Effect of environmental factors on risk of injury of child pedestrians by motor vehicles: a case-control study

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Abstract

***Objective*—To identify and assess contribution of environmental risk factors for injury of child pedestrians by motor vehicles.**

***Design*—Community based case-control study. Environmental characteristics of sites of child pedestrian injury were compared with the environmental characteristics of selected comparison sites. Each comparison site was the same distance and direction from home of control child as was the injury site from home of relevant case child. Two control sites were selected for each injury site.**

***Setting*—Auckland region of New Zealand.**

***Subjects*—Cases were 190 child pedestrians aged <15 who were killed or hospitalised after collision with a motor vehicle on a public road during two years and two months. Controls were 380 children randomly sampled from population and frequency matched for age and sex.**

***Main outcome measures*—Traffic volume and speed and level of parking on curbs at injury sites and comparison sites.**

***Results*—Risk of injury of child pedestrians was strongly associated with traffic volume: risk of injury at sites with highest traffic volumes was 14 times greater than that at least busy sites (odds ratio 14·30; 95% confidence interval 6·98 to 29·20), and risk increased with increasing traffic volume. High density of curb parking was also associated with increased risk (odds ratio 8·12; 3·32 to 19·90). Risk was increased at sites with mean speeds over 40 km/h (odds ratio 2·68; 1·26 to 5·69), although risk did not increase further with increasing speed.**

***Conclusion*—Reducing traffic volume in urban areas could significantly reduce rates of child pedestrian injury. Restricting curb parking may also be effective.**

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Introduction

Injury of pedestrians by motor vehicles is an important cause of childhood mortality and morbidity.[1 2] In New Zealand mortality and hospital morbidity for children aged 0-14 years are 3·6/100 000 a year and 49·6/100 000 a year respectively.[3] Among children aged over 1 year in New Zealand, pedestrian injury by motor vehicles accounts for more than twice as many deaths as does leukaemia (the leading childhood malignancy), four times as many as does asthma, and five times as many as do all infectious diseases combined.[3] Pedestrian injuries are a leading cause of admission to paediatric intensive care facilities. In New Zealand 13% of all hospitalised injured child pedestrians require intensive care facilities, and pedestrian injuries comprise 34% of all admissions to paediatric intensive care for trauma.[4] Between 60% and 80% of these children have severe brain injuries and are likely to experience long term disability.[4]

In Britain, New Zealand, and the United States education of pedestrians has been the main strategy to prevent injury of child pedestrians. There is, however, little evidence to support this approach,[5] and few child pedestrian education programmes have been shown to reduce injury rates.[6] In contrast, countries such as Denmark and Sweden, which have experienced large decreases in mortality of child pedestrians, have placed much greater emphasis on modification of the urban traffic environment.[7] The purpose of this case-control study was to identify and assess the contribution of a number of potentially modifiable environmental risk factors for injury of child pedestrians.

Subjects and methods

SUBJECTS

Cases were all children aged under 15 who were normally resident in the Auckland region and who were killed or admitted to hospital as a result of being hit by a motor vehicle while on foot on a public road between 1 January 1992 and 1 March 1994. The circumstances of these injuries have been described in detail elsewhere.[8] The Auckland region has a predominantly urban population of 936 981, of whom about 213 177 are aged under 15.[9] Children injured in residential driveways and car parks were excluded from this study because these are an aetiologically distinct group of pedestrian injuries for which the risk factors examined in this study would not be relevant. Driveway pedestrian injuries typically involve very young children run over by a vehicle backing out of the driveway.[10] Risk factors for driveway pedestrian injuries have been examined elsewhere.[11]

Fatalities were identified by regular surveillance of the records of the coroner's pathologist. In Auckland all children whose deaths have resulted from injury are subject to a coroner's postmortem. Children who were admitted to hospital were identified through a monitoring system established at both of the hospitals in the region which admit injured children. Monitoring required daily inspection of the case notes of all children admitted for the treatment of an injury.

Two controls were selected for each case and were frequently matched on sex and age (ages <5, 5-9, and 10-14). Controls for injured children of school age were selected by first randomly selecting a school from a list of all schools in the study region, with a sampling probability in proportion to the number of children on the school roll. The selected school was then visited by the study staff, who randomly selected a child from the school roll.

Controls for children of preschool age were selected by initially selecting a schoolchild using the method described above. Then, with the street address of the selected schoolchild as the starting point, homes were visited successively in a predetermined direction until a home with a preschool child was found. The parents of this child were provided with information about the study and invited to participate. If a home was visited when the occupants were out, the neighbours were contacted and asked if a preschool child lived in the selected home. If so, repeated calls were made, at different times of the day, until either the family of the eligible control was contacted or four separate visits were made, in which case a non-response was recorded and the next household was visited.

After each subject was identified, an interview was arranged with one or both parents. Parents of cases and controls completed an interviewer administered questionnaire which included questions on sociodemographic characteristics. Socioeconomic position was classified according to the New Zealand based Elley Irving scale.[12] Both maternal and paternal occupations were classified, with the higher level of the two being chosen as the socioeconomic position for the child. If neither parent had undertaken paid employment, the child was classified as "other" and included with the lowest socioeconomic group.

MEASUREMENT OF TRAFFIC ENVIRONMENT

For each case, the exact location of the accident was determined during parental interview or from police records if the location was unknown to the parents. These sites constituted the case sites for case-control comparison. The control site for a given case site was the roadway location the same distance and direction from the home of the control child as was the case site from the home of the case child. These sites were determined from detailed maps of the study region. Two control sites were selected for each case site. Thus, for a child injured in the road immediately in front of the home, the two control sites for comparison of environmental characteristics were the roads immediately in front of the homes of the two matched controls.

A three hour profile of bidirectional traffic volume and vehicle speed was measured at case and control sites with traffic recorders positioned as near as possible to the site. If the case site was an intersection traffic volume and speed on the street that the vehicle was travelling along immediately before collision was measured. For control sites at intersections, one of the intersecting streets was randomly selected. For cases, measurements were made on the same day of the week and at the same time of the day as when the accident occurred, but one week later. A pilot study had shown that measurements of volume and speed made one week apart corresponded closely, suggesting that measurements made one week later were likely to provide a reasonably accurate indication of the traffic conditions at the time of the accident.[8] For controls, measurements were made on the same day of the week and at the same time of the day as the accident of the case to which the control was matched. The density of parking on the street was determined by measuring the proportion of the curb that was parked on over a 100 metre stretch on both sides of the road. The variable "curb parked" was constructed by averaging the percentage of the curb that was parked on both sides.

STATISTICAL ANALYSIS

Relative risks were estimated by calculation of odds ratios. Analyses were conducted using conditional logistic regression for matched data which estimated odds ratios and 95% confidence intervals. Univariate and adjusted odds ratios were calculated for sociodemographic variables and for variables related to the traffic environment. In the estimation of adjusted odds ratios, variables included in the multivariate model were age, sex, and all other variables. After all cases and their matched controls had been analysed, separate analyses were conducted of the subgroup of cases injured within 500 metres of their home and their matched controls.

Results

A total of 265 injured child pedestrians were identified by the surveillance system over the study period, 12 of whom were identified during surveillance at the coroner's office. However, this second figure may have underestimated the total number of child pedestrian deaths since some children admitted to hospital may subsequently have died. Of the 265 children identified, 196 (74%) were injured on public roads. The parents of 190 of these children agreed to participate in the study, a response rate of 97%. Two controls were selected for each participating case, giving a total of 380 controls. In order to enrol these 380 controls, 381 parents were invited to participate, a response rate of 99·7%. Table I gives the age and sex distribution of the cases and controls. As expected from the frequency matching, the age and sex distribution of the controls was similar to that of the cases.

TABLE I—*Age and sex distribution for cases and controls. Values are numbers (percentages)*

	Cases (n=190)		Controls (n=380)	
Age (years)	Male	Female	Male	Female
1-4	27 (14)	10 (05)	40 (11)	27 (07)
5-9	61 (32)	30 (16)	130 (34)	71 (19)
10-14	30 (16)	32 (17)	63 (17)	49 (13)

Table II shows the odds ratios for sociodemographic variables and for variables related to the traffic environment. In univariate analyses there was an inverse association between socioeconomic position and the risk of child pedestrian injury; the risk of injury for children in the lowest socioeconomic stratum was over twice that of children in the reference category. Maori and Pacific Islander children were also at increased risk, with a risk of injury over twice that of children in the reference category. Children from families without access to a car were also at significantly increased risk. There was a strong association between traffic volume and the risk of child pedestrian injury; a traffic volume greater than 750 vehicles an hour was associated with an odds ratio of 12·50 (95% confidence interval 6·97 to 22·50), and there was a steady increase in the odds ratio with increasing traffic volume. Sites with a mean vehicle speed greater than 40 km/h were associated with a significantly increased risk, although there was little increase in risk over exposure categories. There was a significantly increased risk at sites where more than 10% of the curb was parked (odds ratio 5·33 (2·88 to 9·89)).

For the sociodemographic variables, adjusting for potential confounding factors had the effect of attenuating the magnitude of the odds ratios. For the variables related to the traffic environment adjusting

TABLE II—*Univariate and adjusted odds ratios for risk of injury of child pedestrian by sociodemographic variables and variables related to traffic environment*

	Odds ratio (95% confidence interval)	
Variable	Univariate	Adjusted
Socioeconomic position:		
I, II, and III	1	1
IV and V	1·32 (0·81 to 2·15)	1·81 (0·87 to 3·74)
VI and others	2·32 (1·40 to 3·84)	1·56 (0·68 to 3·56)
Ethnic group:		
Maori	2·26 (1·41 to 3·63)	1·87 (0·98 to 3·58)
Pacific Islander	2·66 (1·71 to 4·13)	1·63 (0·83 to 3·20)
Other	1	1
Access to car:		
No	2·05 (1·36 to 3·10)	1·97 (1·06 to 3·66)
Yes	1	1
Traffic volume (No of vehicles/h):		
<250	1	1
250-499	3·90 (2·04 to 7·44)	4·52 (2·04 to 9·98)
500-749	6·55 (3·18 to 13·50)	7·29 (3·09 to 17·20)
≥750	12·50 (6·97 to 22·50)	14·30 (6·98 to 29·20)
Mean speed (km/h):		
<40	1	1
40-49	1·84 (1·10 to 3·07)	2·68 (1·26 to 5·69)
≥50	1·88 (1·16 to 3·04)	1·26 (0·60 to 2·66)
Curb parked (%):		
<5	1	1
5-9	1·22 (0·63 to 2·38)	1·93 (0·79 to 4·69)
>10	5·33 (2·88 to 9·89)	8·12 (3·32 to 19·90)

for potential confounding factors increased the magnitude of the odds ratios. There were particularly strong associations between risk of pedestrian injury and high traffic volume and a high density of curb parking.

Table III shows univariate and adjusted odds ratios for variables related to the traffic environment for the 118 children injured within 500 metres of their homes and their matched controls. Variables included in the multivariate model were each of the other two traffic environment variables. In both univariate and multivariate analyses there were strong risks associated with traffic volume. The risk of injury for children living in neighbourhoods with the highest traffic volumes was 13 times that of children in the least busy neighbourhoods (odds ratio 13·00 (5·58 to 30·50)).

TABLE III—*Univariate and adjusted odds ratios for risk of injury of child pedestrians within 500 metres of their home by variables related to traffic environment*

Variable	Odds ratio (95% confidence interval)	
	Univariate	Adjusted
Traffic volume (No of vehicles/h):		
<250	1	1
250-499	5·40 (2·31 to 12·60)	6·32 (2·43 to 16·40)
500-749	8·52 (3·34 to 21·70)	7·38 (2·70 to 20·20)
≥750	11·60 (5·51 to 24·50)	13·00 (5·58 to 30·50)
Mean speed (km/h):		
<40	1	1
40-49	2·91 (1·36 to 6·22)	3·22 (1·30 to 7·98)
≥50	4·44 (2·12 to 9·27)	2·23 (0·89 to 5·57)
Curb parked (%):		
<5	1	1
5-9	1·15 (0·53 to 2·48)	1·58 (0·60 to 4·12)
≥10	2·90 (1·29 to 6·49)	3·37 (1·17 to 9·74)

Discussion

This study identified potentially modifiable environmental risk factors for injury of child pedestrians. Particularly strong associations were found between risk of pedestrian injury and high traffic volume. The risk of injury for children living in neighbourhoods with the highest traffic volumes was 13 times that of children living in the least busy areas. A high density of parked vehicles was also associated with a greatly increased risk.

Although it is possible that a small number of cases of pedestrian injury were missed by our surveillance system, incomplete ascertainment of cases would only introduce bias if the prevalence of exposure to risk factors among those included was different from that among those not included. Since there is no reason to suspect this, incomplete ascertainment is unlikely to have biased our results. In addition response rates for both cases (97%) and controls (99%) were high, so that, even if the exposure prevalence among non-respondents was different from that among respondents, no significant bias would be expected.

The choice of an appropriate site for comparison with the injury site is an important methodological issue in studies such as ours. For children injured in their street of residence, the most logical comparison site would be the streets of residence of the control children. Our method of selecting control sites reflects this but also covers selection of comparison sites for accidents that occurred away from the injured children's homes.

TRAFFIC VOLUME

It is possible that more children cross roads at sites where there are high traffic volumes so that the risks associated with high traffic volume are confounded by the number of children crossing. For example, shopping areas may have high traffic volumes and may also be sites where children make more road crossings. However, it is also possible that the converse is true, that children cross quiet streets more often and may even choose to play in quiet streets. Restricting the analysis to the immediate neighbourhoods of cases and controls would be expected to limit the extent to which children's road crossing varies. Nevertheless, when our analysis was limited to children injured within 500 metres of their home and their matched controls, there was still a substantially elevated risk for children living in neighbourhoods with high traffic volumes.

TRAFFIC SPEED

The amount of road crossing may also have confounded the association with vehicle speed. This might explain our finding that the risks associated with vehicle speed were highest in the middle speed category. Fast roads may be crossed less frequently because they are perceived as being dangerous. Because of the method of selection of controls in this study, fast roads may have been selected as control sites, but if they were crossed less frequently they would be less likely to become case sites. The risk estimates for high vehicle speed in this study might therefore be underestimates.

CURB PARKING

Our results also suggest that a high density of parking on streets increases the risk of child pedestrian injury. Parked vehicles may increase risk by obscuring drivers' views of children as they start to cross a road.[13] Our study provides empirical support for the proposition that curb parking should be restricted at certain crossing locations.[2]

COMPARISON WITH OTHER STUDIES

The strong associations we found between the risk of child pedestrian injury and traffic volume are consistent with the results of a North American case-control study, although the magnitude of the risks we obtained was much greater. Mueller *et al* obtained an adjusted odds ratio of 3·1 (95% confidence interval 0·9 to 10·8) for neighbourhoods with the highest traffic volumes.[14] A potential limitation of Mueller's study, however, was that the environmental characteristics at and surrounding the residences of cases and controls were compared, even though only 34% of children were injured in the street where they lived. As the authors acknowledged, this might have led to underestimation of the risks associated with high traffic volume. A further limitation was the use of a 24 hour period of measurement of traffic volume. There is evidence that this may have resulted in an underestimation of the risks associated with traffic volume.[15]

Our results are also consistent with the available ecological evidence. The New Zealand government's restrictions on car use after the 1974 energy crisis were associated with a 46% reduction in child pedestrian mortality, suggesting that traffic volume is a major determinant of the child pedestrian death rate.[16]

CONCLUSION

Our results provide a strong argument for measures to reduce traffic volumes in urban areas in order to prevent child pedestrian injuries. Restricting curb parking at specific crossing points may also be an effective approach. Measures might include traffic management strategies that divert traffic away from residential neighbourhoods and neighbourhood traffic calming schemes that reduce the volume of traffic on residential streets.[17,18] Targeting the implementation of such schemes to the most socioeconomically disadvantaged areas would probably greatly increase the cost effectiveness of this approach.[19,20] Alternatively, the volume of traffic throughout the entire road network might be reduced by introducing transport policies that encouraged a shift from private cars to public transport for longer journeys and to cycling and

Key messages

- Collisions between motor vehicles and child pedestrians are a leading cause of child deaths
- This study showed a strong association between increasing risk of injury of child pedestrians and increasing traffic volume
- High density of curb parking was also associated with greatly increased risk of injury
- Transport policies that reduce traffic volumes in urban areas could substantially reduce rates of injury of child pedestrians
- Restricting curb parking at crossing points may also be effective at reducing risk

walking for shorter journeys. Children and their parents have traditionally been held responsible for the problem of child pedestrian safety.[21] Our results point to the responsibilities of government.

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Predictive value of human papillomavirus type for histological diagnosis of women with cervical cytological abnormalities

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In the past 10 years ablative treatment modalities for cervical intraepithelial neoplasia have been replaced by electrosurgical loop excision of the transformation zone in many centres. Gynaecologists who master the electrosurgical technique are inclined to treat without biopsy. Concern has been expressed that this leads to overtreatment, as cytological abnormalities may result from benign reactive changes.

The broad spectrum of different human papillomavirus types has recently been grouped on the basis of a phylogenetic or evolutionary tree. The main branches of this tree lead to specific groups of human papillomavirus types with similar tissue tropism and oncogenic potential. One of the main branches comprises type 16 and related viruses such as types 31 and 33. Human papillomavirus type 18 belongs to a separate main branch.[1]

We investigated whether analysis of human papillomavirus in cervical scrapes might help in the better selection of patients for loop electrosection at the first visit.

Present study

From 1 September 1988 to 1 September 1993 we surveyed patients who had either one cervical smear showing severe dyskaryosis (n=163) or two cervical smears showing mild or moderate dyskaryosis (n=157). The interval between two abnormal smears was a maximum of one year. The mean age of the patients was 34·8 (SD 8·0) years. Cervical scrapes were analysed for human papillomavirus by a general primer mediated polymerase chain reaction. Positive samples were examined for types 6, 11, 16, 18, 31, and 33 separately by means of type specific primers.[2] If none of these types could be detected the type remained unknown. Four weeks after the cervix had been scraped we took representative colposcopically directed biopsy samples of atypical epithelium. If cervical intraepithelial neoplasia of any grade was diagnosed we performed loop electrosection or cold knife conisation. Cervical neoplasia was classified according to the most severe grade found histologically.

In the group of 163 women with a severely dyskaryotic smear the prior probability of cervical intraepithelial neoplasia grade II or worse was 151/163 (92·6%). For our purpose this high prior probability signified that analysis of human papillomavirus was less useful in this patient category.

Results, comment, and conclusion

The table shows the human papillomavirus types detected in relation to the histological diagnoses in the 157 patients with two mildly or moderately dyskaryotic cervical smears. In this group the prior probability of cervical intraepithelial neoplasia grade II or worse was 91/157 (58·0%). When human papillomavirus type 16 was detected the (posterior) probability of cervical intraepithelial neoplasia grade II or worse was 36/45 (80·0%). Other investigators reported a similar finding.[3] When infections with viruses of the type 16 related phylogenetic branch were considered together, with the exclusion of mixed infections with types 6/11 or 18, the probability of cervical intraepithelial neoplasia grade II or worse was 51/62 (82·3%). Three of the 12 human papillomavirus positive patients without