play and street crossing activities of a sample of urban children struck by automobiles. Specifically, we aimed (1) to characterize the children's overall exposure to traffic during their routine play and pedestrian activities; (2) to quantify the relative proportion of children who were engaged in play activities versus destination based walking immediately prior to the crash; and (3) to examine the differences in traffic exposure between these two subgroups.

SUBJECTS AND METHODS

We performed a cross sectional survey of children presenting to an urban children's hospital emergency department for treatment of acute injuries resulting from a pedestrian-motor vehicle collision from 15 July 1998 through 1 September 1999. Patients eligible for participation were those children ages 4–15 years who resided in and were injured in the city limits. Children were eligible for inclusion whether they were admitted to the hospital or discharged from the emergency department. Children injured during non-pedestrian activities such as bicycling, skate boarding, or roller skating and pedestrian collisions with non-motorized vehicles were excluded. As the aim of this study was to characterize the nature and type of traffic exposures within an injured group and not to identify

Abbreviations: AIS, abbreviated injury scale; CI, confidence interval; MAIS, maximum AIS

risk factors for pedestrian injury, the use of a non-injured control group was not necessary.

Research assistants in the emergency department enrolled subjects during day and evening hours, seven days per week. Potential subjects were identified and a preliminary screening for eligibility based on the patient's age, address, and mechanism of injury was performed. The child selected for the study and the parent/guardian were approached either during the emergency department visit or while the child was hospitalized. A structured interview was performed by trained personnel who were blinded to the primary study hypothesis. The principal objective of the interview was to evaluate each subject's activities on the day of his crash to determine the pre-event circumstance as well as to characterize the child's routine play (number of hours per day in outdoor play) and pedestrian activities (number of streets crossed per week).

The majority of the interview elicited joint responses from both the parent and the child. In order to classify each child's injury event into its circumstance subgroup category, the child was asked questions regarding his activity immediately prior to the event. Selected items from Stevenson's previously validated tool[15] were incorporated into the interview for use (with permission). In his work, Stevenson found that children could accurately recall their routes of travel when compared to direct observations made by an unseen investigator.

The interview instrument was pilot tested on the first 15 eligible subjects. After their completion of the survey, the parent and child were interviewed by an investigator to assess comprehension of the questions and readability of the questionnaire. The questions were modified to address identified limitations. The modifications consisted only of minor changes in sentence structure, hence these 15 subjects were included for analysis.

Two circumstance subgroups were defined *a priori* and were based on the child's activity immediately before the crash. The subgroups, with examples of each, are as follows:

(1) At play: the child was playing football in the street at the time of the collision. The child was playing tag on the sidewalk and ran into the street.

(2) Walking trip: the child was en route to school and was struck while attempting to cross the street. The child was en route to the ice cream truck at the time of the collision.

Study personnel distinct from those conducting the interviews reviewed the medical record. Relevant information was abstracted including the patient demographics and specific injury diagnoses. An abbreviated injury scale (AIS) score was assigned by converting text descriptions of injuries into AIS codes using the AIS90 manual. The AIS is the most well validated and widely used method of classifying injury severity.[16] An AIS score ≥ 2 includes all clinically important injuries such as head trauma with concussion and more serious brain injuries, nearly all internal organ injuries, and most extremity fractures.

Summaries of demographics are presented and compared between the two circumstance groups. Locations of routine play are compared between the two groups using an exact χ^2 test. The various times spent in outdoor play as well as the number of streets crossed are compared using the two sample Wilcoxon rank sum (Mann-Whitney) test. Maximum AIS (MAIS) score is compared using the Kruskal-Wallis test. Statistical analysis was performed using STATA 6.0 software.[17]

The study was designed to detect differences (with 80% power and controlling type 1 error of 0.05) of approximately 25% in percentages of children who may routinely use the street for play in the group injured at play versus the group injured while on a walking trip, assuming that 50% of the children injured on a walking trip also routinely play in the street.

The study was approved by the Institutional Review Board of the study site.

RESULTS

A sample of 139 patients was enrolled during the time period of study. The typical patient enrolled in the study was an elementary school aged boy. Overall, 70% (n=97) were male, 60% (n=83) were ages 4–8 years, while 10% (n=14) were teenagers. Most (64%, n=89) sustained either no injuries or only minor injuries while 36% (n=50) sustained injuries of MAIS 2 or greater severity and 32% (n=44) were admitted to the hospital.

Enrolled subjects were typical of those treated in the emergency department for pedestrian injuries and did not differ significantly from those not enrolled with respect to age (p=0.89), sex (p=0.55), race (p=0.68), zip code of residence (p=0.37), injury severity (p=0.11), or hospital admission rate (p=0.69).

Pre-event circumstance

Immediately before the crash, 29% (n=39; 95% confidence interval (CI) 21% to 37%) of the children were involved in play activities ("at play") and 71% (n=97; 95% CI 63% to 79%) were walking to a specific destination ("walking trip"). Three patients were categorized as "indeterminate" due to incomplete responses and/or missing data.

Of the children who were at play at the time of the crash, 28% (n=11) reported the intentional use of the street for play. The remaining 72% (n=28) initially were playing adjacent to the street and moved into the street during the activities. Of the group, 31% (12/39) were playing tag, 21% (8/39) were playing basketball or football, 10% (4/39) were throwing other objects, 8% (3/39) were "hanging out", and the remainder were playing a variety of other games.

Of the total sample of children, 15% (21/139; 95% CI 10% to 22%) were hit while walking en route to or from school. Of the subgroup of children who were hit during destination based walking, 22% (21/97; 95% CI 17% to 35%) were hit while walking to or from school. The remainder were hit while walking home (26%, 25/97), to stores (13%; 13/97), to friends'/neighbors' houses (12%; 12/97), to playgrounds (2%; 2/97), and to a variety of other places (18%).

As shown in table 1, there were no differences in demographic features between the groups struck while at play versus on a walking trip. In both groups, the mean age was 8.7 years and the children were predominately males. There was no difference in injury severity with the median MAIS equal to 1. The groups were similar in their routine play activities with regard to usual play locations and duration of outdoor play. An isolated exception was a difference in outdoor play on weekdays during the school year. In this subgroup, the children injured while playing spent more hours playing outdoors than did those in the walking trip group. There were no differences in routine pedestrian activities. The proportion of children in each group who walked to school, the median weekly number of street crossings per child on the walking trip to school, and the median weekly number of street crossings per child to other places did not differ between the two groups.

Routine play patterns

The daily times in outdoor play for the entire sample are depicted in table 2. As expected, the children spent more time outdoors during non-school summer months and on weekends. Overall, 39% (n=54) of children reported routine use of the street as a play area and 64% (n=88) reported routine use of the sidewalk as a play area. When stratified by age, 30% (n=25) of 4–8 year olds, 56% (n=23) of 9–12 year olds, and 43% (n=6) of 13–15 year olds reported routine play activities in the street.

Routine pedestrian patterns

The vast majority of the school aged children (84%; 105/125) walked at least one way to or from school at least one day per

Table 1 Comparison of children struck while at play versus on a walking trip

Exposure variable	At play (%) (n=39)	Walking trip (%) (n=97)	p Value
Demographics			
Mean (SD) age (years)	8.7 (3.0)	8.8 (2.8)	0.89
Sex male	30 (77)	66 (68)	0.21
Race			
Black	32 (82)	83 (86)	0.63
White	4 (10)	6 (6)	
Other	3 (8)	8 (8)	
MAIS: median (range)	1 (0–3)	1 (0–5)	0.16
Routine play			
Location			
Street	17 (44)	37 (38)	0.57
Sidewalk	29 (74)	59 (61)	0.16
Playground	18 (46)	43 (44)	0.85
Time in outdoor play*: hours, median (range)			
Summer weekday	4 (2–10)	4 (0–13)	0.74
School year weekday	3 (0–10)	2 (0–8)	0.04
Summer weekend	5 (2–10)	6 (0–13)	0.60
School year weekend	5 (0–10)	4 (0–10)	0.30
Routine pedestrian			
Walk to/from school†	26 (79)	80 (86)	0.33
Weekly number of street crossings: median (range)			
School trip	20 (0–100)	30 (0–120)	0.39
Other trips	6 (0–91)	5 (0–119)	0.29

*Summer = 15 July 1998 to 7 September 1998 and 19 June 1999 to 7 September 1999.
School year = 8 September 1998 to 18 June 1999.
†n=33 for "at play", n=93 for "walking trip" due to exclusion of children not yet attending school.

Table 2 Routine play and pedestrian patterns (of entire study sample)

	Minimum	25%	50%	75%	Maximum
Daily hours in outdoor play per child					
Summer*					
Weekday (n=44)	1	2	4	6	13
Weekend (n=41)	0	3	5	8	13
School year*					
Weekday (n=73)	0	1	2	3	10
Weekend (n=71)	0	2	4	6	10
Weekly number of streets crossed per child					
All walking trips	0	13	27	50	169
To/from school (n=105)	0	10	22	40	120
Other walking trips (n=137)	0	1	5	15	119

*Summer = 15 July 1998 to 7 September 1998 and 19 June 1999 to 7 September 1999.
School year = 8 September 1998 to 18 June 1999.

week. Nearly all of the children (n=137) participated in other walking trips to one or more places including stores (79%, 108/137), friends'/neighbors' houses (60%, 80/134), playgrounds/parks (32%, 43/136), recreational activities (16%, 21/132), and other sites (16%, 21/129). The routine pedestrian patterns, as measured in the weekly number of streets crossed, are described in table 2. The street crossings related to the school walking trips accounted for a large proportion (81%) of the total streets crossed.

DISCUSSION

The results of this study show that urban children struck by cars have a high level of exposure to traffic from a variety of circumstances related to their routine playing and street crossing activities. In this group of injured children, the majority routinely used the streets and sidewalks as play areas. In addition, their routine pedestrian activities resulted in high exposure to traffic when measured by the number of streets crossed. While the majority of this sample of children walked to or from school at least one day per week, only 15% of the children were struck while on the school walking trip. Despite the large proportion of the streets crossed for the purpose of commuting to school, a relatively small proportion of the children were hit while walking to school. The remainder were injured either while playing outdoors or while walking to other places. To our knowledge, this study is the first to characterize the nature of urban children's activities in the traffic environment, thereby providing new detail of relevance to injury prevention efforts.

Although all of the children were struck while on foot, their activities immediately preceding the crash fell into two categories: approximately one third of the children were hit while playing and two thirds were hit while walking to a specific destination. There were no differences in several indicators of potential traffic exposure between these two groups suggesting that in the studied population, a specific pattern of traffic exposure did not appear to be related to the circumstance by which the children were injured. The remarkably similar traffic exposure patterns implies that traffic exposure is so pervasive in the routine outdoor activities of urban children that it may be unpredictable which child is likely to be struck during a particular type of activity.

While the characteristics of the children struck during play did not differ from those struck while walking, the crash events are quite distinct. Accordingly, two approaches to intervention can be considered, targeting either the child or the event. An intervention that targets the child may be expected to yield a reduction in the number of both types of events. To date, there have been several educational programs addressing pedestrian behavioral modification. Most focus on the teaching of street crossing skills, often in the context of the school walking trip.[18–23] Safety rules such as "look both ways" have been commonly employed.[18 22 23] Many programs have been conducted in simulated traffic environments.[20–22] However, there has been little work to determine the durability and the generalizability (that is, to non-simulated environments) of the program effects.

Given the variety of circumstances in which urban children are exposed to traffic, highly targeted child focused interventions, such as those that instruct safe street crossing during the school commute, may yield relatively small reductions in the overall number of pedestrian events occurring. Less specific interventions, such as those that might promote general traffic safety awareness and skills, may be more effective.

Interventions targeting the crash event may have a different impact. Previous research has identified environmental risk factors that may be targeted for intervention. Many experts have advocated the institution of traffic calming measures.[11 24] Others have suggested the removal of children from the traffic environment via the development of off street, supervised recreational activities for children or the building of additional play areas.[21] The effect of an environmental intervention might be expected to yield a reduction in the number of events that occur during circumstances related to the targeted environmental factor. For example, in our community, an intervention that would remove children from traffic during play activities might be expected to decrease the total number of crash events that occur by up to one third. Knowledge of the proportion of children struck during each type of pedestrian event might allow an investigator planning an environmentally based intervention to predict the magnitude of the effect of that intervention.

Limitations

Several limitations should be considered in the interpretation of this study. Data collection was dependent on the parent's and child's self report, which may have been influenced by recall. This may have resulted in inaccuracies in the reporting

of the number of streets crossed. In separate studies, Routledge *et al*[25] and Stevenson[15] have shown that uninjured children can accurately recall their routes of travel when compared to direct observations made by an unseen investigator. Selected items from Stevenson's tool were incorporated into our interview for use. To further enhance precision, neighborhood street maps were provided for reference, and the child and parent were encouraged to answer the questions relating to street crossings jointly. The recall abilities of injured children may differ from that of uninjured children; however, our study sample consisted of only injured children. Therefore, any comparisons made between the two circumstance subgroups are likely to be affected equally by this potential bias. In addition, while the effect of trauma on recall is not known, it might be expected to result in an underestimation of the number of streets crossed due to amnesia or confusion.

In addition, the traffic exposure of the children in our study as related to their play and walking activities may differ from that of other populations. The study was based in the emergency department of an urban hospital that functions as the community hospital for the surrounding neighborhoods. Study enrollment was restricted to include only children residing and injured within the city limits. Our results, therefore, are likely generalizable to other urban populations, but are not likely to be reflective of the experiences of suburban or rural youth.

Finally, because a convenience sample of all eligible patients was enrolled, the true proportion of children struck while at play and the routine play and pedestrian traffic exposures of the population may differ from that measured in this study. However, since the enrolled and non-enrolled patients did not differ with respect to age, sex, race, zip code of residence, injury severity or hospitalization rate, it is not likely that this potential selection bias would substantially alter the results of this study.

It is important to re-emphasize that this study did not aim to identify risk factors for pedestrian injuries. Our objective was to characterize the nature and type of traffic exposure in the routine outdoor activities of children injured as pedestrians. Therefore, no uninjured control group was included.

While it may seem evident that the circumstances during which a given child is struck by a car would be associated with his overall traffic exposure related to that circumstance, our data do not support this. The study was designed with a sample size sufficient to detect differences in exposures between the play and walking subgroups of 25%, a difference we deemed to be clinically relevant for the future planning of circumstance based intervention strategies. In the studied population, the exposure patterns among the subgroups were nearly identical. It is unlikely that a larger sample size would have detected clinically relevant, smaller differences.

IMPLICATIONS FOR PREVENTION

These results have important implications for the future design and implementation of prevention strategies. For a countermeasure to be maximally effective in reducing urban pediatric pedestrian-motor vehicle crashes, it must address the ubiquitous nature of these children's exposure to traffic during their outdoor activities.

The expectations for children to be able to generalize a single safety rule learned in relation to one setting or to adhere to multiple, circumstance specific safety rules may be unrealistic. Efforts to improve pedestrian safety through behavior modification may need to include a more comprehensive approach. Rather than relying on teaching the principles of traffic safety to children, future strategies might incorporate the parent-child dyad. Parental modeling of safe behaviors and enforcement of safety rules influence children's adoption of safe behaviors (for example, helmet[26 27] and seat belt use[28 29]). Alternatively, prevention efforts might be better placed in other areas such as environmental modification, driver education, legislation, or supervision.

Key points

- Urban children struck by cars had high traffic exposure from a variety of circumstances related to their routine outdoor activities.
- These children commonly used the streets and sidewalks as play areas.
- These children negotiated large numbers of street crossings in their routine pedestrian activities.
- Most children were not hit while walking to or from school but rather while on other destination based walking trips.
- Future prevention efforts should target specific circumstances identified in this study that may lead to children's traffic exposure.

This study demonstrated that urban children struck by cars have a high level of exposure to traffic from a variety of circumstances related to their routine playing and street crossing activities. Children have a right to safe play and safe walking.[30] Patterns of physical activity are established during youth and the long term health benefits of fitness have been recognized.[31 32] An effective pedestrian injury prevention program must focus on the reduction of traffic exposure in several aspects of children's outdoor activities, balancing the goal of improving safety with that of preserving mobility.

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LACUNAE

Learner drivers—move on safety, for testers

Reuters reports that French driving students may have to wait for 24 hours before finding out whether they have passed their driving test. The measure is being considered as a means of protecting examiners who fail the students from assault and injury. It is reported that there have been threats of death and rape, often at gunpoint. There has been a fall in such threats where the 24 hour delay has been introduced from 96 in 2000 to 79 in 2001 (Reuters, April 2002).

Simulating a shaken baby

University of Queensland researchers are developing a computerised tool to give courts key evidence in shaken baby cases. Paediatric ophthalmologist, Dr Denis Stark, says that damage to the eyes, particularly retinal haemorrhage, is a key indicator of excessive shaking. He is undertaking a project to develop a computer simulation to determine the force required to cause injury to a baby's brain and eyes (*The Australian*, April 2002).

Report on parachuting incident

The Australian Transport Safety Bureau has released a report into an incident in which a parachutist died and only fast and brave action by a pilot prevented more deaths. In April 2001, a Cessna Caravan carrying 10 parachutists, a camera operator, and a pilot was involved in a fatal incident when a skydiver's reserve canopy deployed while he was exiting the plane. The chute wrapped around the plane's tail, breaking it off and sending the plane into a spin. The pilot was able to hold the plane steady while others dived and to free a jammed door to exit at 1000 feet. The initial problem was found to have been the result of the dead skydiver's reserve chute rubbing against the top of the door as he backed out of the plane with his team. (*The Sunday Age*, April 2002).