

Pedestrian Injuries to Children Younger Than 5 Years of Age

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ABSTRACT. Historically, research on pediatric pedestrian injuries has analyzed children younger than 5 years of age as a single group. However, in this study, these children were divided into two age groups which were reflective of differences in behavior and development. The data demonstrate differences in the circumstances of the pedestrian injury events between toddlers (0 through 2 years and ambulatory) and preschoolers (3- and 4-year-olds). Toddlers were more likely to be injured in nontraffic events whereas preschoolers were more frequently injured in traffic situations. A high proportion of toddler injuries occurred in residential driveways and were caused by vehicles backing up. The majority of preschoolers, often without supervision, were injured while crossing/darting midblock on residential streets near their homes. Reflecting these differences in circumstances and also developmental differences between toddlers and preschool children, there is a need for age-specific interventions to reduce pedestrian injuries in children younger than 5 years of age. *Pediatrics* 1991;88:776-782; pedestrian, injury, motor vehicles, children.

Motor vehicles remain the leading cause of death from injury in children. Substantial attention has been focused on the prevention of motor vehicle occupant injuries through the use of restraint systems; mandatory restraint use laws; and the redesign of restraint systems, motor vehicles, and roadways. Less attention, however, has been directed at preventing pedestrian injuries, which account for 35% of motor vehicle-related fatalities among children.¹ The limited number of interventions aimed

at reducing/preventing pedestrian injuries in children have been primarily educational and have focused on school-age children, who have the highest reported rate of traffic-related pedestrian deaths.²⁻⁶

Younger children, however, also sustain a significant number of motor vehicle-related pedestrian injuries. When fatalities occurring on driveways, sidewalks, and parking lots (nontraffic events) are combined with those occurring on streets, pedestrian injuries are the third leading cause of injury death in children 1 through 4 years of age.¹ In fact, there are nearly as many 1- through 4-year-olds killed as pedestrians each year as there are 5- through 9-year-olds.

Among children 1 through 4 years of age, analysis of pedestrian injuries is typically done by considering them as a single group. However, differences in behavior and developmental capabilities among children in this age group warrant more detailed analyses. Studies of mortality data suggest that grouping of children aged 1 through 4 masks important differences as pedestrians. Brison et al⁷ and *Vital Statistics* data¹ indicate that there are differences in circumstances among pedestrian fatalities in this age group: 1- and 2-year-olds more frequently died in nontraffic events whereas more 3- and 4-year-olds died in traffic events. Whether these same differences in circumstances occur in all young children injured as pedestrians needs to be explored.

The present study analyzes nonfatal as well as fatal motor vehicle-related pedestrian injuries in children younger than 5 years of age for the purpose of understanding the circumstances of the injury events and identifying potential interventions. This study compared toddlers and preschool-age children to determine differences and similarities in (1)

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characteristics of the child and environment, (2) circumstances of the event, and (3) injury severity and patterns.

METHODS AND SAMPLE

Data for this study was obtained through a hospital-based monitoring system of motor vehicle-related injuries to children in Orange County, California, over a 2-year period (April 1987 through March 1989). The monitoring system includes 9 of 38 hospitals in the county as well as the coroner's office. The hospitals include the major children's hospital for the county, the hospital which serves the medically indigent and three of four county-designated trauma hospitals.

A standardized questionnaire was completed for all children up to age 15 years injured in a motor vehicle-related event and evaluated for injuries at one of the participating emergency departments. Telephone interviews were conducted with a child's parent or guardian to obtain information on demographics, the child, circumstances of the motor vehicle event, and mechanism of injury. Information on injuries, treatment, and outcome/disposition was abstracted from the child's medical record. Information on details of the event which was included in the medical record, traffic report, and paramedic report was noted and was used for coding only when no parent interview was completed and/or for verifying information obtained through parent interview. Fatalities were identified through the coroner's office and the standardized questionnaire was completed using the coroner's report (often containing a police report) and the medical record.

The Abbreviated Injury Scale, which assigns a level of severity from 1 (minor) to 6 (most severe, untreatable), was used to grade injuries. Using the Abbreviated Injury Scale, the Maximum Injury Score, which represents the single most severe injury, was determined.⁸ In addition, the Injury Severity Score, which is an overall measure of injury severity, was calculated by summing the squares of the highest Abbreviated Injury Scale of the three most severely injured anatomic areas.⁹ Specific injuries were also assigned to the following groups: soft tissue injuries (contusions, lacerations, sprains); intracranial/facial injuries (concussion, including loss of consciousness, amnesia and lethargy, skull and facial fractures, brain and eye injuries); internal torso injuries (intrathoracic, intra-abdominal, pelvic and hip fractures); and arm and leg fractures.

The sample consisted of 169 children injured as pedestrians over the 2-year time period. Sixty-seven were toddlers (0 through 2 years of age and ambu-

latory); 102 were preschoolers (3 and 4 years of age). All of the toddlers were older than 1 year except for one 10-month-old who was ambulatory. Six children who were riding either a "big wheel" or tricycle at the time of injury were included because the manner in which these children used these cycles was similar to the manner in which other riding/push toys were used by children in this sample. Excluded from the sample were 3 children who were being carried, 3 children riding in strollers, and 2 children riding on the back of a parent's bicycle because it was thought that these children were not actively acting as pedestrians.

Traffic events were defined as those that occurred on either a street or an alley that is considered a public roadway; nontraffic events as those occurring in a parking lot, in a driveway, or on the sidewalk.

The analysis consisted of comparisons between the toddlers and preschoolers. The χ^2 test was used for comparisons of the characteristics of the child and the event, area of injury, and disposition; and *t* tests were used for comparing mean injury number and severity. An α of .05 was used to determine significant differences between the two age groups of children. Additionally, case descriptions of fatalities are presented.

RESULTS

Child Characteristics

Table 1 shows characteristics of the children injured as pedestrians by age group. Significantly fewer toddlers than preschoolers were male (67% vs 80%). Significant differences in race/ethnicity were also apparent between the two groups. A greater proportion of toddlers were white (43% vs 23%) while a greater proportion of preschoolers were Hispanic (63% vs 43%). The percentages of Asians and blacks/others were similar between the two groups.

Among those for whom companionship was known, toddlers were significantly more often in the presence of adults at the time of injury (56% vs 32% for preschoolers). The older children were more frequently alone or with other children (14% toddlers alone vs 26% preschoolers alone and 30% toddlers with other children vs 42% preschoolers with other children).

Significant differences in activity were apparent between the two groups. One half of the toddlers were involved in an activity in the driveway or on the sidewalk when they were injured. Most of these involved playing, and a few involved a child going out into the driveway to meet someone. In contrast,

TABLE 1. Characteristics of Children*

Characteristic	Toddlers (n = 67)	Preschoolers (n = 102)	χ^2 P Value
Sex			.052
Male	45 (67)	82 (80)	
Female	22 (33)	20 (20)	
Race			.045
White	27 (43)	23 (23)	
Hispanic	27 (43)	63 (63)	
Asian	7 (11)	12 (12)	
Black/other	2 (3)	2 (2)	
Not ascertained†	4	2	
Companions			.030
None	7 (14)	19 (26)	
Children	15 (30)	31 (42)	
Adults	28 (56)	24 (32)	
Not ascertained†	17	28	
Activity			<.001
Crossing midblock	16 (28)	44 (51)	
Playing driveway/sidewalk	29 (50)	13 (15)	
In parking lot	6 (10)	9 (11)	
Crossing, other	3 (5)	14 (16)	
Other	4 (7)	6 (7)	
Not ascertained†	9	16	

* Values represent number (percent).

† Not included in the χ^2 test.

more of the preschoolers (51%) were injured while crossing a residential street at midblock. Reasons for the child crossing the street midblock varied among the preschoolers—3-year-olds were frequently crossing to another person whereas 4-year-olds more frequently crossed midblock during play (data not shown).

Temporal Characteristics

There were no significant differences between the two groups with respect to temporal characteristics. The injury events were slightly more frequent during the spring and summer. For both groups, more injury events took place on Fridays, Saturdays, and Sundays. The peak time of occurrence for both groups was late afternoon/early evening (between 4:00 PM and 8:00 PM)—for toddlers the modal time was 7:00 PM and the mode for preschoolers was 6:00 PM. Most of the children—85% of toddlers and 86% of preschoolers—were injured during daylight hours.

Injury Event Characteristics

Location. Significantly more of the toddlers were injured in nontraffic events than were the preschoolers (61% vs 25%) (Table 2). For both age groups, the traffic-related injuries occurred primarily on residential single-lane streets. Among those that occurred in traffic, only two of the toddlers and seven of the preschoolers were injured on multiple-lane streets (data not shown). For both groups,

the children were more likely to be injured in the block in which they lived (71% and 75%, respectively).

Vehicle. There were no significant differences in the type of vehicle that hit the child (Table 2). Among those cases where the vehicle type was known, an automobile was involved with 71% of the toddlers and 74% of the preschoolers. Other vehicles were primarily pickup trucks and vans. Three cases involved motorcycles. However, there were significant differences between the two groups with respect to the action of the vehicle when the child was hit—57% of the toddlers were injured by a vehicle backing up. For the preschoolers, three fourths (75%) were injured by a vehicle traveling straight. There were no significant differences in how the injury occurred once the child was struck by the motor vehicle. Slightly more of the toddlers, however, were run over (36% vs 24%) and knocked down (42% vs 36%) whereas more of the preschoolers were thrown (22% vs 10%).

Trauma Characteristics

There were no significant differences in any of the outcome measures of injury between the toddlers and preschoolers (Table 3). More than half of the children were hospitalized for their injuries (51% of toddlers and 53% of preschoolers). Nine percent of the toddlers and 4% of the preschoolers sustained fatal injuries.

TABLE 2. Characteristics of Event*

Characteristic	Toddlers (n = 67)	Preschoolers (n = 102)	χ^2 P Value
Location			<.001
Traffic	23 (39)	67 (75)	
Nontraffic	36 (61)	22 (25)	
Not ascertained†	8	13	
Distance from home			.578
Same block	36 (71)	60 (75)	
Greater	15 (29)	20 (25)	
Not ascertained†	16	22	
Type of vehicle			.729
Automobile	35 (71)	52 (74)	
Other	14 (29)	18 (26)	
Not ascertained†	18	32	
Action of vehicle			<.001
Turning	2 (4)	6 (8)	
Traveling straight	22 (39)	57 (75)	
Backing	32 (57)	13 (17)	
Not ascertained†	11	26	
Mechanism of injury			.089
Run over	24 (36)	24 (24)	
Knocked down	28 (42)	37 (36)	
Thrown	7 (10)	22 (22)	
Other, unspecified	8 (12)	19 (19)	

* Values represent number (percent).

† Not included in the χ^2 test.

TABLE 3. Outcome Variables*

Variable	Toddlers (n = 67)	Preschoolers (n = 102)	P Value
Disposition, no. (%)			.397†
ED treated only	27 (40)	44 (43)	
Hospitalized	34 (51)	54 (54)	
Died	6 (9)	4 (4)	
Injury severity (mean \pm SEM)			
MAIS	2.09 \pm 0.189	1.96 \pm 0.111	.548‡
ISS	10.27 \pm 2.289	7.20 \pm 1.067	.227‡
No. of injuries (mean \pm SEM)	2.7 \pm 0.185	2.98 \pm 0.163	.268‡
No. (%) with internal injuries			
Head/face	18 (27)	38 (37)	.160†
Torso	10 (15)	14 (14)	.827†
Lower extremity	10 (15)	19 (19)	.532†
Upper extremity	2 (3)	8 (8)	.190†

* Abbreviations: ED, emergency department; MAIS, Maximum Injury Score; ISS, Injury Severity Score.

† χ^2 .

‡ t Test.

Injury severity and injury distributions by body area, likewise, did not significantly differ between the two groups. The mean Maximum Injury Score for toddlers was 2.09 and the mean Injury Severity Score was 10.3, and for preschoolers the mean Maximum Injury Score was 1.96 and mean Injury Severity Score was 7.2. Toddlers sustained an average of 2.7 injuries and preschoolers 2.98 injuries. A large percentage of children in both groups sustained internal injuries, which were most frequently to the head. Twenty-seven percent of the toddlers sustained intracranial/facial injuries, 15% internal torso injuries, 15% lower extremity fractures, and

3% upper extremity fractures. Among the preschoolers, 37% sustained intracranial/facial injuries, 14% internal torso injuries, 19% fractures of the lower extremity, and 8% arm fractures.

Patterns of injury are depicted in the Figure. More than half (52%) of the toddlers sustained only soft tissue injuries such as abrasions, contusions, lacerations, and sprains. Thirty-six percent of the toddlers received a single internal injury with or without soft tissue injury and only 12% sustained multiple internal injuries. Among preschoolers, the same proportion sustained a single area of internal injury as sustained soft tissue injuries (42%) and

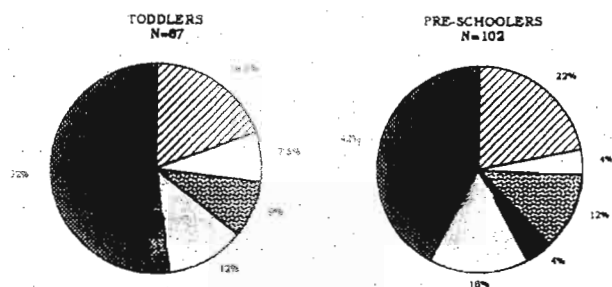


Figure. Patterns of injury in toddlers and preschoolers. ■, multiple body areas of internal injury; ▨, soft tissue injuries. Single body area of internal injury: ▩, intracranial/skull/facial; □, intrathoracic/intraabdominal; ▤, lower extremity fractures; ▥, upper extremity fractures.

16% had multiple internal injuries (not significantly different).

Fatalities: Characteristics of Injured Children and Events

Table 4 describes the cases of fatally injured children for each of the two groups. The fatal cases exemplify characteristics of the injured children and circumstances of the events for both fatal and nonfatal injuries.

The six toddler fatalities were injured by a vehicle backing up and five occurred in driveways. All of the toddler fatalities, except one, were in the attendance of adults at the time of injury. Often numerous adults and children were present in the context of a family gathering, where perhaps no one was taking primary responsibility for the child. In the one exception where the child was not with an adult, a 22-month-old, who was supposedly playing with older siblings inside the house, opened the front door and wandered out of the house while her mother was on the telephone. She then walked behind her next-door neighbor's pickup truck as she was backing out of the driveway. All of the fatal injuries except one were intracranial and were caused by the vehicle actually running over the child.

The four fatal cases among preschoolers are similar in that all happened midblock and all of the children were with adults at the time of injury. This is different from the sample of nonfatal cases: only 29% of the nonfatal cases were known to be with adults. In three of the fatal cases, the adults contributed to the behavior of the child which placed the child at risk for the injury. In two situations, the child crossed a residential street to be with his or her mother (in one the mother actually called the child across). In the third situation, the child was jaywalking with her mother and grandmother on a large thoroughfare when hit. For the preschool

children, all of the fatal pedestrian injuries were intracranial.

DISCUSSION

Previous research has analyzed pedestrians younger than 5 years old as a single group. If these children are homogeneous with respect to characteristics of the children and circumstances of injury, then it would be acceptable to make general recommendations regarding interventions. However, if significant differences within this group exist, then it is necessary to understand what these differences are and target appropriate interventions.

Data from this study demonstrate the need for age-specific interventions to reduce pedestrian injuries in children younger than 5 years. Results indicate significant differences in circumstances surrounding pediatric pedestrian injuries between toddlers and preschool children. Because of developmental differences in abilities and differences in circumstances of the pedestrian injuries between toddlers and preschool-age children, interventions must be based on the developmental level of the child and the risks to which they are exposed. The following discussion will characterize pedestrian injuries for each age group and make recommendations for age-specific interventions.

Toddlers

Toddlers (2 years of age or younger and ambulatory) were more likely to be injured in nontraffic locations (primarily driveways) and by a vehicle backing up. Serious injury in the driveway was unique to young children. In the entire sample of child pedestrians 0 through 14 years of age, all of the hospital admissions for driveway-related events were to children younger than 5 years of age and all of the fatalities were younger than 2 years of age.

Parents or care givers of young children need to be made aware of the hazards of the driveway for young children. The issue of adequate supervision must also be addressed because most of these children were in the company of adults at the time they were injured. Similar to drowning and other injuries common to these young children, a temporary lapse in attention can result in a terrible tragedy. An approach that may be more appropriate would be to separate children from the area used by vehicles and prohibit play in the driveway or in adjacent unfenced front yards. Not only are driveways dangerous for nontraffic pedestrian injuries, there have also been published accounts on the hazards of the driveway for injuries related to automatic garage doors and children causing an unattended vehicle

TABLE 4. Case Descriptions of Pedestrian Fatalities

ID	Age	Race	Location	Activity	Vehicle	Action	Injuries
91029-11	9 mo	Hispanic	Driveway	With aunt, out to see mother off	Van	Backing	Chest, arm, abdomen
91026-16	18 mo	Hispanic	Driveway	With mother, wandered behind neighbor's truck	Pickup	Backing	Head, abdomen
91022-100	22 mo	White	Driveway	Playing inside; wandered out and went next door	Pickup	Backing	Head
91021-2	21 mo	Hispanic	Front of church	Dropped off with family	Van	Backing/ parking	Head
91009-12	14 mo	Samoan	Driveway	Playing in yard during family gathering	Car	Backing	Head
91004-2	20 mo	Hispanic	Driveway	With family in front yard on Easter	Car	Backing	Head
91005-12	3 y	White	Midblock, multiple lanes	Jaywalking with mother and grandmother	Motorcycle	Straight	Head, leg
91006-11	3 y	Hispanic	Midblock, single lane, parked cars	Called across street by mother	Car	Straight	Head, chest
91032-11	4 y	Hispanic	Midblock, single lane, parked cars	Playing, at party with family	Car	Straight	Head
91036-13	4 y	Black	Midblock, single lane, parked cars	Ran to mother across street	Car	Straight	Head

to move which in turn caused injury to the child or a bystander.^{7,10-13}

Environmental approaches to prevent nontraffic pedestrian injuries among toddlers must also be strongly urged. Separating children from driveways could be accomplished by redesign of driveways (ie, circular drives) and fenced front yards. Back-up alarms on all vehicles may also serve as a warning to remove small children from the path of backing vehicles. Another technology that could reduce the incidence of these events would be sensing devices installed in the rear of vehicles which would alert the driver to an out-of-sight object such as a small child when backing the vehicle.

Preschool Children

Preschool children (3 and 4 years of age) were more frequently injured in a street or an alley. Fewer than one third of the children were with adults at the time of injury; most were near their homes playing with other children or alone. The majority of the preschoolers sustained their injuries while crossing a residential street at midblock (similar to the familiar midblock dart-out seen with older children). In the entire sample of pediatric pedestrian injured children, 3-year-olds were second only to 8-year-olds as the most frequently injured in midblock crossings.

Rivara et al¹⁴ has found that parents' perceptions and expectations of children's pedestrian capabilities and skills are often inappropriate and unrealistic. Parents must be made aware of the fact that preschool-age children are not able to be safe pedestrians. Children 3 and 4 years of age cannot be taught to safely cross the street—they lack the cognitive awareness to be responsible pedestrians.^{14,15}

Children 3 and 4 years of age are also too young to responsibly play alone or with other children in or near traffic environments. Similar to this study, Thackray and Dueker¹⁶ revealed a high proportion of young children, 78% of 1- through 5-year-olds, playing in a "near-the-street setting" without adult supervision. The dangers of allowing young children to play in the street and/or unsupervised in an unfenced front yard should be stressed. It is questionable whether these children would remember not to go in the street when they are distracted and playing. They have the ability to focus on only one task at a time and have almost no regulatory mechanism to inhibit impulses.

In addition to allowing children to be involved in pedestrian behaviors beyond their capabilities and not providing adequate supervision, adults often place children at risk by involving children in inappropriate pedestrian behavior. Van der Molen¹⁷ found that adults frequently did not provide com-

plete supervision and in some cases actually crossed unsafely while accompanying children in a crosswalk. In the present study, the four preschool pedestrian fatalities were with adults at the time of the injury event and in several instances, the behavior of the adult actually contributed to the occurrence of the child's injury event. Adults should serve as role models as pedestrians and not involve young children in dangerous pedestrian activities.

Environmental approaches to prevent pedestrian injuries in preschool children must also be implemented. Inasmuch as the majority of the preschool children were injured crossing a residential street midblock (often between parked cars), intervention strategies would include reducing the traffic density and speed on residential streets, increasing the visibility of children, and establishing means to separate children from traffic. Thackray and Dueker¹⁶ found greater street-side parking, a 50% higher traffic volume, and four times as many street side play groups in areas with high compared with low pedestrian accident rates. Providing a more protective environment for child pedestrians must be considered. Some measures that could accomplish this would relate to slowing residential traffic by installing speed controls and enforcement activities, design of cul de sacs and other features to reduce the density and speed of through traffic, and restructuring or limiting curbside parking to enhance both pedestrian and driver visibility. An additional environmental approach would be provision of neighborhood play areas to separate children from traffic because many children use the street and adjacent areas for play.

SUMMARY

Present campaigns to prevent injury in children do not address adequately the prevention of pedestrian injuries in children younger than 5 years of age. Age-specific interventions are needed to reduce pedestrian injuries in these children. For toddlers, education regarding the hazards of the driveway, separating the child from the area used by the vehicle (redesign of driveways, fenced front yards), and means for vehicles to warn or detect out-of-sight objects and persons are some suggested measures that could be taken. For preschool children, interventions should focus on educating parents regarding the risks for midblock pedestrian injuries (ie, allowing play in the street or without adult supervision in the front yard). In addition, parents must realize that young children are not cognitively able to become safe pedestrians. To protect young children in a traffic environment, parents must provide proper supervision and role models for safe

pedestrian behavior. Environmental interventions to protect preschool children would include reducing the speed and density of traffic on residential streets (ie, cul de sacs, speed controls) and restructuring street parking. In addition, the provision of neighborhood play areas must be considered. Multifaceted, multidisciplinary approaches that involve both age-specific educational messages for parents and specific environmental modifications are needed if we are to protect young child pedestrians from the dangers of motor vehicles.

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