REVIEW ARTICLE

A review of risk factors for child pedestrian injuries: are they modifiable?

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Abstract
***Purpose*—To identify modifiable risk factors for child pedestrian injuries.**

***Data sources*—(1) MEDLINE search from 1985 to 1995; search term used was traffic accidents; (2) review of reference lists from retrieved articles and books; (3) review of reference lists from three systematic reviews on childhood injuries and (4) consultation with 'key informants'.**

***Study selection*—All studies that examined the risk factors for child pedestrian injuries were targeted for retrieval. Seventy potentially relevant articles were identified using article titles, and, when available, abstracts. Of the 70 retrieved articles, 44 were later assessed as being relevant.**

***Quality assessment*—Articles were classified on the basis of study design as being either descriptive (hypothesis generating) (26) or analytical (hypothesis testing) (18) studies. Consensus was used for difficult to classify articles.**

***Data extraction*—Variables judged to be risk factors for child pedestrian injuries were extracted by one author.**

***Data synthesis*—A qualitative summary of the information extracted from relevant articles is presented in tabular form.**

***Results*—Risk factors for child pedestrian injuries were classified as: (1) child, (2) social and cultural, (3) physical environment, and (4) driver. Risk factors within each classification are summarized and discussed.**
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For the past 30 years unintentional injuries have been the leading cause of childhood mortality among children. The rate in Canada is among the highest in the developed world.[1-3] Unintentional injuries cause more potential years of life lost than any other single cause.[4] Furthermore, in 1986, 11 billion dollars were spent on medical care for injuries (2 billion dollars more than was spent on cancer or musculoskeletal disease), making injuries the second largest cost to the Canadian health care system.[5]

Motor vehicle injuries lead the list of injury deaths at all ages during childhood and adolescence.[6] Among the 5 to 9 year old age group, pedestrian injuries overshadow occupant injuries as a cause of death and are, in fact, the leading cause of death from unintentional injuries in this age group.[1 7] A 1992 analysis of data from one community, found that children in this age group were three times more likely to be involved in a collision with a vehicle than any other age group.[8]

We searched the literature for primary research studies and review articles that identified risk factors for child pedestrian injuries. Two kinds of studies were identified: (1) observational studies analysing injury and exposure data, and (2) studies evaluating the impact of interventions. The findings from high quality intervention studies are summarized elsewhere in one of the three recent systematic reviews of the prevention of childhood injuries.[9] This paper summarizes the findings from analytical research studies that examined risk factors for child pedestrian injuries.

Methods

DATA SOURCES

Articles were identified using three methods. First, the MEDLINE bibliographic database was searched from 1985 to 1995 using the exploded Medical Subject Heading (MeSH) 'traffic accidents' to produce the widest possible search. The search was restricted to humans, English language articles, and study populations between 2 and 18 years of age. This search strategy yielded 433 articles. The titles of all articles identified were then carefully scrutinized for those that may have examined risk factors for child pedestrian injuries. In instances where, from the title, it was unclear whether the study examined risk factors for child pedestrian injuries, abstracts (when available), were also examined. This resulted in the selection of 53 potentially relevant articles for retrieval. Those not selected for retrieval appeared to deal primarily with preventive interventions, methodological issues, or descriptive information about types of injuries.

Second, the reference lists of the 53 retrieved articles were reviewed for other potentially relevant articles, as were the reference lists of three recent systematic reviews.[3 9 10]

Finally, a number of experts were contacted for additional published and unpublished articles. Together, these two additional data sources yielded another 31 potentially relevant articles, some of which dated as far back as 1959. We were able to obtain 17 of these 31 articles. Those not available were government documents, unpublished papers, or conference proceedings. A total of 70 studies were retrieved (table 1).

STUDY SELECTION
The 70 retrieved articles were then assessed for relevance, that is if it provided statistical data on risk factors for child pedestrian injuries. Twenty six of the 70 articles were excluded for failing to provide such data. The 44 remaining studies excluded review articles and editorials that did not include data. Other excluded articles focused on response systems, hospital stays, details about the type of injury, policy impact, potential interventions, or did not distinguish between adults and children.

STUDY CLASSIFICATION AND QUALITY ASSESSMENT
The relevant articles were separated into two types of study designs: individual and ecological. In individual studies, the unit of analysis is a single person, be it a case or a control. In ecological studies, however, the unit of analysis is a group or groups of people. Ecological studies are useful for understanding the etiology of injuries at the population level but have serious limitations when attempting to make causal inferences at the individual level. Nevertheless, ecological studies (for example, those using census tract data) have frequently been used to identify environmental risk factors.

Individual and ecological studies were further separated into two types of study design representing two levels of methodologic quality, descriptive and analytical. The descriptive studies (primarily cross sectional surveys without comparison groups) usually described general characteristics of the distribution of child pedestrian injuries with respect to demographic factors (such as age, gender, or race), geographic distribution, (such as variations within cities or neighbourhoods) and the time the injuries occurred (such as the time of day, day of week, or month). The findings from descriptive studies are thus helpful in formulating hypotheses about potential risk factors, but are not able to test these hypotheses as they lack appropriate comparison groups.

For this review, we elected to include only the findings from analytical studies (studies that included a comparison group) such as case-control studies, cohort studies, or randomized control trials. We also considered cross sectional surveys and ecological studies with a comparison group to be analytical studies. The presence of a comparison group in analytical studies allows for the testing of hypotheses concerning whether the risk of injury is different in those exposed to, or not exposed to, hypothesized risk factors. As such, analytical studies were judged to be of higher methodologic quality than descriptive studies for identifying risk factors. Of the 44 reports retrieved, we classified 18 as analytical[11–28] and 26 as descriptive (table 1).[1 29–53]

DATA EXTRACTION
For each of the 18 analytical studies, an attempt was made to extract information on the year and country in which the study was completed, the age of the study population, the source of the data, the study design, and the magnitude and significance of risk factors. If an article did not include the magnitude of risk, we calculated odds ratio or relative risk estimates whenever possible (that is when data were available to calculate these estimates).

Results
Information abstracted from the 18 analytical studies is presented in three tables. Table 2 summarizes the results of analytical studies that identified risk factors for the incidence of child pedestrian injuries. Table 3 summarizes those same risk factors as identified in studies with an ecological design. Table 4 summarizes those studies that only examined predictors of more severe injuries.

In addition to identifying potential risk factors, an attempt was made to identify factors that at least doubled the likelihood that a child would be injured. We classified these risk factors into the following types: (1) child, (2) social and cultural, (3) physical environment, and (4) driver. Risk factors within each classification are described below and presented in tables 2 to 4.

CHILD RISK FACTORS
Child factors include, age, sex, race, physical defect, education, behaviour/social adjustment, or action of the child.

Age
One of the ecological studies found that 'demographic structure' was the most important risk factor,[24] and contributing approximately one third of the variability in incidence of injury to children in each census tract (table 3). In other studies, children 5 to 12 years of age were found to be at highest risk of being injured by a vehicle[18 19] (table 2). For children

Table 1 Number of observational studies on child pedestrian injuries identified, copied, selected, and reviewed in a search of MEDLINE, retrieved article reference lists, systematic reviews, and contacts with experts in the field

	MEDLINE	*References, systematic reviews, and experts*	*Total*
All studies identified in search	433	31	464
Studies identified as potentially relevant (abstract read)	53	17	70
Studies meeting inclusion criteria	36	8	44
Analytic studies reviewed			
Individual studies on incidence of injuries (table 2)	7	4	11
Ecological studies on incidence of injuries (table 3)	4	0	4
Individual studies on severity of injuries (table 4)	3	0	3
Total	14	4	18

8 to 12 years of age, the rate of injury per kilometre or time spent on the road, or per road crossing, was about twice as high as in children ages 3 to 7 and six times as high as in children 13 to 17 years of age.[18] The actual rate of injury per child 8 to 12 years of age was, however, only 1.1 times higher than those of the two other age groups combined. In a similar exposure study,[19] it was found that children of age 5 were at higher risk than those of age 9. Five year old children had rates of injury per child, per crossing, and per car encountered of 1.4, 3.6, and 9.5 times higher, respectively. Children 4 years of age and

Table 2 Summary of analytic studies and risk factors identified for the incidence of child pedestrian injuries

Study	*Country*	*Age of study population*	*Data sources*	*Study design*	*Risk factor (referent group in brackets)*	*Odds ratio estimate and/or finding*	*Confidence interval or p value*
Roberts *et al* 1995[11]	New Zealand	0 to 11 years	Record of coroner, pathologists and monitoring system in Auckland's two hospitals; community controls; January 1992 to March 1994	Case-control study adjusted for age, sex, and SES; 53 cases and 159 community controls	Race (other)	1.6 (Pacific island)	0.59 to 4.71
						2.92 (Maori)	1.02 to 8.35
					Crowding (<2 children)	3.36 (≥3 children)	1.19 to 9.50
					Rental property (not rental)	2.59 (rental)	1.11 to 6.06
					Play area (fenced)	3.50 (unfenced)	1.38 to 8.92
					Driveway (not shared)	3.24 (shared)	1.22 to 8.63
Pless *et al* 1995[12]	Canada	5 to 15 years; cyclists and pedestrians	Injury monitoring system in Montreal Children's Hospital for cases and controls; 1990s	Case-control study; 286 cases and 572 controls	Attentiveness (more)	Less attentive	p<0.01
					Impulsiveness (less)	More implusive	p<0.01
					SES (higher)	Lower SES	p<0.05
Roberts *et al* 1995[13]	New Zealand	0 to 15 years	Record of coroner, pathologists and monitoring system in Auckland's two hospitals; January 1992 to March 1994	Case-control study adjusted for age, sex and SES; 190 cases and 380 community controls	Speed limit (<40 kph)	3.22 (40–49 kph)	1.3 to 7.98
					Traffic volume (250 vehicles/hour)	6.32 (250–499/hour)	2.43 to 16.40
						7.38 (500–749/hour)	2.70 to 20.20
						13.0 (≥750/hour)	5.58 to 30.50
					Curb parking (<5%)	3.37 (≥10%)	1.17 to 9.74
King and Palmissano 1992[14]	US	0 to 15 years	Pediatric injury discharge surveillance data, Alabama Children's Hospital, 1987	Case-control study adjusted for SES; 56 cases and 122 controls	Race (white)	2.95 (non-white)	1.51 to 5.77
					SES (insured)	2.38 (indigent)	1.24 to 4.56
Mueller *et al* 1990[15]	US	0 to 15 years	King County residents records in trauma registry of Harborview Medical Center and Medical Examiner's Office; 1985 to 1986	Case-control study * adjusted for SES; 98 cases and 196 controls	SES (>$30 000)	1.9 ($20–30 000)	1.1 to 3.1
						7.0 (<$20 000)	2.3 to 21.2
					Lanes (≤2)	*2.1 (>2)	0.8 to 5.7
					Speed limit (<40 kph)	*3.2 (45–55 kph)	1.2 to 8.8
						*6.0 (>64 kph)	1.4 to 26.9
					Traffic volume (<5000/day)	*3.1 (≥15 000/day)	0.9 to 10.8
					Apartment/condominium (house)	5.5	2.5 to 12.3
					Play area (present)	5.3 (absent)	2.6 to 11.0
					(fenced)	1.3 (not fenced)	0.7 to 2.6
Pless *et al* 1989[16]	England, Scotland, Wales	7 to 16 years	National Child Development Study; 1958 to 1974	Retrospective case-control study; 1021 cases and 5400 controls	Fidgety (not)	1.4 (boys 7 to 11)	1.1 to 1.8
						1.2 (girls 12 to 16)	1.00 to 1.41
					Social adjust (adequate)	1.5 poor (girls 7 to 11)	1.1 to 2.1
					Family problems (none)	1.2 (girls 7 to 11)	1.00 to 1.52
					In care of local authorities (not)	1.4 (boys 12 to 16)	1.01 to 1.89
					Crowding (none)	1.3 (girls 12 to 16)	1.04 to 1.60
Pless *et al* 1989[17]	Canada	0 to 15 years	Monitoring system in two children's hospital and nine other hospitals in Montreal; July 1980 to December 1981	Case-control study adjusted for age, sex and SES; 200 cases and 400 controls	Cautious behaviour (high)	1.7 (low)	0.9 to 3.2
					Mother's education (<7 years)	0.5 (>12 years)	0.3 to 0.8
					Preventive behaviour (high)	3.0 (low)	1.6 to 5.6
					Environmental risks (low)	3.4 (high)	2.0 to 5.6
					Crowding (≤4 children)	1.8 (>4 children)	1.0 to 3.1
					Family history of accidents (no)	1.6 (yes)	1.1 to 2.3
					Supervision (good)	2.6 (poor)	1.5 to 4.7
Johan and Engel 1983[18]	Canada	All ages	Police motor accident reports for Ottawa-Carleton for 1979; telephone and face-to-face interviews in the fall of 1980	Cross sectional study; 470 cases and 956 survey subjects		Estimated from data*	
					Age (age 3 to 7)	2.0 (inj/km) (age 8 to 12)	
					(age 13 to 17)	6.0 (inj/km) (age 8 to 12)	
					(both combined)	1.1 (inj/child) (8 to 12)	
					Time (<3 pm)	2.60 (3 to 5 pm)	
						2.72 (6 to 9 pm)	
					Weather (clear)	2.29 (rain)	
						0.25 (fog)	
					Lighting (light)	2.26 (dark)	
Howarth *et al* 1974[19]	England	5 to 11 years	Exposure survey of Nottingham schoolchildren from November 1970 to November 1971. Transport and Road Research Laboratory National Data	Cross sectional study; 288 survey subjects		Estimated from data*	
					Age (boys aged 9)	3.6 (inj/cros) (age 5)	
						9.5 (inj/car) (age 5)	
						1.4 (inj/child) (age 5)	
					Sex (girls aged 5)	2.3 (inj/cros) (boys 5)	
						2.0 (inj/car) (boys 5)	
						2.8 (inj/child) (boys 5)	

Table continued

Table 2 Continued

Study	*Country*	*Age of study population*	*Data sources*	*Study design*	*Risk factor (referent group in brackets)*	*Odds ratio estimate and/or finding*	*Confidence interval or p value*
Read *et a* 1963[20]	Canada	5 to 11 years	Vancouver police department reports, hospital records, home and school questionnaire, health and welfare agency index, driver and insurance company questionnaire for 1958 to 1959 (retrospective) and for 1960 (prospective)	Cross sectional survey; and prospective case-control Retrospective 540 cases, prospective 209 cases and 110 controls	Physical defects†	Fewer, especially visual	
					Education	'Not working to capacity'	
					Behaviour	'More daring and defiant', 'accident repeaters'	
					SES	Lower income, fewer owners, higher health and welfare services users	
					Mother	Younger, more often working	
					Crowding	Higher with more extended family	
					School attendance	More absent for reasons of 'family responsibility' and 'truancy'	
					Supervision	Discontinued sooner	
					Housing	More multidwellings and denser	
Backett and Johnston 1959[21]	England	5 to 14 years	Home interview of cases as identified from Royal Ulster Constabulary and controls as identified from record of school health service for 195	Prospective case-control; 100 cases and 100 controls	SES (<4 dependents: earners)	1.94 (≥4)	p<0.05
					Mother (at home)	2.51 (working)	p<0.05
					Family illness (none)	2.25 (yes)	p<0.05
						2.53 (mother in hospital)	p<0.05
					Crowding (<1.6/bedroom)	2.18 (≥1.6/bedroom)	p<0.05
					Play area (yes)	2.33 (no play area)	p<0.01
					Play area (protected)	2.56 (unprotected)	p<0.01

*Findings were estimated from data provided in the original article and represent relative risks. †The Read *et al* article did not provide statistical data. This reference was included however, since it was a high quality study, in terms of its study design.
inj/km=injury/km; inj/child=injury/child; inj/cros=injury/crossing; inj/car=injury/car encountered.

Table 3 Summary of ecological studies and risk factors identified for the incidence of child pedestrian injuries

Study	*Country*	*Age of study population*	*Data sources*	*Study design*	*Risk factor*	*Relative risk estimate, correlation coefficient (r) or % explained variability*	*p value*
Kendrick 1993[22]	UK	0 to 11 years	Police department data from Greater Nottingham; census data; 1988 to 1990	Cross sectional survey and ecological study	SES of census tract (high)	Estimated from data* 3.5 (low)	
Braddock *et al* 1991[23]	US	0 to 15 years	Hartford police department accident reports for 1986 to 1987; census data	Ecological study		Correlation between census tract variable and injury rate	
					Age	r=0.55 (% aged 0 to 15)	p<0.05
					Race	r=0.53 (% non-white)	p<0.05
					SES	r=0.43 (% poverty)	p<0.05
					Mother	r=0.46 (% single support)	p<0.05
					Crowding	r=0.53 (>1.01/room)	p<0.10
					Density	r=0.72 (mean child/acre)	p<0.05
						r=0.48 (mean occupied unit/acre)	p<0.05
Joly *et al* 1991[24]	Canada	0 to 15 years	Emergency monitoring system in two children's hospitals and nine other hospitals; police accident report data; census data; October 1980 to March 1982	Cross sectional survey and ecological study		Per cent variability in census tracts explained by risk factor	
					Demographic structure	33.1%	
					SES	15.3%	
					Density	10.3%	
					Neighbourhood	6.7% (low SES)	
					Mobility	5.7%	
					Single mother	4.4%	
Doughtery *et al* 1990[25]	Canada	0 to 17 years	Montreal policy reports, hospital admissions, outpatients and emergency departments from two Montreal Children's Hospitals and nine other hospitals for 1991; census data	Ecological study		Estimated from rates, provided*	
					Income (highest)	5.7 (lowest)	

*Findings were estimated from data provided in the original article.

Table 4 Summary of analytic studies and risk factors for severity of child pedestrian injuries

Study	*Country*	*Age of study population*	*Data sources*	*Study design*	*Risk factor (referent group in brackets)*	*Relative risk estimate*	*Confidence interval or p value*
Olsen *et al* 1993[26]	US	0 to 11 years	Office of the Medical Investigator, New Mexico; 1986 to 1990	Cross sectional survey; 573 cases	Preditor of mortality:		
					Age (age 5 to 9)	1.9 (age 0 to 4)	1.2 to 3.0
					Sex (girls)	2.0 (boys)	1.2 to 3.3
					Race (non-native)	2.5 (native)	1.5 to 4.3
Stevenson *et al* 1993[27]	Australia	0 to 14 years	ROTARS database complied by the Perth Police and Main Roads Department 1980 to 1989	Cross sectional survey; 1282 cases	Age (age 5 to 9)	1.6 (age 0 to 4)	1.08 to 1.73
					(age 10 to 14)	1.7 (age 0 to 4)	1.22 to 2.45
					Time (before 9am)	1.97 (after 7pm)	1.17 to 3.3
					Location (off road)	3.69 (on road)	1.00 to 13.6
					Road (urban unclassified)	2.90 (main road)	0.87 to 9.66
Pitt *et al* 1990[28]	US	0 to 19 years	Pedestrian Injury Causation Study data from National Highway Traffic Safety Administration Police Reports; September 1977 to March 1980	Cross sectional survey; 1035 cases	Age (age 5 to 9)	2.03 (age 3 to 4)	0.69 to 5.94
					Action (on road)	2.80 (crossing road)	0.16 to 48.28
					Time (12 to 3pm)	6.5 (3 to 6pm)	1.7 to 24.2
						22.3 (6 to 9am)	3.5 to 140.5
					Location (first lane)	4.15 (3rd/4th/other lane)	0.77 to 22.9
					Residential zone	0.21 (apartment zone)	0.04 to 1.13
					Driver action (steer/brake)	25.17 (none)	3.40 to 186.2
					Vehicle speed (10 to 19 mph)	7.22 (30 to 39 mph)	1.78 to 29.21
						30.68 (40 to 65 mph)	4.42 to 213.0

Table 5 Summary of analytic studies of interventions for reducing child pedestrian injuries and overall summary odds ratio and reported in review by Klassen

Study	*Country*	*Age of study population*	*Data sources*	*Study design*	*Intervention*	*Odds ratio estimate (likelihood of injury or dangerous behaviour)*	*Confidence interval*
Rivara *et al* 1991[55]	US	4 to 10 years	Three Seattle public elementary schools with children in kindergarten to grade 4; 1989 and 1990	Before and after study; 229 cases	Teacher hired for study taught curriculum on pedestrian safety versus no intervention	0.50 (pedestrian skills 10 days after intervention)	0.23 to 0.93
Nishioka *et al* 1991[56]	Japan	5 to 6 years	Children attending kindergarten in Tokyo; 1983	Randomized control trial; 81 cases	Detailed instructions on how behave near streets versus simple instruction versus no instructions	0.24 (behaviour in simulated road environment)	0.08 to 0.75
Preusser and Lund 1988[57]	US	9 to 12 years	Wisconsin Department of Transportation data tapes for crashes; 1980 to 1986	Before and after study and case-control study; 33 000 cases	Film 'And Keep on Looking' shown to all schoolchildren age 9 to 12 in Milwaukee	1.04 (pedestrian skills changes pedestrian injury rates)	0.60 to 1.80
Fortenberry and Brown 1982[58]	US	11 to 12 years (cases); all ages for controls	Alabama Office of Highway and Traffic Safety injury data for a four city geographic area	Before and after and case-control study; 18 000 cases	Pedestrian safety program versus no intervention	0.68 (pedestrian injuries over a two year period)	0.51 to 0.90
Overall summary odds ratio estimate (meta-analysis using the above four studies)						0.67 (risk of dangerous behaviour or injury)	0.53 to 0.84

younger, however, were 1.6 to 2.0 times more likely to be severely injured or killed than those 5 to 9 years of age[26-28] (table 4).

Sex

Howard *et al* found that boys were at higher risk of being injured than girls of the same age. Boys 5 years of age had 2.8 times more injuries per child, 2.3 times more injuries per crossing, and 2.0 times more injuries per car encountered, than girls.[19] Boys are also twice as likely to be killed when injured by a car.[26]

Race

Three studies found that non-whites were more likely to be injured than whites,[11 14 23] while two studies did not find any such difference.[13 28] Roberts *et al* identified New Zealand's Maori children as 2.9 times more likely to be injured than other children (non-Maori, non-Pacific Island),[11] while King and Palmissano found American children of non-white race to be at 2.6 times higher risk of injury.[14] Both adjusted their findings for age, sex, and socioeconomic status (SES). One ecological study found the proportion of non-whites living in a census tract was highly correlated (r=0.53) with the rate of pedestrian injuries to children.[23] Native children are reported to be 2.5 times more likely to die when injured.[26]

Physical defect and other child risk factors

In one study it was noted that injured children were less likely to have had prior physical defects, particularly, visual disabilities.[20] Three other studies, however, found physical defect not to be a statistically significant risk factor.[12 16 17] It was also noted that injured children were more likely to be 'not working to capacity' academically,[20] a finding not duplicated in two other studies.[16 21] It has also been noted that injured children were 'less attentive', 'more impulsive', 'more daring and defiant'[20] as well as three times more likely not to be cautious.[17] Another study found children who were fidgety and less well adjusted socially to be slightly more likely to be injured when analysed in subgroups of ages and sex.[16] And, although none of the studies identified examined the action of the child as a risk factor, one study found that a child crossing a road was 2.8 times more likely to be severely injured than a child standing on the road at the time of the injury.[28]

In summary, child risk factors are, in descending order, age (up to 7 times), behaviour (up to 3 times), race (up to 2.9 times) and sex (up to 2.8 times).

SOCIAL AND CULTURAL RISK FACTORS
Social and cultural risk factors include SES, crowding characteristics of mother, family environment and family stress.

Socioeconomic status
A number of studies examined SES[11 12 14 15 16 20 21] and most reported that children of lower SES were at higher risk for pedestrian injury.[12 14 15 20 21] American children without health insurance were 2.4 times more likely to be injured than insured children.[14] Moreover, those from families earning less than $20 000/year were seven times more likely to be injured than those from families earning more than $30 000/year.[15] Ecological studies echo these results.[22–25] Children living in lower income neighbourhoods were 3.5 to 5.7 times more likely to be injured,[22 25] while SES and other income proxy variables (mobility or living in low SES neighbourhood) were found to account for 28% of the variability in injury rate, second only to demographics.[24]

Crowding
Children from homes with three or more children in the family were 3.4 times more likely to be injured than those from homes with two or fewer children.[11] Other studies show a range of 1.3 to 2.2 times greater likelihood of injury for children living in crowded homes.[16 17 20 21] One ecological study found crowding to account for 10% of the variability in injury rate.[24]

Mother
Mothers of injured children were more likely to be younger,[20] less educated[17] (2 times), hospitalized in the past (2.5 times),[21] and working[21] (2.5 times). Two studies, however, found that mother's working status was not statistically significant.[16 17] One ecological study also found a correlation (r=0.46) between single mother status and injury rate.[23]

Family environment
The injured child's parents were three times less likely to practice preventive behaviours,[17] 2.6 times less likely to provide good supervision,[17] and were quicker to discontinue child supervision (two years sooner).[20] A history of accidents was 1.6 times more likely in the family of the injured child.[17]

Family stress
Pless *et al* found that for injured British children, there was a higher likelihood of family problems and state guardianship in a sex and age subgroup analysis.[16] Backett and Johnston found that family illness was 2.3 times more likely in families of injured children,[21] and Read *et al* noted that injured children were more likely to miss school due to 'family responsibilities and truancy'.[20] Family stress, however was not found to be significant in a study of injured children in Montreal.[17]

In summary, social and cultural risk factors that increase the likelihood of child pedestrian injuries are, in descending order, income (up to 7 times), crowding (up to 3.4 times), preventive behaviours (up to 3 times), mother's working status and history of hospitalization (both up to 2.5 times), illness in the family (2.3 times), and mother's education (2.3 times).

PHYSICAL ENVIRONMENT RISK FACTORS
Physical environment risk factors include time of day, day and month, weather and lighting, road conditions, number of traffic lanes, location on the road, speed limit, volume of traffic, play areas, and neighbourhood.

Time of day
Jonah and Engel found that per hour spent outside, children were 2.6 times more likely to be injured between 3 pm and 5 pm and 2.7 times more likely to be injured between 6 pm and 9 pm[18] than before 3 pm. Severe injuries were more likely to occur at the beginning or end of the day. One study reported that children injured after 7 pm were almost twice as likely to be severely injured than those injured before 9 am.[27] Another study found that in comparison with children injured between 12 pm and 3 pm, those injured between 3 pm and 6 pm were 6.5 times more likely to be severely injured, and 22.3 times more likely to be severely injured between 6 am and 9 am.[28]

Day and month
Day and month were not found to be correlated with child pedestrian injuries.[27]

Weather and lighting
Children were 2.3 times more likely to be injured during rainy weather than clear weather and also 2.3 times more likely to be injured during periods of darkness than during daylight hours.[18]

Road
The condition and classification of the road was not examined as a risk factor for child pedestrian injuries, but, when it was examined as a predictor of severe injury,[27 28] only road classification was significant. Children were 2.9 times more likely to be severely injured on main roads than on urban, unclassified roads.[27]

Lanes
Children were 2.1 times more likely to be injured on roads with more than two lanes than on roads with two or fewer lanes.[25]

Location on the road
Being on the road put a child at higher risk (3.7 times) of a severe injury than being off the road,[27] as did being on the third or fourth lane (4.2 times).[28]

Speed limit
Two studies found that children were more likely to be injured as vehicle speed increased.[13 15] One study reported that children were 3.2 times more likely to be injured when mean vehicle speed ranged from 40 to 49 kph compared with less than 40 kph.[13] A second study found that children were 3.2 and 6.0 times more likely to be injured when posted speeds were 45 to 55 kph, and greater than 63 kph respectively, compared with when the posted speed was less than 40 kph.[15]

Volume
The volume of vehicles per street was also directly correlated with injury likelihood.[13 15] Compared with streets with less than 250 vehicles per hour, children on streets with 250–499, 500–749, and greater than 750 vehicles per hour, were 6.3, 7.4, and 13.0 times more likely to be injured, respectively.[13]

Play areas
Children not having play areas are 2.3 to 5.3 times more likely to be injured than those with paly areas.[15 21] When compared with a fenced play area, an unfenced play area increases the likelihood of a child pedestrian injury by 1.3 to 3.5 times.[11 15 21] Children playing in areas with a shared driveway were 3.2 times more likely to be injured.[11] When curb side street parking exceeds 10%, children are at a 3.4 times higher risk of injury.[13]

Neighbourhood
Children are 2.6 times more likely to be injured on streets with predominantly rental units[11] and 5.5 times more likely on streets with apartments and condominiums.[15] Read *et al* also found living around multidwelling apartments to be a risk factor.[20] Housing density was identified as the most important risk factor in one ecological study[23] (a correlation of 0.72 with the mean number of children per acre and 0.48 with the mean number of occupied units per acre). Pitt *et al*, when looking at severely injured children, found those living in apartment zones were less likely to be severely injured compared with those living in residential neighbourhoods.[28]

In summary, physical environment risk factors that increase the likelihood for child pedestrian injuries are, in descending order, volume of traffic (13 times), speed limit (6.0 times), predominant type of dwelling (up to 5.5 times), absence of play area (5.3 times), location on road (4.2 times), protection of play area (3.5 times), proportion of curb side parking (3.4 times), street mean vehicle speed (3.3 times), shared driveway (3.2 times), type of road (2.9 times), time of day (up to 2.7 times), weather and lighting (up to 2.3 times).

DRIVER RISK FACTORS
Few studies here examined risk factors for drivers in child pedestrian injuries. Pitt *et al* found that when the driver did not attempt to avoid the child, the child was 25.2 times more likely to be severely injured. Furthermore, in comparison with children hit at 10–19 mph, children hit at 30–39 and 40–65 mph were 7.2 and 30.7 times more likely to be severely injured, respectively.[27] No driver risk factors have been identified for incidence of child pedestrian injuries.

Discussion
This paper, which reviewed 18 analytical studies, identified risk factors for child pedestrian injuries from three of four categories. None of the studies examined driver characteristics as a risk factor of injuries. Based on the magnitude and level of significance of the potential risk factors, the three most important risk factors come from three separate categories: (i) physical environment—high volume of traffic, (ii) social and cultural—lower income, and (iii) child—younger age. Most of the remaining significant risk factors were related to the physical environment: higher speed limits, absence of play areas, predominantly apartment and condominium zoning, lack of protection of play area, high proportion of curbside parking, crowding, high mean vehicle speed, shared driveway, risky behaviour, and lack of preventive behaviours.

Risk factors for severe injuries were slightly different. These studies did not identify any significant social or cultural factors but did identify driver risk factors. Overall, young boys (ages 0 to 4), native children, and children injured in the morning or in the afternoon were more likely to be severely injured. Furthermore, children on a main road, standing or crossing, and at the time of the injury, on the third or fourth lane, were at highest risk of being gravely injured. Mention should also be made regarding the importance of the speed of the involved vehicle[28] (7.2 times more likely at 30–39 mph and 30.7 times at 40–65 mph when compared with vehicles travelling at less than 30 mph) and of the driver action[27] (25.2 times more likely for no action when compared with braking or steering away). Time of injury also put a child at higher risk in one study[28] (6.5 times more likely from 3 to 6 pm and 22.3 times for 6 to 9 am, in comparison with injuries at 1 to 3 pm). Living in an apartment zone, however, protected a child from a severe injury.

IMPLICATIONS

This review of analytical studies underlines the large number and the variable importance of risk factors for child pedestrian injuries. There are a number of plausible explanations for this. First, the studies were international and thus regional variations in urban engineering, education, or behaviour could account for some of the variation. Second, no single study examined all the variables. The closest was the study of Pitt *et al* but it only examined predictors for severe injuries.[28] Third, only five studies adjusted for age, sex, and SES.[11 13 14 15 17] The relative importance of individual risk factors may be distorted in studies that did not adjust for potential confounding factors. Fourth, this review included a number of study designs, each with their own strengths and weaknesses. Any of these could have contributed to the relative importance of the identified risk factor. Fifth, some of the variability in the findings may be due to the methodologic quality of the studies. Finally, as underlined by Haddon's model of injury causation and prevention,[54] injuries are complex events with many risk factors. The injury to a pedestrian, ultimately the result of a transfer of energy from the vehicle to the pedestrian, may be influenced by the triad of host (the characteristics of the child susceptible to injury), agent (the means by which the child is injured), or the environment (physical and social cultural) in which the injury occurs. In this model, each of these characteristics encompass three phases: before the event, event, and after the event.

Faced with so many possible risk factors, of varying importance, what are the implications for prevention? Is there enough evidence about the etiology of these injuries for the introduction of control measures? What level of evidence is enough for intervention?

The best level of evidence is the intervention study, with the most valid being the randomized control trial. Such a study identifies risk factors by exposing children randomly to interventions, such as education programs, and seeing whether those exposed are at higher or lower risk for injury than those not exposed to that factor. One systematic review was identified that exclusively reviewed interventions aimed at reducing child pedestrian injuries.[9] This review included studies with a control group, where the intervention was educational, legislative, or environmental, and the outcome was the incidence or severity of injuries, mortality, or behavioural changes. All four studies identified were educational interventions (table 5).[55–58] A meta-analysis of these educational interventions found a statistically significant reduction of 33% in the rate of injuries or frequency of dangerous pedestrian behaviour. This benefit was, however, played down by Klassen because of the known tendency to publish studies that have positive findings (that is publication bias).

The next level of evidence available to elucidate the etiology of injury is the observational study. This paper reviewed 18 such studies and found numerous risk factors in three of the four risk factor categories. In order of importance they were: high volume of traffic, lower income, younger age. Next came higher speed limits, absence of play area, predominantly apartment and condominium zoning, lack of protection of play area, high proportion of curbside parking, high mean vehicle speed, crowding, shared driveway, risky behaviour, and lack of preventive behaviours.

Having selected studies of higher methodologic quality (observational studies as opposed to descriptive studies) in our search for risk factors, what strategies for prevention should be chosen? One approach, suggested in the past,[43] and reflecting the multifactorial causality of injuries, is a multipronged strategy that includes education, legislation, and environmental modifications. Another strategy, would see the directions for intervention refined by the distinction between *directly* and *indirectly* modifiable risk factors. *A directly modifiable risk factor* is one that can be affected directly by an intervention. For example, decreased speed limits, speed bumps, stop signals, and other traffic calming measures, would directly reduce vehicle speed and thus reduce or eliminate speed as a risk factor. *Indirectly modifiable risk factors* are those that are difficult, not feasible, or impossible to modify such as age and sex.

The implications for prevention can then be determined by revisiting each category of risk factor. Starting with the child, three of the four most significant risk factors (that is sex, age, and race) are indirectly modifiable. The only directly modifiable one is behaviour (with up to a three times increase in risk). This could be modified by means of education. And although sex, age, and race are not modifiable, an intervention such as education could be tailored to those at highest risk.

Of the social and cultural risk factors, preventive behaviour is the only directly (that is, feasible) modifiable risk factor. This could be affected by education targeted at parents, perhaps by community interventions or physicians. The other risk factors are indirectly modifiable (SES, crowding, mother's working status, history of hospitalization, illness in the family, and mother's education) and thus difficult to change but again interventions can be tailored to those at greatest risk.

The significant physical environment risk factors, on the other hand, are mostly directly modifiable. They include volume of traffic, speed limit, absence of play area, location on road, protection of play area, proportion of curbside parking, mean vehicle speed, and shared driveway. This review found the environmental risk factors to have the greatest magnitude of risk associated with them (other than age and SES). This combination of important and modifiable risk factors, might explain why Denmark and Sweden, jurisdictions with the largest decreases in mortality due to child pedestrian injuries and the lowest pedestrian injury rates, have focused their attention to modifying environmental risk factors.[59 60]

LIMITATIONS

There were several limitations to our review. One limitation was that our search was not systematic in that we used only one database (MEDLINE) and limited our search to the last 10 years. The search was improved, however, by hand searching the reference lists of all retrieved articles, three recent systematic reviews, and the personal database of the author of one of the review papers. As well, a number of experts in the field were contacted. These additional strategies expanded our search well beyond the MEDLINE database and specified time frame and included some unpublished literature. We were also limited in our ability to include foreign language articles and retrieve some of the government documents, conference proceedings, and unpublished papers. However, the inclusion of additional studies would not likely change the factors identified, or the magnitude of risk found.

The reviewers were not blinded to the source or results of the studies. This may have introduced a bias in the assessment of each study but, the criteria for selection were objective enough to minimize this problem.

The decision to include ecological studies might be seen as weakening the strength of the review. However, although they do not provide information on risk factors for an individual, ecological studies offer essential information on risk factors at the community level.

Not assessing the validity of each article included in this review, using a pretested quality assessment instrument, may also be considered a limitation. However, we were concerned that the application of validity criteria would exclude several studies, especially the earlier ones, because they failed to provide explicit details about their methodology and not because they were poor quality studies. We decided *a priori* to exclude all studies without a comparison group, that is descriptive studies. We felt that for the purpose of identifying potential risk factors for injury, the inclusion of a comparison group was an appropriate cut off point for methodologic quality. This paper therefore summarizes only the findings from identified analytic studies.

The variables identified as potential risk factors were extracted primarily by one author and this may have lead to a bias in the summary of the studies. However, the variables extracted in this review not only include significant but non-significant findings.

Finally, it should be noted that the relative importance of potential risk factors identified in this review was based on the magnitude of relative risk estimates and level of significance. This provides useful information in judging causality. Once causality is assumed, however, the implications for prevention depend on population attributable risks. For example, a weak but prevalent risk factor may be a more appropriate target for intervention than a strong risk factor that was rare.

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Driver, 10, kills mother in Kansas

A women who allowed her 10 year old son to back the family car down the driveway stumbled while directing the boy and was fatally run down when he stepped on the gas pedal instead of the brake. The 28 year old accident victim died at the scene. The boy was unhurt. Witnesses said the woman's son and a friend wanted to play basketball in the driveway, but the car was in the way. The boy at first resisted his mother's wish that he move the car, but then agreed to try. While the mother stood behind the car, helping guide the manoeuvre, she stumbled after walking backwards. The boy then apparently panicked with his foot on the gas and backed over his mother.

Editor's note: Anara Guard, who contributed this item, commented that this horror story struck her for a number of reasons: the age of the mother when she had him (did she ever have any parenting education?), the fact that the boy was loathe to attempt this driving stunt in the first place, and the fact that the report claims that she 'allowed' him to drive when it actually sounds like she persuaded him to do so!