

Preventing Pediatric Pedestrian Injuries

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Pedestrian-related crashes cause an estimated 1.2 million deaths and 50 million injuries worldwide. There were 32,590 nonfatal injuries reported among children 0 to 14 years of age in the United States in 2006. The incidence of pedestrian injuries seems to be decreasing due to im-

provements in trauma care and a nationwide decline in walking. This article is a special communication and overview of selected literature regarding efforts to decrease the frequency of pediatric pedestrian trauma. WalkSafe an elementary school-based pedestrian injury prevention

program will be discussed as an example of a program that has been able to demonstrate a decrease in injuries in children.

Key Words: Childhood trauma, Pediatric Injuries, Injury Prevention, Education.

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Pedestrian traffic injuries are of increasing global concern, accounting for an estimated 1.2 million deaths and 50 million injuries worldwide (Fig. 1).^{1,2} In 2006, 4,784 pedestrians were killed in traffic accidents in the United States or one pedestrian injured every 9 minutes.³ The elderly and the young are at highest risk for pedestrian injury compared with other age groups.⁴ This monograph will focus on pediatric pedestrian injuries.

In motorized countries, pedestrian crashes are the second-leading cause of deaths related to unintentional injury among children aged 5 to 14 years.^{5,6} In 2006, 20% of children aged 5 to 9 who were killed in traffic crashes were pedestrians struck by vehicles.³ In this age group, pedestrian injuries are the most common cause of severe head trauma. Each year, more than 39,000 nonfatal injuries occur to children.⁷ Additionally, children who are 15 years old or younger accounted for 25% of all pedestrians injured in traffic crashes. Over the last few years, the fatality rates associated with pedestrian injuries have declined nationally. This decline may be attributed either to improvements in trauma care or to decline in walking.³

Most school-aged pedestrians are killed in the hours after school, with approximately 40% of fatalities result from crashes occurring between 3:00 PM and 8:00 PM and 79% take place at locations other than intersections.³ Mid-street crossing and mid-street dart-outs account for 60% to 70% of injuries to children younger than 10 years.⁸ Figure 2 shows

the cause of pedestrian injury in a single county over a 3-year time period.⁹

For this special communication, we have reviewed most of the English literature on the subject of pediatric pedestrian injury with particular attention to prevention strategies. Our purpose is to provide the reader with material, which could aid in constructing an effective and sustainable pediatric pedestrian injury prevention program in their high-risk communities.

OVERVIEW OF RELEVANT PEDIATRIC PEDESTRIAN PREVENTION PROGRAMS

There are relatively few well-designed comprehensive interventions aimed at reducing pediatric pedestrian injuries. In a number of developed countries, including the United Kingdom, Australia, and the United States, considerable grant dollars have been allocated to research pedestrian injury prevention programs.

In the 1950s, clinicians in the United Kingdom employed the Kerb Drill, which advocated a military style of rule recitation. Subsequently, the Green Cross Code was introduced as a general set of road-crossing guidelines that children could easily learn and apply; it is still widely used throughout Britain today. In the mid 1990s, the Children's Traffic Club shifted focus from child-centered activities to those that encouraged parent-child interaction. Even though these programs were believed to be educational, the developers failed to assess effectiveness.¹⁰

In the 1970s, two British physicians formed a committee focused on child accident prevention, which evolved into the Child Accident Prevention Trust (CAPT) after gaining charitable status.¹¹ The aims of this group are to reduce the number of children injured by unintentional events. CAPT achieves their goals of reducing unintentional injuries by raising awareness of the issue among decision makers and parents, increasing knowledge of successful measures in the prevention of unintentional injuries in children, and reducing inequalities in unintentional injuries. CAPT addresses their

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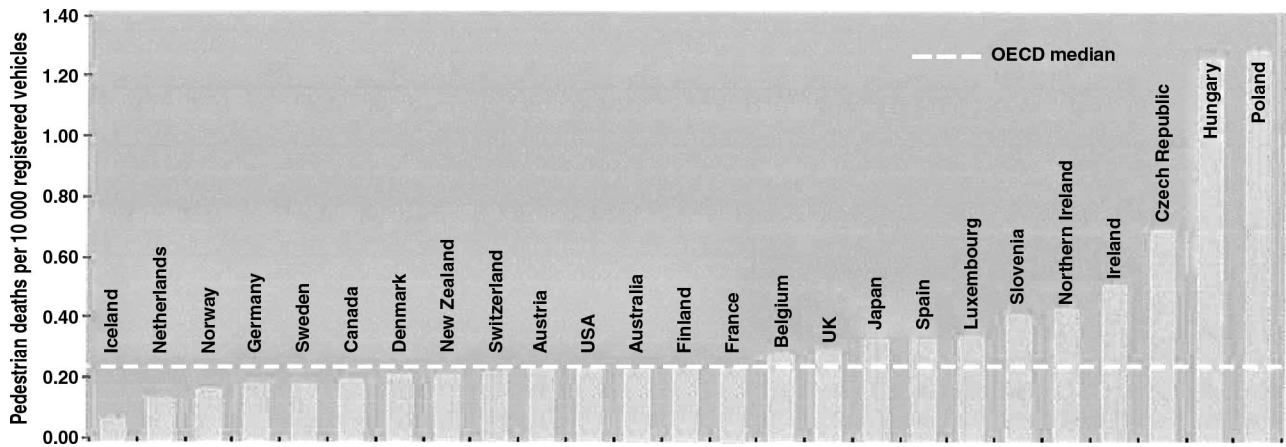


Fig. 1. Pedestrian deaths per 10,000 registered motor vehicles, member countries of the Organization of Economic Co-operation and Development.²

**Actions Leading to Pedestrian Injury or Death
Miami-Dade County 2003-2005
Children Aged 5-13**

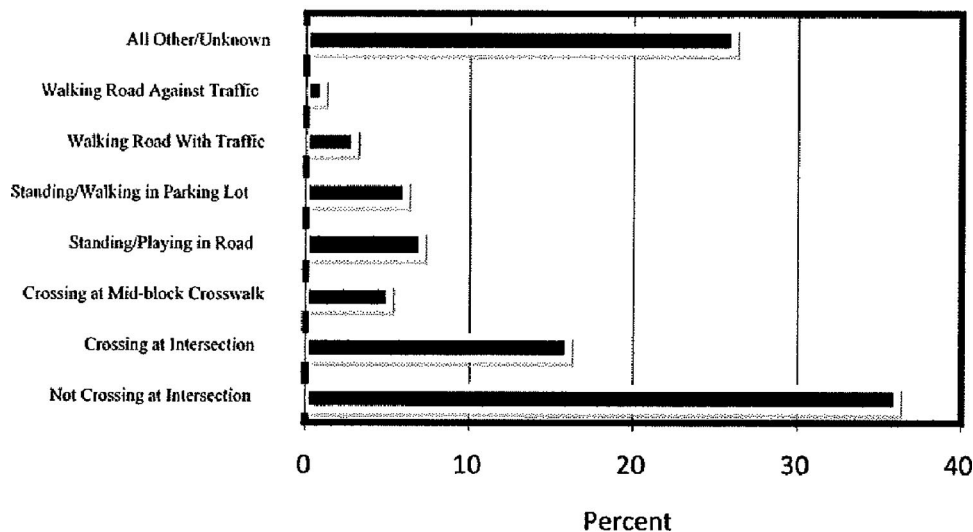


Fig. 2. Causes of injury or death in Miami-Dade county.⁹

target audiences through various safety campaigns, through the annual Child Safety Week, and through community projects.¹¹

During the late 1980s, World Health Organization studies found that the best model for reducing the rate of childhood pedestrian injury combines education with community and environmental interventions. The World Health Organization Safe Communities concepts state that safety can be achieved through integrated, collaborative efforts that are implemented in a supportive social, cultural, and political environment. This work resulted in the three E model: education, engineering, and enforcement.¹²

In 1987, the SafeKids organization was established in Washington, DC, by the Children's National Medical Center with funding from Johnson and Johnson.¹³ The goal of the

Safe Kids program is to change attitudes, behaviors, laws, and the environment to prevent injury to children. The Safe Kids Worldwide program is very active at local levels through education, environmental changes, legislative enactment of safety regulations and standards, evaluative research, and injury surveillance. It is dependent on support of grass root networks to implement safety programs throughout the world. The Safe Kids Worldwide has achieved positive results throughout the world with reductions in child accidental deaths. Safe Kids programs are widely available with branches in over 150 cities in the United States, and more than 500 chapters worldwide.¹³

In response to the vast number of preventable injuries seen in Seattle, the Harborview Injury Prevention and Research Center was founded in 1985.⁸ The Harborview Injury

Prevention and Research Center is 1 of 10 injury-control centers that is supported by the Centers for Disease Control and Prevention (CDC) in the United States and has become one of the leaders in prevention research.⁸

The Pediatric Injury Prevention Research Group in Orange County, CA, is part of the Center for Health Policy and Research at the University of California, Irvine. This group conducts research to obtain mortality and morbidity data on childhood injuries to develop appropriate interventions in the local community. Studies conducted by this program have highlighted environmental, social, and cultural factors that influence pediatric pedestrian injuries.¹⁴⁻¹⁷

In 1991, Rivara et al.¹⁸ in Seattle studied the effectiveness of an eight-session school training program that targeted students in kindergarten through grade 4. Four street-crossing behaviors were observed and graded before and after training: walking on the sidewalk, stopping at the curb, looking left-right-left before crossing, and continuing to look while crossing. The researchers observed different groups of children and found that before training nearly all children walked on the sidewalk, fewer than 50% of children stopped at the curb, only 25% looked L-R-L, and fewer than 20% continued to look. Although training did not improve children's performance of the first two behaviors, it did significantly increase the percentage of children who looked L-R-L and continued to look while crossing. They concluded that children's pedestrian skills can be improved by a classroom training program.

In 1997, the Australian Child Pedestrian Injury Prevention Project¹⁹ was one of the first intervention research projects to evaluate the effectiveness of a comprehensive school, home, and community education program in association with changes in road environments. This project focused on the pedestrian-related knowledge of children aged 6 to 9 years with regard to road-crossing and playing behavior. This multicomponent project provided an educational component for students, parents, and teachers, and also several environmental interventions. Three communities were assigned to the treatment conditions: a high-education group given community and environmental interventions; a moderate-education group given the intervention only; and a comparison group given the usual road safety education. The school-based component of the Child Pedestrian Injury Prevention Project intervention comprised developmentally appropriate pedestrian-related knowledge, attitude, and interpersonal skills-based activities, as well as essential "real" road practice. The environmental component of the program was based on a community development model. A community advisory committee of key road-safety stakeholders and other representatives was formed.¹⁹ Child pedestrian knowledge and road-crossing and playing behaviors were assessed with a pretest and post-test self-report questionnaire. Researchers found that children in the high-education and moderate-education groups were significantly more likely than the comparison group to cross the road with an adult and to play

away from the road. They found no differences between the groups in children's pedestrian safety knowledge. However, they reported that a combination of community and environmental interventions and education is likely to reduce the rate of childhood pedestrian injuries and may also decelerate the natural increase of pedestrian-related risk taking by children.²⁰ This was one of the first studies to use observation and follow-up interviews to validate self-report road-crossing behaviors in children aged 6 to 9 years.²¹

Another review conducted in 1997 by Laflamme and Diderichsen²² examined social inequalities in injury risks through a search of 13 international databases. The authors examined social differences in traffic injury risks for childhood and studied how social context, position, and other exposures may work together to form health inequalities. They found that children of lower social status and those from deprived socioeconomic areas are at a consistently higher risk of injury than others, and that the risk varied according to sex, age, and mechanism of traffic injury. Mortality rates were also higher among children from lower social positions.²²

A 2002 review by Duperrex et al.²³ examined safety education of pedestrians for injury prevention. The authors reviewed 15 randomized controlled trials of safety education programs for pedestrians, 14 of which targeted children. None of these trials assessed the effect of safety education on the number of pedestrian injuries, but six trials assessed its effect on behavior. The effect of pedestrian education on behavior varied considerably across studies, but overall, it was found that pedestrian safety education can change observed road-crossing behavior. Whether the risk of pedestrian injury in traffic crashes is reduced by this education method is unknown. Limitations of the review included the absence of trials conducted in low- or middle-income countries.

Finally, the Cochrane Collaboration, an international effort that prepares and maintains systematic reviews of randomized controlled trials, reviewed nine community-based prevention programs that targeted all injuries for children aged birth to 14 years. Only three of the studies found that an intervention had a significant effect; two studies without control groups noted significant reductions in injury rates after the intervention period.²⁴

Child pedestrian safety is clearly a complex problem and solutions reside in a multifaceted approach and collaboration among experts from diverse fields.²⁵ In 2002, the CDC and the National Highway Traffic Safety Administration sponsored a Multidisciplinary Conference: Reducing Childhood Pedestrian Injuries.²⁵ This group of experts developed six strategies for reducing childhood pedestrian injuries: enhancing awareness of child pedestrian safety needs combined with health benefits; changing behaviors of pedestrians and drivers; making the built environment conducive to pedestrian traffic; creating programs for effective safe-walking; research knowledge gaps and transferring the findings into policy and program changes; and conducting surveillance on pediatric pedestrian injury. The results of the conference led to an

Table 1 Summary of the Pediatric Pedestrian Traffic Injury Literature

Location	Author(s) and Year	Study Type	Participants/ Injuries	Conclusion	Level of Evidence*
Memphis, Tennessee	Rivara and Barber ²⁹	Retrospective	210	Traffic engineering modifications are practical solution	2b
Washington State	Brisson et al. ²⁸	Retrospective	71	Prevention strategies must be age-specific	2b
King County, Washington	Mueller et al. ³¹	Case-control	98	Busy streets, multifamily homes are strong risk factors	3b
Hartford, Connecticut	Braddock et al. ³²	Retrospective	198	High-density areas are problematic	2b
Seattle, Washington	Rivara et al. ¹⁸	Case-control	229	The evaluation of training school children in street-crossing skills showed that pedestrian skills of children can be improved, but such a program must be part of a broader effort to decrease pedestrian injuries	3b
Auckland, New Zealand	Roberts et al. ³⁰	Case-control	190	High traffic volume in urban areas should be reduced	3b
Orange County, California	Agran et al. ¹⁵	Case-control	39	Parked cars and reduced speed would decrease injuries	3b
Australia	Cross et al. ¹⁹	Randomized control trial	1603	The Child Pedestrian Injury Prevention Project (CPIPP) found that educational intervention decelerated the increase in children's pedestrian-related risk behavior	1b
Stockholm, Sweden	Laflamme and Diderichsen ²²	Literature review	13 International databases	Children from lower social status and more deprived socioeconomic areas are at greater risk than others of traffic injury, mortality, and morbidity	5
Jefferson County, Alabama	Calhoun et al. ³³	Retrospective	91	Manageable environmental risk factors were identified; education should be targeted toward grade school children	2b
Harlem, New York	Durkin et al. ³⁴	Retrospective	981	Community interventions (play areas, education) may be helpful in preventing injury	2b
Miami-Dade County, Florida	Hameed et al. ³⁵	Retrospective review	235	Ongoing surveillance is required for continued development of focused prevention strategies	2b
Geneva, Switzerland	Duperrex et al. ²³	Systematic review of RCTs	15 randomized controlled trials	Pedestrian safety education can change observed road-crossing behavior, but whether this reduces the risk of pedestrian injury in road traffic crashes is unknown	1a

* Oxford Center for Evidence-based Medicine Levels (May 2001).

agreement that neither classroom education nor environmental modification was a sufficient solution in itself, and that education should be coupled with skills training and behavior evaluation.²⁵

Results of pedestrian education programs for children have often been disappointing.²⁶ Most education programs have taken place in the classroom with the aim of increasing children's knowledge about traffic and generalizing what they learn in the classroom to real-life traffic situations. The results of these programs have been mixed, with little evi-

dence produced suggesting fewer children are subsequently injured.^{27,28} Table 1 summarizes pediatric pedestrian injury literature, which may be valuable in developing a new pediatric pedestrian injury program.^{15,18,19,22,23,28-35}

KEY RISK FACTORS Impact of Population Density and Socioeconomic Factors

If prevention programs are to be properly planned and implemented, relevant risk factors for pedestrian injuries

must be determined. The risk of pediatric pedestrian injury has been shown to be inversely related to socioeconomic status.³⁶ Social indicators such as low income, poverty, crowding, single parenthood, absence of high-school degree, and lack of employment by mothers and caregivers frequently influence the creation of a high-risk environment.³⁷ Of the socioeconomic indicators, low income and poverty are associated with the largest numbers of pediatric pedestrian accidents.²⁹ Crowding frequently refers to the external environment, meaning housing units per acre, but can also refer to the number of occupants within rooms of the housing unit, which is associated with pediatric pedestrian injuries.²⁹ Research has also shown that, for one fourth of the households affected by a pediatric pedestrian accident, the head of household is unemployed.³⁸

In addition to social risk factors, environmental risk factors are important with regard to pediatric pedestrian injury. The level of urbanization, population density, and crowding are important factors. Pediatric pedestrians from urban areas are involved in accidents five times more frequently than those in rural environments, and their death rate is twice as high.³⁹ Vehicle volume and speed are other risk factors positively correlated with pediatric pedestrian injuries.³⁹ On-street parking is also associated with higher risks for pediatric pedestrians because it is known to hinder children's vision and to increase the number of dart-outs.³⁰

Studies have also detected injury patterns related to children's sex and race. Almost two thirds of pedestrian deaths involve male children, whose death rate is 57% higher than that of female children.⁷ Minority children, specifically African American children, also have a higher risk of injury, and the death rate for black children is double that for white children. The main risk factors for involvement in child pedestrian trauma are presented in Table 2.

Effect of Age

An important factor related to pedestrian injuries is age. Age determines a child's degree of mobility and independence. Children are at higher risk of pedestrian injury than adults because they are smaller and lack perception and judgment. Because of their size, they are often not visible to drivers, and their inability to judge the driver's actions and speed, combined with their lack of understanding of traffic signals and street-crossing safety, also increase their risk. For these reasons, young children should not walk by themselves. As children age, they become more mobile, require less supervision, tend to travel independently farther from home, and may focus on play, thus diverting their focus away from traffic. Also, children of certain age groups are at risk of pedestrian injuries at certain locations (Table 3).⁴⁰

Limited peripheral vision of young children can hinder their ability to see vehicles as well.⁴¹ Overall, children have one third less peripheral vision than adults.⁴¹ Previous research has shown that the difference in acuity between adults' and children's peripheral vision is not significant and does not explain the

Table 2 The Five W's for Pediatric Pedestrian Injuries^{7,29,36-39}

What: pediatric pedestrian injuries: greatest risk factors

Who:

- Boys
- Age 5-9
- African American

Where:

- Urban areas
- Residential streets
- Low-income neighborhoods
- High-traffic volume areas

When:

- Late afternoon, early evening

Why:

- Children are at higher risk of pedestrian injury than adults because of their small size (drivers cannot see them), lack of perception, and lack of judgment (of both driver's actions and vehicle speeds)

Table 3 Summary of Age Group Risks⁴⁰

Infants (less than 1-yr-old):

- Are considered pedestrians when carried in the arms of an adult or transported in a stroller; thus, their risk is closely related to that of the caregiver

Toddlers (aged 1-2 yr):

- Sustain the highest overall number of pedestrian injuries. Their small size and limited traffic experience are main factors. Also they are the most likely group to be involved in pedestrian injuries not related to traffic, especially driveway back-overs and injuries in parking lots and on sidewalks

Preschool age children (aged 3-4 yr):

- Are most often struck as they enter the roadway at mid-block, particularly if cars parked along the side of the road shield them from the view of drivers. They also experience a high number of back-overs in driveways

Younger elementary schoolchildren (aged 5-9 yr):

- According to some sources, they are at higher risk because their knowledge and key perceptual skills concerning traffic are not yet fully developed. Children of this age often have poor judgment in recognizing and avoiding dangerous road situations. They also tend to choose the most direct route when walking, considering convenience rather than safety; therefore, they often walk diagonally across intersections or cross mid-street to chase a ball

Preadolescents and young adolescents (aged 10-14 yr):

- This age group is most often injured on busy streets farther away from home

difference in pedestrian injury rates. However, pedestrian safety requires visual accuracy, and some have suggested that children aged 6 to 11 years cannot use visual information as well as adults can because their ability to detect hazards is still developing.⁴² This finding supports those of other studies showing that adults and 11 year olds detect peripheral cues faster than children aged 6 to 8 years.⁴³ Being unable to detect and understand objects in the periphery creates a challenge for young children and this can lead to hazardous situations.^{3,43}

Pedestrian Injury Types

Vehicle size and pedestrian size can substantially affect injury patterns.⁴⁴ Pedestrians of different ages can experience the same mechanism of injury but suffer very different injuries.⁴⁵ Pediatric pedestrian injury occurs at three typical impact points: the bumper; the hood or windshield; and the ground. These points are known as Waddell's Triad.⁴⁶

At the initial bumper impact, children tend to be hit while facing the vehicle, whereas adults tend to be hit from the side while bracing for impact.⁴⁶ For children, bumper impact causes injuries to lower limbs, such as fractures of the femur and tibia.⁴⁵ Because children are smaller than adults, trauma may result in deep lacerations with substantial blood loss, head injuries, blunt chest, and abdominopelvic trauma.⁴⁴ Pediatric thoracic trauma often results in hemothorax or pneumothorax; abdominal trauma may lead to damage to the liver, spleen, renal organs, gastrointestinal organs, or some combination of these.⁴⁵

After the initial impact, children are typically thrown onto the hood or windshield of the vehicle. Depending on the bumper location, some children are thrown from the impact zone directly to the ground.⁴⁶ The injuries associated with ground impact or with hood or windshield impact typically affect the head and spine.⁴⁵ Traumatic brain injury is the most common injury, followed by injuries to the extremities, and trauma to the chest and abdomen.⁴⁷ The proportionately large heads of children younger than 10 years seems to increase the likelihood of traumatic brain injury after head-to-ground impact.⁴⁸

Financial and Productivity Losses Associated With Pediatric Pedestrian Injuries

In 2000, the cost of the 50 million injuries suffered by children in the United States amounted to \$406 billion.⁴⁹ Injuries to children aged 5 to 14 years accounted for \$34.6 billion (9%) of the total lifetime cost of injuries in the same year.⁴⁹ These figures include medical costs and productivity losses. The CDC calculated that 140,482 years of potential life were lost in 2003, with pediatric pedestrian fatalities accounting for the largest number of years lost, resulting in a substantial economic burden for society.²⁷

The WalkSafe Program

The WalkSafe program was developed to assist in decreasing the number of pediatric pedestrian injuries in Miami-Dade County. We designed our program to be effective, easy to implement, free, and readily available. A number of excellent programs have died to financial woes (i.e., when grant funding is terminated). We attempted to involve multiple agencies and have created a sustainable program. Since its inception in 2001, the WalkSafe program focused on research validation to confirm the effectiveness of the program. Grant funding and corporate sponsorship has permitted our program to expand from a countywide program in Miami-Dade to

Table 4 Miami-Dade County Crash Data Child Pedestrian-Hit-By-Car Injuries⁵⁰ (From FDHMSV)

Ages (yr)	0-4	5-10	10-14	Total (Fatalities)
2001	50	93	150	293 (2)
2002	52	104	116	272 (3)
2003	36	101	120	257 (4)
2004	27	63	130	220 (4)
2005	34	73	105	212 (3)
2006	29	55	90	174 (2)

involve school systems throughout the State of Florida. In Miami-Dade County, the program has led to a 41% decrease in injuries from 2001 to 2006. Table 4 illustrates the number of injuries and fatalities in the county over a 5-year period.⁵⁰

The purpose of the WalkSafe program is to reduce the incidence of pediatric pedestrian injuries by providing an elementary school-based pedestrian injury prevention program. This multiagency program focuses on five Es: classroom safety education through the Miami-Dade County Public Schools; engineering modifications around the schools by the Department of Public Works; enforcement by Miami-Dade County, the City of Miami, and the School Police Departments; evaluation in the form of various research assessments; and encouragement primarily comprised Parent-Teacher Association interactions. All program materials including publications, teacher surveys, and guardian permission slips are available online at www.walksafe.us.

The WalkSafe program uses videos, formal educational curricula, workbooks, and outside simulation activities to promote pedestrian safety among school-aged children. The curriculum is hierarchically based to account for the different stages of children's behavior and development of pedestrian skills and is geared for each grade level. The educational curriculum has been designed for implementation on three consecutive days, with daily half-hour sessions of classroom education, outside simulation, and a poster contest and review. A teacher survey is administered to obtain feedback about program materials and any difficulties noted with the educators who implemented the WalkSafe program.

Miami-Dade County is the fourth largest school system in the country⁵¹ and therefore implementing the program to students in more than 200 elementary schools was challenging. The children in our study were primarily 5 to 11 years of age and were enrolled in grades K through five. According to Miami-Dade County Public School District Profiles for 2002 to 2003,⁵² 60% were Hispanic, 28% were black non-Hispanic, 9% of students were white non-Hispanic, and 3% were multi-racial. The goal was to educate all students in 207 public elementary schools and to have the approximately 160,074 students participating in the WalkSafe program.

Educational data are collected before, immediately after, and 3 months after the program, and our results have demonstrated that students in all grades acquire significant information and that this educational material is retained. In a pilot

behavioral study, students in grades K through 5 at 4 randomly selected schools were videotaped as they walked home. Valid data were not collected partly because the sample of walkers was small and the quality of the recorded videos was poor.^{53,54} Similar to other investigators, we found education to be an effective strategy for teaching injury prevention.⁵⁵ In the pilot study, we were able to begin to demonstrate that the educational street-crossing lessons that children learned in school could be translated into correct street-crossing behavior shortly after implementation of the program.^{53,54} This study has now been expanded and revised and the behavioral component will be investigated again this year by also identifying the grade of the child.

The WalkSafe program has been successful in significantly lowering the number of childhood pedestrian injuries (Table 4). If the WalkSafe program was to be duplicated in another region, the first step would be to bring the representatives from multiple agencies together, and then obtain the support of the local school system. Some funding would likely be needed by the local trauma center for the planning, training, implementation, and dissemination of materials and promotional items, and evaluation of the program. All materials required can be found at www.walksafe.us.

Future Research and Recommendations

Pediatric pedestrian trauma is a complex problem for which no single intervention is completely effective. Collaboration between multiple agencies at the local, state, and national levels are needed to collectively decrease the number of injuries experienced by children. Trauma centers that see a high incidence of injury associated with pediatric pedestrian trauma may find it beneficial to create a WalkSafe type task force and implement a program beginning with the districts with the highest incidence of such injuries.

It is important to recognize that schools not only have direct access to children but also have the ability to affect staff, parents, and the community. Our study provides evidence that early school-based injury-prevention programs have a positive impact on young children by increasing their pedestrian safety knowledge, promoting behavioral changes, and ultimately decreasing the number of injuries experienced by children in our community.

Given the attention now focused on childhood obesity (one third of children and adolescents in America are either overweight or obese), efforts are underway to increase children's physical activity. Encouraging children to walk to and from school may be beneficial in this campaign, which will certainly require the application of pedestrian safety skills.⁵⁶ Programs such as WalkSafe may assist in this effort and help create a safer environment for children to walk to and from school. There is a federally funded initiative called Safe Routes to School (SRTS) that was initiated by the Department of Transportation. In August 2005, federal transportation legislation devoted \$612 million for The National SRTS Program from 2005 to 2009. The purpose of the program is to

encourage children K-8 to walk and bike to school. Each State is allocated a specific amount of dollars to provide support for these programs. The WalkSafe program is partially funded by SRTS in Miami-Dade county.⁵⁷

In 2005, investigators from the United Kingdom⁵⁸ studied the influence of virtual reality training on roadside crossing judgments of groups of child pedestrians aged 7, 9, or 11 years. All groups showed similar improvement, and judgment had not deteriorated when retested 8 months later. Researchers at the University of Alabama at Birmingham are currently using funding from the CDC to develop and validate virtual reality software as a tool for training children about pedestrian safety. Certainly, the ultimate solution for childhood pedestrian injury is prevention.

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