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THE AUCKLAND CHILD PEDESTRIAN INJURY STUDY:
A Case-Control Study

by Ian Gray Roberts

A thesis submitted for the degree of Doctor of Philosophy at the University of Auckland, Auckland, New Zealand.

January 1994
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Pedestrian injuries are the leading cause of death in New Zealand children between the ages of one and fourteen years. Although child pedestrian mortality rates are declining, mortality rates in New Zealand are substantially higher than those of comparable motorised countries. For the children who survive pedestrian-motor vehicle collisions, the injuries are often particularly severe. Pedestrian injuries are a leading cause of severe brain injury in childhood, with high levels of long term disability. However, very little is known about the risk factors for child pedestrian injury and as a consequence there are few well established prevention strategies.

The Auckland Child Pedestrian Injury Study is a population based case-control study designed to identify and assess the contribution of potentially modifiable risk factors for pedestrian injuries in childhood. In particular the study was designed to examine the risks associated with traffic volume, vehicle speed, parked vehicles and the availability of safe areas for children’s play.

The study was conducted between 1 January 1992 and 1 November 1993. Cases were all children, younger than fifteen years, killed or hospitalised as a result of a pedestrian-motor vehicle collision in the Auckland region. Both motor vehicle traffic and motor vehicle non-traffic (driveway related) pedestrian injury cases were included. Controls were a random
sample of the child population. Two controls were selected for each traffic pedestrian injury case and three for each non-
traffic pedestrian injury case. Controls for school aged cases were randomly selected from school rolls. Controls for pre-
school cases were selected by first randomly selecting a school aged child and then, using the street address of this school aged child as the starting point, visiting homes until an eligible pre-school control child was found.

The parents of 600 children participated in the study, the parents of 200 cases and the parents of 400 controls. Of the 200 cases, 156 were injured on public roads and 38 were injured in residential driveways, the remaining 6 children were injured in car parks and public parks. The response rate in the case group was 97%, the response rate in the control group was 99%. Exposure information was collected by way of interviewer administered questionnaires and the direct measurement of environment factors.

High traffic volume is a major risk factor for child pedestrian injury. Children living in neighbourhoods with the highest traffic volumes had close to ten times the risk of pedestrian injury. There was a dose response relationship with a steady increase in the magnitude of the risk as traffic volume increased. Vehicle speed was also a strong risk factor for child pedestrian injury and may be particularly important in residential streets. Having a street with a mean vehicle
speed of over 40 kph within 500 metres of the home increased the risk of child pedestrian injury six fold.

A high density of on street parking was associated with a fourfold increase in risk of pedestrian injury. Children from homes without a fenced play area were at a significantly increased risk of pedestrian injury, although the prevalence of this risk factor in the Auckland population was very low. Children from homes where the play area was unfenced were at a significantly increased risk of injury, close to twice the risk of children from homes where the play area was fenced. For driveway related pedestrian injuries, children from homes where there is no fence separating the driveway from the play area had twice the risk of injury.

The Auckland Child Pedestrian Injury Study has provided, for the first time, information on the aetiology of child pedestrian injury in a large population based sample in New Zealand. In addition the study has provided the opportunity to examine a number of methodological issues in this comparatively new sphere of epidemiologic inquiry.
The study presented in this thesis was funded by the Health Research Council of New Zealand. Their support is gratefully acknowledged.

Robyn Norton, Director of the Injury Prevention Research Centre was the co-principal investigator and my principal supervisor. Had it not been for her tremendous drive to establish the Injury Prevention Research Centre this research project would never have been possible. I gratefully acknowledge her support and guidance throughout the conduct of the study. Rodney Jackson was my secondary supervisor. His enthusiasm for epidemiologic methods and willingness to discuss methodological problems were very much appreciated.

I was most fortunate to have a marvellous team of people working with me on this study. Binki Taua and Judy Rudd the research interviewers did a superb job, their commitment to the aims of this study was clearly evident throughout and is gratefully acknowledged. I would also particularly like to thank Trevor Lee Joe, the study civil engineer, who collected and double entered the all of the environmental data. His meticulous attention to detail was integral to the success of the study.

I would like to thank the ward clerks Pauline Whitehead, Cathie Connel, Mary Curtis and Carol Johnson for their help
in the identification of cases and Sergeant David Watson for help in the identification of sites of injury. I would also like to thank Auckland school principals for their assistance in the identification of controls.

A number of people were consulted during the planning stages of this study and I would like to thank Chic Cooper, Roger Dunn, Ian Hassall, Anne Kolbe and Liz Segedin for their input. I gratefully acknowledge Alistair Stewart who was particularly helpful in providing advice on statistical and computing issues. I would also like to thank Carolyn Coggan with whom I share an office, for continually pester me to get started on the writing.

Finally I would like to thank the parents who participated in the study and my wife Rhian and daughter Caitlin for putting up with me whilst I worked on this thesis.
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INTRODUCTION
CHAPTER 1: INTRODUCTION

1.1 Background to the study.

This thesis is based on the Auckland Child Pedestrian Injury Study, a population based case-control study, which was conducted in Auckland, New Zealand between January 1992 and November 1993. The primary objective of the study was to identify and assess the contribution of modifiable risk factors for pedestrian injuries in children.

In New Zealand children between the ages of one and fourteen years, pedestrian injuries are the leading cause of death (Roberts et al. 1992a). In 1987, there were 2.5 times more child pedestrian deaths than deaths from leukaemia, the leading childhood malignancy, four times more deaths than from asthma and five times more deaths than from all infectious diseases combined. For the children who survive a pedestrian-motor vehicle collision the injuries are particularly severe. Pedestrian injuries are the leading cause of paediatric trauma admission to intensive care facilities in Auckland (Roberts et al. 1991). Between 60% and 80% of these children have severe head injuries and are likely to experience long term disability. The effects on the families of such seriously injured children are equally profound, manifesting as behavioral problems in uninjured siblings and worsening of marital relationships.
Since 1967 child pedestrian injury mortality rates in New Zealand have fallen by approximately 9% for children aged 0-4 years and 24% for children aged 5-14 years (Roberts 1993 a). However these reductions are substantially lower than those observed in other comparable countries (Roberts 1993 a). Moreover most of the decline in the mortality rates took place in the mid seventies and there has been very little change in the child pedestrian mortality rate over the past decade. This suggests that pedestrian injuries will continue to represent a major child health problem unless efforts are directed towards prevention. However at present relatively little is known about risk factors for child pedestrian injury and consequently there are very few well established prevention strategies. Whilst international research would also be relevant to the New Zealand setting, worldwide there have been few controlled studies which have attempted to identify risk factors for child pedestrian injury.

In the absence of aetio logic information, the traditional approach to the prevention of child pedestrian injuries in New Zealand has been pedestrian skills training programmes. However, none of the programmes implemented in New Zealand and indeed very few programmes internationally, have ever been shown to reduce injury rates. In general however, countries which have experienced major decreases in child pedestrian mortality are distinguished by having placed relatively greater emphasis on environmentally based prevention strategies than on educationally based approaches (Roberts
Identification and quantification of the risks associated with potentially modifiable environmental risk factors was therefore a primary goal of the present study. This information would be valuable for the design of prevention strategies both in New Zealand and internationally.

Auckland provides an ideal setting for a study of risk factors for child pedestrian injury using a case-control design. The Auckland region has a predominantly urban population of 936,981 of whom 213,177 are under fifteen years (Department of Statistics 1991). All children in this population requiring hospital admission for the treatment of injuries are admitted to one of the two public hospitals in the region, thus providing relatively easy access to a large number of cases. Controls for the study were randomly selected from a sampling frame of all school children in the Auckland region. The same boundaries defined both the Auckland Area Health Board region and the school educational catchment area providing the potential for the conduct of a population based case-control study. A population based study has the advantage that the distribution of exposures in the controls can be readily extrapolated to the Auckland population for the calculation of attributable risk, which for the purposes of prevention is a more germane measure than an index of the strength of an association such as relative risk (Wacholder 1992).

Previous epidemiologic studies of childhood pedestrian injuries have been limited in the extent to which they are
able to address environmental factors because of the technical issues involved in the accurate measurement of environmental exposures such as traffic volumes and vehicle speeds. An important strength of the Auckland Child Pedestrian Injury Study was the collaboration between the disciplines of epidemiology and civil engineering which facilitated the provision of accurate exposure information on such environmental factors. These interdisciplinary links had already been established under the auspices of the University of Auckland Injury Prevention Research Centre.

The development and conduct of the Auckland Child Pedestrian Injury Study were supported by funding from the Accident Compensation Corporation (ACC) and the Health Research Council of New Zealand (HRC). During the development of the proposal to conduct a case-control study of child pedestrian injuries, the author was supported as an ACC Training Fellow. The pilot study was jointly funded by the ACC and the HRC with the main phase of data collection being funded entirely by the HRC.
LITERATURE REVIEW
2.1 Introduction.

The primary aim of the Auckland Child Pedestrian Injury Study was to identify and assess the contribution of potentially modifiable risk factors for pedestrian injury in children. In particular, the study aimed to examine the role of the environmental risk factors, traffic volume, vehicle speed, parked vehicles and the availability of safe areas for children's play. In this chapter an overview is presented of the descriptive epidemiology of child pedestrian injury, with particular emphasis on New Zealand data. This is followed by a critical review of previous analytical epidemiologic studies of childhood pedestrian injuries. Finally, the rationale for the emphasis in the present study on the identification of environmental risk factors is presented in detail.

2.2 Occurrence of child pedestrian injuries.

2.2.1 Patterns of pedestrian injury mortality and morbidity.

In New Zealand children between the ages one and fourteen years pedestrian injuries are the leading cause of death. In 1987, there were 2.5 more pedestrian deaths than deaths from leukaemia, the leading childhood malignancy, four times more deaths than from asthma and five times more deaths than from
all infectious diseases combined (Roberts et al 1992 a). Sex, age and ethnic specific child pedestrian mortality and hospital morbidity rates are shown in Tables 2.1 and 2.2 respectively. The data for these tables were obtained from the National Health Statistical Services (Roberts et al 1992 a). Boys account for 59.0% of all child pedestrian deaths with a fatality rate significantly higher than that for girls. They account for 62.6% of hospital discharges, a discharge rate approximately 50% higher than that for girls. The reasons for the higher pedestrian injury rates for boys however, are unknown. Howarth found that exposure to risk as pedestrians, in terms of numbers of roads crossed, was similar for boys and girls and suggested that the different rates may reflect sex determined differences in behaviour (Howarth et al 1974). The rate of hospitalisation was highest for children aged 5-9 years whereas the fatality rate was highest for the 0-4 age group. This is likely to reflect the higher case fatality rate for the younger children.

The rate of pedestrian injury hospitalisation for Maori children, was approximately three times that for non-Maori children. An Auckland study of admissions to the Department of Critical Care Medicine for child pedestrian injury, also found that the admission rate for Maori children was three times higher than that for non-Maori children (Roberts et al 1991). This suggests that the ethnic differences in hospitalisation rates are likely to reflect actual differences in injury occurrence rather than differential admission criteria. The
finding that pedestrian mortality rates differ little between non-Maori and Maori children is therefore surprising, but might reflect misclassification of ethnicity in mortality statistics, as has been reported previously (Graham et al 1989). In contrast there appears to be little misclassification of ethnicity in New Zealand hospital discharge statistics (Priest et al, in press). Several overseas studies have shown that the risk of pedestrian injury is inversely related to socioeconomic status, with poor children having a three times greater risk of pedestrian injury than the least poor (Pless et al 1987), (Dougherty et al 1990), (Office of Population Censuses and Surveys 1988). Since it is well documented that Maori are over-represented in the lower socioeconomic groups it is possible that the increased risk of pedestrian injury for Maori children is a reflection of socioeconomic factors.
Table 2.1 Fatal pedestrian injuries in children in New Zealand 1978 to 1987.

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>Per cent</th>
<th>Rate/100,000 population (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>177</td>
<td>59.0</td>
<td>4.2 (3.6,4.9)</td>
</tr>
<tr>
<td>Females</td>
<td>123</td>
<td>41.0</td>
<td>3.0 (2.4,3.5)</td>
</tr>
<tr>
<td>Age group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-4</td>
<td>136</td>
<td>45.3</td>
<td>5.3 (4.5,6.3)</td>
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<tr>
<td>5-9</td>
<td>114</td>
<td>38.0</td>
<td>4.1 (3.4,4.9)</td>
</tr>
<tr>
<td>10-14</td>
<td>50</td>
<td>16.7</td>
<td>1.7 (1.2,2.2)</td>
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<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Maori</td>
<td>256</td>
<td>85.3</td>
<td>3.5 (3.1,4.1)</td>
</tr>
<tr>
<td>Maori</td>
<td>44</td>
<td>14.7</td>
<td>4.1 (2.9,5.4)</td>
</tr>
<tr>
<td>Cause</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>MV Traffic</td>
<td>265</td>
<td>88.0</td>
<td>3.2 (2.8,3.6)</td>
</tr>
<tr>
<td>MV Non-Traffic</td>
<td>35</td>
<td>12.0</td>
<td>0.4 (0.3,0.6)</td>
</tr>
<tr>
<td>Year</td>
<td></td>
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</tr>
<tr>
<td>1978</td>
<td>35</td>
<td></td>
<td>3.9 (2.7,5.5)</td>
</tr>
<tr>
<td>1979</td>
<td>32</td>
<td></td>
<td>3.7 (2.5,5.2)</td>
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<tr>
<td>1980</td>
<td>34</td>
<td></td>
<td>4.0 (2.7,5.5)</td>
</tr>
<tr>
<td>1981</td>
<td>32</td>
<td></td>
<td>3.7 (2.6,5.3)</td>
</tr>
<tr>
<td>1982</td>
<td>21</td>
<td></td>
<td>2.5 (1.7,3.8)</td>
</tr>
<tr>
<td>1983</td>
<td>22</td>
<td></td>
<td>2.7 (1.7,4.0)</td>
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<tr>
<td>1984</td>
<td>32</td>
<td></td>
<td>3.9 (2.7,5.5)</td>
</tr>
<tr>
<td>1985</td>
<td>29</td>
<td></td>
<td>3.6 (2.3,5.2)</td>
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<tr>
<td>1986</td>
<td>29</td>
<td></td>
<td>3.6 (2.3,5.2)</td>
</tr>
<tr>
<td>1987</td>
<td>34</td>
<td></td>
<td>4.3 (2.9,6.0)</td>
</tr>
<tr>
<td>Total</td>
<td>300</td>
<td></td>
<td>Average 3.6 (3.2,4.0)</td>
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Table 2.2 Hospital discharges for pedestrian injury in children in New Zealand 1978 to 1987.

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>Per cent</th>
<th>Rate/100,000 population (95%CI)</th>
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<tr>
<td><strong>Sex</strong></td>
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<tr>
<td>Males</td>
<td>2572</td>
<td>62.6</td>
<td>60.6 (58.2, 62.9)</td>
</tr>
<tr>
<td>Females</td>
<td>1537</td>
<td>37.4</td>
<td>37.8 (36.0, 39.8)</td>
</tr>
<tr>
<td><strong>Age group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-4</td>
<td>1409</td>
<td>34.3</td>
<td>55.3 (52.5, 58.3)</td>
</tr>
<tr>
<td>5-9</td>
<td>1714</td>
<td>41.7</td>
<td>62.0 (59.0, 64.9)</td>
</tr>
<tr>
<td>10-14</td>
<td>987</td>
<td>24.0</td>
<td>32.9 (31.0, 35.1)</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
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<tr>
<td>Non-Maori</td>
<td>2914</td>
<td>70.9</td>
<td>40.3 (38.8, 41.8)</td>
</tr>
<tr>
<td>Maori</td>
<td>1196</td>
<td>29.1</td>
<td>110.3 (104.5, 117.1)</td>
</tr>
<tr>
<td><strong>Cause</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MV Traffic</td>
<td>3793</td>
<td>92.3</td>
<td>45.6 (44.2, 47.1)</td>
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<tr>
<td>MV Non-Traffic</td>
<td>316</td>
<td>7.7</td>
<td>3.8 (3.4, 4.2)</td>
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<tr>
<td><strong>Year</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td>464</td>
<td></td>
<td>52.4 (47.7, 57.3)</td>
</tr>
<tr>
<td>1979</td>
<td>416</td>
<td></td>
<td>48.0 (43.5, 52.8)</td>
</tr>
<tr>
<td>1980</td>
<td>478</td>
<td></td>
<td>56.2 (51.3, 61.5)</td>
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<tr>
<td>1981</td>
<td>380</td>
<td></td>
<td>45.2 (40.7, 50.0)</td>
</tr>
<tr>
<td>1982</td>
<td>395</td>
<td></td>
<td>47.4 (42.7, 52.2)</td>
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<tr>
<td>1983</td>
<td>362</td>
<td></td>
<td>43.8 (39.4, 48.5)</td>
</tr>
<tr>
<td>1984</td>
<td>486</td>
<td></td>
<td>59.4 (54.3, 64.9)</td>
</tr>
<tr>
<td>1985</td>
<td>375</td>
<td></td>
<td>46.4 (41.8, 50.1)</td>
</tr>
<tr>
<td>1986</td>
<td>399</td>
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<td>50.3 (45.5, 55.6)</td>
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<td>1987</td>
<td>355</td>
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<td>45.2 (40.6, 50.1)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4110</td>
<td></td>
<td>49.4 (47.9, 51.0)</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
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</tr>
</tbody>
</table>
A strong relationship between pedestrian injury morbidity and socioeconomic disadvantage has also been demonstrated in Auckland (Roberts et al 1992 b). In an ecologic analysis, undertaken by the author, child pedestrian injury morbidity rates were found to be strongly correlated with census area unit unemployment rates, which were used as an index of socioeconomic deprivation (Spearman rank correlation coefficient 0.53, p < 0.0001). This study also revealed distinct geographical variations in census area child pedestrian injury morbidity rates. Child pedestrian morbidity rates were above average in parts of the central urban area and South Auckland and were below average on the North Shore (Figure 2.1).
Figure 2.1 Standardised morbidity ratios for child pedestrian injuries in the Auckland region
The majority of pedestrian motor vehicle collisions occur on public roads and are classified as "motor vehicle traffic accidents" by the International Classification of Diseases (ICD9) E coding system (WHO 1977). The remainder are classified as "motor vehicle non-traffic accidents" and occur off public roads in locations such as car parks and residential driveways. Of the 300 child pedestrian deaths occurring in New Zealand between 1978 and 1987, 265 (88.3 per cent) were coded as traffic deaths (ICD9 E814.7) and 35 (11.7 per cent) were coded as non-traffic deaths (ICD9 E822.7). Over the same period there were 4,110 hospital discharges for child pedestrian injury of which 3,793 (92.3 per cent) were coded as traffic events and 316 (7.7 per cent) were coded as non-traffic events. However, there is evidence to suggest that Health Statistical Services data underestimate the proportion of pedestrian injuries that are non-traffic related. A study by the author found that close to half (48%) of all non-traffic pedestrian injury hospital admissions in the Auckland region had been misclassified as traffic pedestrian injuries (Roberts et al 1993 b). After correcting for misclassification, non-traffic injuries were found to account for 15.4% of all pedestrian injuries. It was also found in this study that 87% of non-traffic injury deaths and 93% of the injuries requiring hospitalisation occurred in residential driveways, most often involving a child run over by a reversing vehicle.
2.2.2 Trends in pedestrian injury mortality.

Trends in pedestrian injury mortality rates for children aged 0-4 and 5-14, for New Zealand, England and Wales, Denmark, Sweden, and the USA are shown in Figures 2.2 and 2.3 respectively (Roberts 1993a). For children aged 0-4 there are marked international differences in mortality rates, with New Zealand having the highest rates and Sweden the lowest. By comparison with Sweden in 1987 (0.3/100,000) the pedestrian mortality rate in New Zealand was 13.3 times higher (4.0/100,000). Between 1967 and 1987 pedestrian mortality rates for children younger than five years have declined in all five countries with a similar pattern of decline being observed throughout. There was a marked decline in the early to mid seventies, a slight increase following 1976 and a further major decline between 1978 and 1982. However since 1967 New Zealand has experienced both the smallest absolute reduction (0.4/100,000) and the smallest percentage reduction (9%) in mortality rates.

For children aged 5-14 years there are again conspicuous international differences in mortality rates. By comparison with Sweden in 1987 (1.2/100,000) the mortality rate in New Zealand was 2.1 times higher (2.5/100,000). Again there has been a decline in mortality rates since 1968, although the decline for children aged 5-14 years has been less pronounced than that for the 0-4 year age group. Between 1968 and 1987 the smallest absolute reduction in mortality rates was again
in New Zealand, a reduction of 0.8/100,000 representing a 24% reduction in mortality rates.
Figure 2.2

Child pedestrian mortality
(0-4 years)
*international trends*

![Graph showing trends in child pedestrian mortality from 1970 to 1990 for different countries: New Zealand, USA, England & Wales, Denmark, and Sweden.](image-url)
Figure 2.3

Child pedestrian mortality
(5-14 years)
international trends

Rate/100,000

Year

70 75 80 85 90

England & Wales
New Zealand
USA
Denmark
Sweden
2.3 Risk Factors for child pedestrian injuries.

William Haddon (1980) described injury causation in terms of the epidemiologic triad of host, agent and environment, suggesting that modification of any of these components has the potential to interrupt the causal sequence. Haddon’s triad also provides a valuable conceptual model for aetiology injury research. In this section, analytical epidemiologic studies which have examined the contribution of host, agent and environmental risk factors for child pedestrian injury are critically reviewed.

2.3.1 Host risk factors.

The contribution of host factors in child pedestrian-motor vehicle collisions has been examined in both cohort and case-control studies. Pless et al (1989 a) used data from the British National Child Development Longitudinal Study to examine the role of physical, developmental, educational, behavioral and family risk factors for traffic injury. The outcome in this study was all childhood traffic injuries requiring medical attention, although pedestrian injuries would have comprised the largest proportion of these injuries. Data were collected from parents, teachers and physicians on a birth cohort (born during one week in March 1958) of more than 16,000 children, when they were 7 and 11 years of age. The results were then related to traffic injuries occurring for the first time during each subsequent four year period.
Approximately 10% of the cohort was lost to follow up, with attrition being disproportionately greater for lower socioeconomic families. Although the relatively low loss to follow up is reassuring, it is surprising that no significant association between traffic injury and social class was found in this study. This may have been the result of the disproportionate loss to follow up of families in the lower socioeconomic groups. The strongest host risk factors identified in this study were fidgety, abnormal behaviour OR=1.4 (95%CI 1.1, 1.8), and three measures of familial disruption or disadvantage namely, household crowding OR=1.3 (95%CI 1.04, 1.60), family problems OR=1.2 (95%CI 1.00, 1.52) and being in the care of the local authority OR=1.4 (95%CI 1.01, 1.89). Overall, the most striking finding in this study was the paucity of strong host risk factors for traffic injury in children.

The lack of strong host risk factors (apart from age, sex and socioeconomic status) was also apparent in a case-control study of pedestrian and cycle injuries, conducted in Montreal (Pless et al 1989 b). If the concept of host is widened to include family, the strongest risk factors identified in this study were a low level of preventive behaviours OR=3.0 (95%CI 1.6, 5.6), a low level on a parental supervision index OR=2.6 (95%CI 1.5, 4.7) and history of accident in the family OR=1.6 (95%CI 1.1, 2.3). However the potential for recall bias is a serious threat to the validity of these results. In particular, guilt may have caused parents of injured children
to understate the degree to which they engaged in preventive behaviours and supervised their children. The presence of a behavioral problem, as assessed by the Child Behaviour Checklist score, was not associated with the risk of injury in this study.

In neither of the above studies were population attributable risks calculated. Since a weak risk factor, if highly prevalent may account for a large proportion of cases this information would be important for the design of preventive strategies. Nevertheless, since few of the host risk factors above are readily identifiable in child populations nor would they appear to be easily modifiable, the potential for the prevention of child pedestrian injuries through host interventions would appear to be limited.

2.3.2 Agent risk factors.

The identification of driver risk factors for child pedestrian-motor vehicle collisions has received scant attention in pedestrian injury research. To date, no controlled studies have been published which have considered driver characteristics. Several case series however, have suggested that driver negligence may be a factor in pedestrian motor vehicle collisions. Baker et al (1974) reviewed the police records of 182 fatally injured pedestrians (mostly adults) in the city of Baltimore and concluded that drivers were probably negligent in 46% of these cases. In Memphis,
Rivara and Barber (1985) considered the driver to be at fault in 21% of child pedestrian-motor vehicle collisions.

Studies which have addressed vehicle factors have largely been aimed at the identification of aspects of vehicle design that might influence the severity of injury sustained in a pedestrian-motor vehicle collision. Robertson (1990), in a cohort analysis compared front corner impact death rates (pedestrian deaths/100,000 years car use) for cars with sharp front corner designs and cars with smooth front corner designs. Sharp front corner designs were associated with a significantly increased risk of death RR=1.26 (95%CI 1.05, 1.50). That there was no increased risk of death for sharp front corner design cars for impacts other than frontal, provided evidence for the validity of the results. However the only study to examine the influence of vehicle design on injury severity during child pedestrian motor vehicle collisions was the Pedestrian Injury Causation Study which found that frontal design features had no effect on injury severity in children (Pitt et al 1990).

2.3.3 Environmental risk factors.

Traffic volume: At the ecological level there is some evidence that the volume of road traffic is a determinant of the child pedestrian mortality rate. A study undertaken by the author examined the relationship between the child pedestrian mortality rate and traffic volume in New Zealand between 1967
and 1987 (Roberts et al 1992 c). A 46.4% decline in the child pedestrian mortality rate occurred between 1975 and 1981, a period in which there was very little growth in traffic volume as a consequence of government restrictions on car use following the energy crisis. Poisson regression modelling supported a relationship between the mortality rate and traffic volume. A significant positive coefficient was derived for the traffic volume variable, suggesting that as volume increases child pedestrian mortality also tends to increase.

Although it has been suggested that higher traffic volumes are likely to be responsible for the increased risk of pedestrian injury for children living in poor neighbourhoods, only two controlled epidemiological studies have examined the association between high neighbourhood traffic volume and the risk of child pedestrian injury. The first was a case-control study of child pedestrian and cycle injuries conducted in Montreal in 1980 (Pless et al 1989 b). In this study, an environmental risk index was created from four items describing the parents assessment of traffic density and general safety. Children from neighbourhoods scoring the highest on this index had a three times greater risk of pedestrian or cycle injury than children from neighbourhoods with the lowest scores OR=3.4 (95%CI 2.0, 5.6). Cases in this study were 200 children seen in the city's two children's hospitals with pedestrian or cycle injuries that received a score of two or more on the Maximum Abbreviated Injury Severity Score. Controls were selected from patients treated
for medical problems in the same emergency rooms as the cases. However uncertainty as to whether the distribution of exposures in the controls is the same as that in a random sample of the study base is a major disadvantage of hospital based case-control studies. Nevertheless, arguably the major weakness of this study is that the exposure measure was a parental assessment of traffic density, with the ensuing potential for reporting bias. Parents whose children have been injured as pedestrians may understandably exaggerate the degree to which their neighbourhood is dangerous.

The second study to examine traffic volume as a risk factor for child pedestrian injury was a case-control study conducted by Mueller et al (1990). It was found that children living in neighbourhoods with the highest traffic volumes had three times the risk of pedestrian injury when compared with children living in the least busy areas OR=3.1 (95%CI 0.9, 10.8). Cases in this study comprised all children, in a defined geographic area, who were either killed or admitted to the regional trauma centre having been injured as pedestrians. Two age and sex matched control groups were selected. The first, a hospital based control group, was selected from children undergoing appendectomy at one of the region’s surgical facilities. The second, a population based control group, was selected by random digit dialling. One potential problem with the former control group is that although the hospital from which controls were selected was the largest in the region, the environmental characteristics of the
neighbourhoods it served might not have been representative of the study base. For the control group obtained by random digit dialling, incomplete telephone coverage, residences that can be reached by more than one number and non response would be the potential threats to validity. In particular, for exposures related to low telephone coverage such as socioeconomic status, it has been found that random digit dialling may result in substantial bias (Wacholder et al 1992).

A further potential methodological problem in this study concerns the traffic volume exposure data. Traffic volume data for case and comparison sites were obtained from the regional traffic engineering authority and were available for only 45% of the study sites. Analyses relating to traffic volume were therefore restricted to the 44 case-control sets for which these data were available. As a result the precision of the estimated odds ratios were low. More importantly however, since the sites for which data were available are likely to have been the more major routes, with higher traffic volumes, this data limitation may have introduced a significant degree of selection bias.

Second, the traffic volume exposure data used in this study were mean weekday traffic volumes for case and comparison sites. However the period of traffic volume aetiologically related to the occurrence of a child pedestrian motor vehicle collision is likely to be the traffic volume at the instant
the child enters the roadway, effectively an induction time of zero. A twenty four hour exposure measurement period would inevitably have included exposure information outside of the time window that is aetiollogically related to the outcome and therefore may represent a potent source of exposure misclassification bias (Roberts 1993 d).

Finally, because no site comparable to the injury site could be found for the control, the exposures for comparison in this study were those at or surrounding the children’s homes, whether or not this was the site of injury. However, when the characteristics of the collision sites were compared with those of the children’s neighbourhoods, it was found that collision sites had greater mean daily traffic volumes. As the authors acknowledged, the risk estimates obtained may therefore have underestimated the true risk of exposure to environments where there are high traffic volumes.

Vehicle speed: In some countries, Denmark and Sweden in particular, efforts to reduce vehicle speeds in residential areas have been a major focus of pedestrian injury prevention programmes (Kjemtrup et al 1992). Although these countries have significantly lower child pedestrian mortality rates than New Zealand, this cannot be taken as conclusive evidence for the efficacy of speed reducing measures since there may be other confounding factors which account for the differences in mortality rates. Quantifying the magnitude of the risk of child pedestrian injury associated with vehicle speed, would
provide an insight into the potential efficacy of speed reduction measures.

The relationship between vehicle speed and the severity of child pedestrian injuries was examined in the North American Pedestrian Injury Causation Study (Pitt et al 1990). A total of 469 child pedestrian injuries, for which the calculated travel speeds of the impacting vehicle were available, were classified into serious (death or ISS 16 or above) or not serious (ISS below 16). A logistic regression model was then used to examine the relative risk of serious injury across different categories of calculated travel speed. Vehicle speed was found to be highly associated with injury severity, with a mean ISS difference of 11.02 between the lowest and highest travel speed categories.

In the case-control study by Mueller et al (1990), it was found that after controlling for traffic volume, the risk of pedestrian injury for children living in neighbourhoods where the posted speed limit was greater than 40 mph was over three times that of children from neighbourhoods where the posted speed limit was 25 mph or less OR=3.4 (95%CI 0.6, 18.9) However because of the relatively small size of this study the precision of the estimated odds ratio was low. Whether posted speed limit is an appropriate exposure measure is questionable. In Auckland it has been shown that the mean speed is in excess of the posted speed limit at 45% of child pedestrian injury sites, suggesting that posted speed limit is
a crude measure of either the actual vehicle speed or the mean speed (Roberts et al, in press). Also a limitation of the Mueller study was the lack of information for many subjects on other environmental factors which limited the investigators ability to control for potential confounding factors in the analysis.

Parked vehicles: A British case series of police recorded pedestrian-motor vehicle collision data found that obstructed vision due to parked cars was recorded as a contributory factor in 57% of nearside pedestrian motor vehicle collisions involving children under five years (Lawson 1990). Parked vehicles were considered to be particularly important for the "dart out" injury scenario which is responsible for between 60% and 70% of pedestrian injuries to pre-school children. Restricting kerb parking has been suggested as a potential countermeasure (Rivara 1990). Nevertheless only one controlled epidemiologic study has examined the risk of child pedestrian injury associated with parked vehicles. In an analysis restricted to children injured immediately outside their homes and their age/sex matched controls, Mueller et al (1990) estimated an odds ratio of 2.2 (95% CI 0.6-8.4) for streets where more than 50% of the curb was parked. Once again, the main limitation of this study was the small number of subjects studied with the resulting low precision of the effect estimate.

Availability of safe areas for children’s play: Studies
conducted in Canada and the United Kingdom have found that the risk of pedestrian injury is inversely related to socioeconomic status (Pless et al 1987), (Dougherty et al 1990), (Office of Population Censuses and Surveys 1988). A lack of safe places for children to play in the poorer urban areas, with fewer alternatives to playing in the street, has been postulated as a possible explanation for these socioeconomic gradients (Rivara 1990). This hypothesis was first tested in a case-control study conducted in Belfast in 1959 (Backett et al 1959). Cases in this study were 100 injured child pedestrians, between 5 and 14 years, ascertained by random sampling of police records. Controls were selected from the records of the school health service and were matched to cases on age, sex, school and neighbourhood. Children were classified according to whether there was a garden, yard, or playroom at home and whether there were playgrounds nearby. Although the results of this study were presented as percentage ratios of observed to expected, it is possible to calculate odds ratios from the tabular data presented. Children without play amenities had an increased risk of injury, OR=2.56 (95%CI 1.37, 4.79). Since the analysis was unmatched, matching on neighbourhood may have resulted in a more similar exposure distribution between cases and controls than would otherwise have been found consequently underestimating the risks associated with a lack of play amenities.

More recently, in the case-control study conducted by Mueller
et al, an increased risk was found for children from homes without a play area $OR=5.3$ (95%CI 2.6, 11.0). Controlling for neighbourhood income level, resulted in a slightly decreased estimate $OR=3.7$ (95%CI 1.5, 9.2). The absence of fence around the home to separate it from the street, however, was not associated with a greatly increased risk $OR=1.3$ (95%CI 0.7, 2.6). A particular strength of this study was that exposure information was determined by direct inspection by a research assistant who was blind as to whether the home was that of a case or control. This would effectively eliminate the possibility of recall bias. However the failure to adjust for other potentially confounding household and environmental factors is an important limitation.

2.4 Strategies for prevention.

The emphasis on the identification of the pedestrian injury risk associated with environmental factors in the Auckland Child Pedestrian Injury Study was the result of an assessment of the potential efficacy of environmental strategies relative to strategies aimed at modification of either the host or the agent. In this section, the current strategies for the prevention of child pedestrian are critically reviewed in an attempt to justify the emphasis on environmental factors.

2.4.1 Education or environmental change?

Pedestrian skills training programmes have been the
traditional approach to the prevention of child pedestrian injuries in New Zealand. Nevertheless, none of the programmes currently implemented in New Zealand and indeed very few programmes internationally have ever been shown to reduce injury rates (OECD 1983). The efficacy of pedestrian education programmes can be evaluated using improved traffic knowledge, improved road crossing behaviour or reduced injury rates as the outcome measure. Because child pedestrian injuries are relatively rare occurrences, improved traffic knowledge and road crossing behaviour have been the most commonly used outcome measures. However, a clear relationship between injury reduction and either improved knowledge or behaviour has yet to be demonstrated (Tanz et al. 1985). Several evaluation studies have demonstrated improvements in traffic knowledge but much less often has improved road crossing behaviour been demonstrated. Rivara et al. (1991) evaluated a school training programme, using pre and post test observations on 229 children. They found that training resulted in a significant increase in the proportion of children who kept looking for cars as they crossed, although no improvement was shown for the other target behaviours. How long such behaviour changes persist following training and whether they result in reduced injury rates remains unknown.

To date, only two published studies have demonstrated reduced injury rates following pedestrian skills education. Fortenberry and Brown (1982) evaluated child pedestrian education campaigns conducted in four Alabama cities and found
a 33% reduction in the number of injuries in the target age group of 6-7 year old children, in the two years following the programme. Although the decline was greatest in the target age group compared to younger and older children, it nevertheless remains possible that the results may have been confounded by changes in the background rate. Preusser and Blomberg (1984) demonstrated a significant improvement in both knowledge and behaviour following a televised pedestrian education programme conducted in three North American cities. The authors claimed a 20% reduction in injury morbidity following the programme. However the 20% injury reduction was inconsistent with an observed improvement in correct crossing behaviour of only 7%, again suggesting that changes in the background rate may have been responsible for the apparent effect.

There is also scant evidence to suggest that driver education is likely to be an effective prevention strategy. Baker found that 23 of the 180 drivers who killed pedestrians had previously been assigned to driver rehabilitation clinics. Moreover, in the group of drivers who had killed pedestrians, a similar number were convicted of speeding offence in the four months following the fatal collision as in the same period prior to the collision (Baker et al 1974).

Some insight into the relative efficacy of educational and environmental prevention strategies is provided by an examination of international trends in pedestrian mortality rates (Roberts 1993 a). Between 1967 and 1987, for children
aged 5-14 years, Sweden experienced a 91% reduction in pedestrian mortality while there was an 84% reduction in Denmark. In comparison there was a reduction of only 9% in New Zealand over the same period. Similarly Denmark achieved an absolute reduction in mortality rates of 5.6/100,000 over this period compared with a reduction of only 0.4/100,000 in New Zealand. With regards to preventive strategies, the most striking difference between the Scandinavian countries and New Zealand is the greater emphasis given to environmental approaches to prevention in the former as opposed to educationally based prevention strategies in the latter. In particular Denmark, which changed its ranking from having the highest mortality rates in 1970 to being second only to Sweden in 1988, made a major commitment to a programme environmental change which resulted in lower vehicle speeds in urban areas. Local streets were designated as "living areas" with speed limits of either 30 km/h or 15 km/h and give way rules were reversed to give priority to pedestrians. Major roads passing through towns were modified with the introduction of "environmentally adapted through roads" which used traffic engineering measures, such as road narrowing, to reduce speed. Similarly in Sweden, efforts were made to separate children from traffic and also to reduce traffic volume, by bringing activities closer together and by improving public transport systems. Although the international differences and trends in pedestrian mortality cannot be taken as conclusive evidence for the efficacy of environmental prevention strategies, since there may be other confounding factors that account for them,
they do provide some support for the view that greater emphasis should be given to environmental approaches in future prevention efforts.

The results from community intervention trials of speed reducing measures provide further evidence for the efficacy of environmental approaches to prevention. For example, a large scale controlled community intervention trial of speed humps conducted in Denmark, estimated a 78% reduction in serious injury (95% CI 26%-93%) in areas where speed humps had been installed (Engel et al 1992). In a review of nineteen studies of casualty reductions following traffic calming, efficacy estimates of a similar magnitude were found (Preston 1992). Although the injury reductions quoted in these studies were for all road users, including motor vehicle occupants and cyclists, it is likely that child pedestrians would have comprised a significant proportion.

In summary, the paucity of modifiable host or agent risk factors for child pedestrian injury in case-control and cohort studies, the lack of evidence for the efficacy of pedestrian skills education programmes, the ecological evidence presented above and the results of community intervention trials of traffic calming, suggest that environmental approaches may hold the greatest potential for the prevention of child pedestrian injuries. Identification and quantification of environmental risk factors was therefore the primary aim of the Auckland Child Pedestrian Injury Study. Specifically the
study sought to identify and assess the contribution of four potentially modifiable risk factors for child pedestrian injury: traffic volume, vehicle speed, parked vehicles and the availability of safe areas for children’s play. These risk factors appeared from review of the literature to hold the greatest potential for prevention.
METHODS
CHAPTER 3: METHODS

3.1 Introduction

This chapter describes in detail the methodology of the Auckland Child Pedestrian Injury Study.

The case-control methodology was chosen for several reasons. First, for the study of relatively rare occurrences, such as child pedestrian injuries, a case-control design is considerably more efficient than a cohort design. The efficiency of a study may be defined either as the amount of information (information being defined as the reciprocal of the variance of the effect estimate) about the exposure effect per study participant or alternatively the amount of information per unit of cost (Rothman 1985). Regardless of the definition used, a case-control study is considerably more efficient than a cohort study which would require that a large population were followed for a long time period. Second, the case-control design enables the investigation of causal factors which operate over a short time period before the occurrence of interest. This is not possible in follow up studies unless participants are reexamined frequently.

In theory every case-control study takes place within a cohort, the study base (Wacholder et al 1992). The study base is the set of persons or person time in which diseased (or
injured) subjects become cases. For the valid conduct of a case-control study, cases must be representative of all cases in the study base with respect to the exposures studied and controls must be representative of all individuals in the study base with respect to the exposures studied (Miettinen 1985). The first step in the design of a case-control study is therefore to define the study base.

3.2 The study base.

The Auckland Child Pedestrian Injury Study is a population based case-control study. The study base was defined both geographically and temporally. The study base comprised all children younger than fifteen years, normally resident within the Auckland Area Health Board Region, between 1 January 1992 and 1 November 1993. The study base is a dynamic population with people moving in and out of the area. The definition of normally resident includes all current residents except for visitors, such as children on holiday in the Auckland region.

The Auckland Area Health Board Region is identical to the Central Auckland Statistical Region and the Auckland Coroner's District. It extends from Mercer in the south to Wellsford in the north covering 5,590 square kilometres. At the time of the 1991 census, Auckland had a population of 936,981, of whom 213,177 were under fifteen years (Department of Statistics 1991).
3.3 Selection of cases.

Study cases comprised all children younger than fifteen years, normally resident within the Auckland Area Health Board Region who were admitted to public hospitals or killed as a result of a pedestrian-motor vehicle collision during the study period. Children resident outside of the Auckland Area Health Board Region, who were transferred to Auckland for hospital care, were excluded from the case group. For the purposes of the study, "pedestrian" and "motor vehicle" were defined according to the International Classification of Diseases (9th edition) definitions given below:

A **pedestrian** is any person involved in an accident who was not at the time of the accident riding in or on a motor vehicle, train, animal-drawn or other vehicle or on a bicycle or animal. Includes: person in or on a pedestrian conveyance ie baby carriage, pram, pushchair, roller skates, scooter, skateboard, sled or wheelchair.

A **motor vehicle** is any mechanically or electrically powered device, not operated on rails, upon which any person or property may be transported or drawn upon a road. Any object such as a trailer, coaster, sled or wagon being towed by a motor vehicle is considered a part of the motor vehicle (WHO 1977).

Hospitalised cases were identified through a monitoring system
established at both of the public hospitals in the region which admit injured children (Starship Children's Hospital and Middlemore Hospital). At the Starship Children's Hospital, cases were identified by regular examination of the daily hospital admission lists. All children admitted as a result of injury were identified from these lists. The hospital notes of these children were then examined for pedestrian injury as the external cause. At Middlemore Hospital pedestrian injury cases were identified from the admission log of the ward admitting injured children.

A major prerequisite for validity in a population based case-control study is that all (or a random sample of) cases arising from the study base are identified. If there is incomplete case ascertainment and the exposure prevalence amongst those included is different from that amongst those who are not included, this represents a selection bias. In the study, the exclusion of children admitted to private hospitals for the treatment of pedestrian injuries might therefore have introduced selection bias. However, in 1991, of all childhood injury and poisoning admissions in New Zealand only 2% were admitted to private hospitals (Department of Health 1992). Furthermore, because pedestrian injuries are generally more severe than other types of injury and private hospitals in New Zealand have minimal facilities for dealing with acute severe trauma, the proportion of all child pedestrian injuries admitted to private hospitals is likely to be very small indeed and therefore unlikely to introduce a significant
Selection bias.

Children killed as pedestrians were identified by regular surveillance of the records of the Auckland Coroner’s pathologist. In Auckland, all children whose deaths have resulted from injury are subject to a coroner’s postmortem. The pathologist’s records include the external cause of injury, enabling identification of all children killed as pedestrians.

3.4 Selection of controls.

The major goal of control selection in a population based case-control study is to obtain a random sample of the study base (Wacholder et al 1992). In the Auckland Child Pedestrian Injury Study a random sample of the study base was selected using a sampling frame of school children and frequency matched to cases by age and sex. The method used to select pre-school control children was also based on this sampling frame but was adapted as described below.

3.4.1 School age controls.

A list of all schools, including private and special schools, in the Auckland Area Health Board region, was obtained from the Ministry of Education. This list provided the address of each school and the number of children on the school roll. A school was randomly selected from this list, 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 control child from the school roll. This two stage random sampling process is equivalent to the random selection of a child from a list of all school children in the study region.

To reduce the possibility of severe loss of efficiency due to substantial age and sex differences between cases and controls, controls were frequency matched to cases on age (0-4, 5-9, 10-14 years) and sex. The incidence rate of child pedestrian injury varies substantially across age groups and is significantly higher for boys than girls. Age and sex might also be related to the some of the exposures of interest in which case they would be confounding factors. Without matching the ratio of controls to cases in each age/sex stratum would have varied substantially on either side of unity, resulting in an inefficient stratified analysis (Rothman 1986). Although matching means that age and sex cannot be the objects of inquiry in the study, the effect of these variables is well known from descriptive epidemiology and therefore is of little new scientific interest. Case and control selection took place concurrently with the age and sex distribution of controls being based on the anticipated age and sex distribution of cases, as determined from previously published New Zealand data (Roberts et al 1992 a).
3.4.2 Pre-school controls.

Pre-school controls were selected by initially selecting a school aged control using the method described above. Using the street address of the selected school child as the starting point, homes were visited successively, in a pre determined direction, until a home with a pre-school child was found. The parents of this child were then 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 pre-school 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, when the next household was visited.

3.5 Study size.

Previous studies have indicated strong (although imprecise) associations between environmental exposures and the risk of child pedestrian injury (Mueller et al 1990). It was therefore considered important that the present study have sufficient power to detect odds ratios of 2.0 or more with precision.

Because it was anticipated that child pedestrian injury cases would be relatively scarce but controls more plentiful, it was proposed that two controls would be identified for each case. By increasing the control-to-case ratio to 2:1 it was possible
to obtain significantly greater precision in the estimation of exposure effects than would have been possible with a 1:1 apportionment ratio. However, increasing the ratio of controls to cases further would have provided proportionately much smaller increases in precision (Rothman 1986).

Auckland Area Health Board data suggested that an average of 120 children with pedestrian injuries are discharged from Auckland hospitals each year. Over a two year study period, with an estimated 85% response rate amongst cases, approximately 200 cases would be recruited. With a 2:1 control to case ratio, it would be possible to detect with 95% power, at the 0.05 level of significance, an odds ratio of 2.0 or greater associated with a factor present in 25% of controls (expected proportion of controls with unfenced playing areas). However for many of the study exposures, no information was available on the exposure proportions amongst the controls, so that these could only be estimated for the power calculation. For this reason the study power to detect an odds ratio of 2.0 or greater for a range of exposure proportions amongst the controls are presented below. It can be seen that the present study would have sufficient power (over 80%), at the 0.05 level of significance, to detect an odds ratio 2.0 or greater for exposures present in between 10% and 15% of controls (Table 3.1).
Table 3.1 Power for an unmatched case-control study of child pedestrian injury, with 200 cases and 400 controls at the 0.05 level of significance.

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An alternative approach to study size estimation has been suggested by Rothman (Rothman 1986). This method involves anticipating the study data and the magnitude of the effect and then calculating the precision of the effect estimates as one would do in the data analysis, using confidence intervals.

Based on the effect estimate and the control exposure prevalence for the exposure "high traffic flow" as reported in a previous case-control study of child pedestrian injuries (Mueller et al 1990), the 95% confidence intervals which would be obtained with the proposed study size have been calculated below:

200 cases, 400 controls: OR=3.1 (95%CI 2.17, 4.54)

This compares favourably with the precision of the measured odds ratio in the Mueller study of:

44 cases, 88 controls: OR=3.1 (95%CI 0.9, 10.8)

3.6 Study procedures and data collection.

3.6.1 Overview.

In this section the procedures for identifying individual study subjects and the data collection methods are described. There were two distinct methods of exposure data collection. The first involved a structured, interviewer administered,
parental questionnaire (Appendix 2). This took between 20 and 40 minutes to complete. The second method of exposure data collection, involved direct measurement of aspects of the traffic environment at sites of child pedestrian injury and at comparable locations for the controls. These data were collected by a qualified civil engineer and recorded on an environmental data collection form (Appendix 3).

3.6.2 Contacting study subjects.

The parents of children injured as pedestrians were approached by the study interviewer at a suitable stage in their child’s clinical course, determined after consultation with the hospital nursing staff. Written information was given to the parents, outlining the purpose of the study and inviting their participation. If the child had been discharged from hospital before contact with the study staff had been made, the parents of the injured child were sent a letter outlining the purpose of the study and inviting their participation. The parents of deceased children were also given the opportunity to participate, but after a six week delay. This time interval was used in the New Zealand Cot Death Study and appeared to be acceptable to bereaved families (Mitchell et al 1991). Interviews were scheduled with the child’s usual care giver, however both parents were given the opportunity to contribute to the study.

The parents of school aged control children were initially
sent a letter to discuss the possibility of arranging an interview. The letter contained the same information about the study as was given to the study cases. One week later they were telephoned, or if not on the phone, visited by the study interviewer. If the parents did not wish to be interviewed, this was recorded and the parents of the next eligible control child were approached. Parents of pre-school control children were asked to participate at the time of selection and if willing, a convenient time for interview was scheduled. If a home with an eligible pre-school control child was found but the parents were not in, a letter was posted to the householder, outlining the purpose of the study and inviting their participation.

3.6.3 Interviews.

In view of the likely ethnic distribution of the study participants it was decided that both a Maori and a Pakeha interviewer would be required. Therefore a 0.4 full time equivalent (FTE) Maori interviewer and a 0.3 FTE Pakeha interviewer were appointed. In appointing the former assistance was obtained from the Maori and Pacific Island Health Unit at the Department of Community Health.

Although blinding of interviewers as to whether parents are of cases or controls has been suggested as a method of reducing interviewer bias, it was neither appropriate or feasible in this study (Schlesselman 1982). In particular, it was
considered important for the study interviewers to be aware of families' situations, particularly when there had been a bereavement or if the child had been seriously injured and disabled. However every effort was made to minimise interviewer bias by using a pre-tested, structured questionnaire with regular close monitoring of study interviewers.

The majority of interviews with parents of injured children were conducted in hospital, in a confidential setting. Whenever possible interviews were conducted on the day prior to the child’s hospital discharge. However approximately 8% of interviews with parents of injured children were conducted in their own homes, usually because the injured child had been discharged before contact had been made with the study staff. All interviews with parents of controls were conducted in their own homes.

3.6.4 Questionnaire.

A copy of the study questionnaire is included in Appendix 2. This section describes the information sought during the interview including the derivation of the study questions. Due to the lack of previous studies in this area, there were few previously validated questions and many of the questions were either developed by the author and co-principal investigator Dr R. Norton, in conjunction with the study collaborators, or adapted from the questionnaires of studies which were being
developed overseas.

Information sought solely from cases included the date and time of the injury, the exact location of the injury and environmental conditions, such as weather and illumination. Parents of cases were asked to describe the circumstances of the injury collision and to identify potential contributory factors.

For cases and controls standard questions were asked about the type and tenure of housing, the number of occupants and access to a car. These questions were taken from the New Zealand Cot Death Study questionnaire. Questions on the availability of safe areas for children's play, including the degree of physical separation of the main children's play area from the road and the driveway were developed by the author and study collaborators.

Questions on parental supervision practices, such as adult accompaniment on the school home journey, were adapted from questionnaires developed by Professor Phyllis Agran at the University of California (personal communication) and Dr Elizabeth Towner at the University of Newcastle upon Tyne (personal communication). For cases, questions on parental supervision were focused on the day of the injury with the corresponding questions for controls focused on a nominated day. For example, parents of controls were questioned about parental accompaniment on the school-home journey, for the
last full school day that their child attended.

Questions on pedestrian skills education and parental expectations of children's road crossing abilities were adapted from a questionnaire developed by Professor Frederick Rivara at the Harbourview Injury Prevention and Research Centre, Seattle (personal communication).

Some of the health status questions were adapted from the Dunedin Multidisciplinary Health and Development study (Dr. David Chalmers, personal communication), others were developed by the author.

Demographic data sought from parents of cases and controls included: age; ethnicity; marital status; family constellation, including numbers and ages of children; educational level completed; employment status and occupation. These were standard questions taken from the Auckland Heart Study questionnaire (Jackson 1989).

The questionnaire was initially pre tested by the author in the context of mock interviews with staff in the Department of Community Health, friends and relatives. Interviewer training involved the conduct of further mock interviews resulting in a number of questionnaire alterations. Additional changes were made during the conduct of a pilot study involving fourteen case interviews and thirty eight control interviews. Details of the pilot study will be presented in a later section.
Throughout the conduct of the study, weekly meetings were held with the study staff during which general issues and specific problems relating to the questionnaire were discussed. In the early stages of data collection, these meetings provided an opportunity for the study interviewers to draw attention to ambiguous, poorly phrased or poorly sequenced questions and for the necessary changes to be made.

3.6.5 Identification of injury and comparison sites.

The exact locations of the pedestrian-motor vehicle collisions, the "case sites", were determined during the interviews with the parents of the injured children. However, if an injury site was unknown to a parent, it was determined from police or ambulance officer's records.

"Control sites" were roadway locations the same distance and direction from the home of the control child as was the injury site from the home of the injured child. Control sites were selected using a computer programme developed for the purposes of this study. The grid references of the home of the injured child, the injury site, and the home of a matched control child, were determined from detailed maps of the study region and entered into the software programme. The grid reference of a site the same distance and direction from the home of the control child, as was the injury site from the home of the case child, would then be selected. If there was no roadway location at or within 100 metres of the chosen point, the
direction was changed 90 degrees clockwise until a roadway control location was found. The software programme for control site selection was designed so that the selection process was as objective as possible.

The selection of sites comparable to the injury sites, for the controls, is an important methodological issue in studies aimed at the identification of environmental risk factors for child pedestrian injuries, and therefore will be considered in detail. In the study by Mueller et al, because no logical comparison site for the site of injury could be found, environmental characteristics at and surrounding the residences of the cases and controls were compared, even though only 34% of children were injured in the street where they lived. However, when the traffic characteristics of the injury sites and those surrounding the injured children's residences were compared, it was found that collision sites were more likely to have faster posted speeds and greater mean daily traffic volumes than the respective home sites. The authors concluded that this might lead to risk estimates for these exposures which were underestimates of the true risks.

For an injury occurring in the street of residences of a case, the most logical comparison site for a control would be the street of residence of the control. The method of control site selection would have to address this, but also select comparison sites for injury sites occurring away from children's homes. It was therefore proposed that the
comparison site should be a site the same distance and
direction from the control residence as was the injury site
from the case residence to which the control was matched.
Cases and controls would therefore be individually matched,
the matching providing the most feasible method of selecting
control sites. It might be argued however, that control
children may never visit the control sites and therefore would
not have the same opportunity to be exposed to the traffic
volume and vehicle speeds at such a site. However as Poole has
demonstrated, it is the fact of exposure rather than the
opportunity for exposure which is of interest (Poole 1986).

An alternative way of conceptualising the environmental
component of the present study is as an independent case-
control study, with roadway sites as the units of observation.
The study base would comprise all roadway sites in the
neighbourhoods of children in the study region, with all
cases, ie sites of pedestrian-motor vehicle collision,
occuring in the study base being ascertained. Control sites
would ideally be a random sample of the study base. However
the differing probabilities that children would ever be at
such sites would potentially introduce confounding. For
example, industrial sites may have high traffic volumes but
few children and consequently few child pedestrian injuries.
Matching on distance and direction from children’s residences
effectively restricts the study base to roadway sites in the
neighbourhoods of children. Regardless of the way the study is
conceptualised, the data would be analyzed in the same way, as
an individually matched case-control study.

Whilst the majority of pedestrian injuries in childhood occur on public roads and are classified as "motor vehicle traffic accidents" by the ICD 9 E coding system, previous studies have shown that in Auckland approximately 8% of the deaths and 16% of injuries resulting in hospitalisation occur away from the road in non-traffic situations, most often when a child is reversed over in the residential driveway (Roberts et al 1993b). Driveway pedestrian injuries are classified as "motor vehicle non-traffic accidents" by the ICD 9 E coding system. In order to identify risk factors for driveway related child pedestrian injuries a case-control study of driveway related child pedestrian injuries was also conducted. Parents of children injured in driveway related pedestrian motor vehicle collisions were interviewed by the study interviewers and a detailed examination of the site of injury was conducted by the civil engineer. Controls were selected using the methods described earlier in this chapter for pre-school controls. The driveways at the homes of the control children were examined by the civil engineer using the same data collection instrument as for the cases (Appendix 3). Whenever possible the engineer was blind as to whether the driveway was that of a case or control child.

3.6.6 Collection of environmental data.

Direct measurements of the environmental exposures were made
at both injury sites and comparison sites. For cases, measurements were made on the same day of the week and at the same time of day as the injury, usually one week later. For controls, measurements were made on the same day of the week and at the same time of the day as the injury of the case to which the control was matched. In this situation, matching provided time comparability for cases and controls for exposures, such as traffic volume, that vary over time. By matching on the day of the week and the time of the day, a simple reference point for the measurement of time dependent exposures was achieved.

A 24 hour profile of bi-directional traffic volume and vehicle speeds at case sites and comparison sites was measured using GK-5000 traffic counters (Appendix 3), positioned as near as possible to the site. If the case site was at an intersection, the traffic volume on the street the vehicle was travelling on immediately prior to the collision was measured. For controls at intersections one of the intersecting streets was randomly selected. Placement of traffic counters was undertaken by a qualified civil engineer, under the supervision of Mr R Dunn, Senior Lecturer in the Department of Civil Engineering at the University of Auckland. Permission for the placement of the traffic counters was obtained from each of the local authorities in the study area prior to the start of the study. The density of on street parking was measured by making parked vehicle counts over a predetermined distance of roadway at case and control sites. Copies of the environmental data
collection forms, which show the range of environmental data collected, for both roadway and driveway injury and comparison sites are included in appendix 3.

3.7 Pilot study.

A pilot study, of eight weeks duration, was conducted prior to the main phase of data collection. During the pilot study fourteen cases were identified by the surveillance system. There were no child pedestrian deaths during this period. Of the fourteen cases identified, the parents of thirteen (93%) agreed to participate in the study and completed the study interview. To check on the comprehensiveness of the surveillance system, a list of all eligible children transported to hospital by ambulance was obtained from the Auckland St John’s Ambulance. All child pedestrians who were transported by ambulance and subsequently admitted had been identified.

Over the eight week period, thirty eight control children were selected. Of these, 24 were school aged controls and 14 were pre-school controls. For pre-school controls the median number of homes visited before an eligible household was found, was one (range 1-3). Thirty seven of the thirty eight potential control parents (97%) agreed to participate and completed the study interview.

The pilot study provided an opportunity for a review of all
the study procedures. In particular the technique of administration of the questionnaire and the procedures for the measurement of environmental parameters were determined. In addition during the pilot study the reliability of the environmental data collection instrument was assessed as shown in the following section.

3.7.1 Reliability study.

Because traffic volume and vehicle speed could not be measured at the time of the pedestrian-vehicle collision, measurements were made on the same day of the week and at the same time of day as the collision, but one week later. It was therefore assumed that these data would provide a reasonably accurate indication of traffic conditions at the time of injury. In order to ascertain whether traffic volume and vehicle speed measured one week following an injury would accurately reflect volume and speed at the time of injury, during the pilot study repeat measurements were made for a random sample of ten injury sites, both one and two weeks following the injury. If these measurements corresponded closely it would suggest that the speed and volume characteristics of a particular site are a stable characteristic and that the data collection instrument is reliable. Differences in the means of the two volume and speed measurements were examined with both parametric (paired t test) and non parametric (sign test) significance tests. As a further test of reliability, the regression equations describing the relationship between the
week one and week two volume and speed measurements respectively were obtained, with regression t-tests used to test the hypotheses that the intercepts are zero and that the gradients are unity.

The volume and speed data for the ten injury sites for which repeat measurements were made are shown in Table 3.2. There was no significant difference between the mean traffic volumes (t test $p=0.59$, sign test $p=0.85$) or the mean vehicle speeds (t test $p=0.73$, sign test $p=1.00$) between the two measures. In a plot of the traffic volume data, with $y$ the traffic flow at week 1 and $x$ the traffic volume at week 2, the fitted model was $y = -19.26 + 1.00309 x$. The test of intercept $= 0$ gave $p=0.68$, while the test of gradient $= 1$ gave $p=0.92$. Similarly, for the speed data, the fitted model was $y = -0.59 + 1.00943 x$. The test of intercept $= 0$ gave $p=0.66$, while the test for gradient $= 1$ gave $p=0.71$. These results therefore suggest that the study data provide a reasonably accurate indication of the conditions at the time of injury.
Table 3.2 Reliability of speed and volume measurements at injury sites.

<table>
<thead>
<tr>
<th>Injury Site</th>
<th>Week 1</th>
<th>Week 2</th>
<th>change (absolute)</th>
<th>% change (relative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume (vehs/hr)</td>
<td>3039</td>
<td>3012</td>
<td>+27</td>
<td>1</td>
</tr>
<tr>
<td>Mean speed (kph)</td>
<td>64</td>
<td>65</td>
<td>-1</td>
<td>2</td>
</tr>
<tr>
<td>Site 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume</td>
<td>1078</td>
<td>1348</td>
<td>-270</td>
<td>20</td>
</tr>
<tr>
<td>Mean speed</td>
<td>65</td>
<td>64</td>
<td>+1</td>
<td>2</td>
</tr>
<tr>
<td>Site 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume</td>
<td>609</td>
<td>663</td>
<td>-54</td>
<td>8</td>
</tr>
<tr>
<td>Mean speed</td>
<td>38</td>
<td>39</td>
<td>-1</td>
<td>3</td>
</tr>
<tr>
<td>Site 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume</td>
<td>892</td>
<td>799</td>
<td>+93</td>
<td>10</td>
</tr>
<tr>
<td>Mean speed</td>
<td>56</td>
<td>57</td>
<td>-1</td>
<td>2</td>
</tr>
<tr>
<td>Site 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume</td>
<td>51</td>
<td>39</td>
<td>+12</td>
<td>24</td>
</tr>
<tr>
<td>Mean speed</td>
<td>42</td>
<td>41</td>
<td>+1</td>
<td>2</td>
</tr>
<tr>
<td>Site 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume</td>
<td>822</td>
<td>796</td>
<td>+26</td>
<td>3</td>
</tr>
<tr>
<td>Mean speed</td>
<td>60</td>
<td>59</td>
<td>+1</td>
<td>2</td>
</tr>
<tr>
<td>Site 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume</td>
<td>355</td>
<td>385</td>
<td>-30</td>
<td>8</td>
</tr>
<tr>
<td>Mean speed</td>
<td>41</td>
<td>42</td>
<td>-1</td>
<td>2</td>
</tr>
<tr>
<td>Site 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume</td>
<td>283</td>
<td>278</td>
<td>+5</td>
<td>2</td>
</tr>
<tr>
<td>Mean speed</td>
<td>32</td>
<td>32</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Site 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume</td>
<td>178</td>
<td>175</td>
<td>+3</td>
<td>2</td>
</tr>
<tr>
<td>Mean speed</td>
<td>59</td>
<td>59</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Site 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean volume</td>
<td>3413</td>
<td>3384</td>
<td>+29</td>
<td>1</td>
</tr>
<tr>
<td>Mean speed</td>
<td>66</td>
<td>66</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
3.8 Data editing and analyses.

3.8.1 Data editing.

Each week, all completed questionnaires were checked by the author for accuracy, consistency and completeness and any problems were discussed at the weekly study meeting. When necessary, subjects were re-contacted to check unusual results. After the completion of each questionnaire, the data were entered by the study interviewers, into a structured data entry programme, constructed using the Epi-info software programme. This programme allows inadmissible or unusual values to be identified during data entry, providing a further opportunity for data editing. Each interviewer entered their own and the other interviewers questionnaires, so that each completed questionnaire was double entered. The two entries were then compared using the Epi-info "validate" option when any differences between the two entries arising from transcription errors were identified. Finally, a further editing check of the stored data was made by the author prior to analysis, to check on completeness of the data and the plausibility of the distribution of each variable.

3.8.2 Data analyses.

Although data were collected on a wide range of potential risk factors for child pedestrian injury, the primary aim of the Auckland Child Pedestrian Injury Study was to identify and
assess the risks associated with four potentially modifiable risk factors, specifically, traffic volume, vehicle speed, parked vehicles and the availability of safe areas for children's play. These exposures therefore constitute the major analytic focus in subsequent chapters.

From the 24 hour profile of bi-directional traffic volume measured at sites of injury and control sites, the hourly traffic volumes for the three hour period around the time of injury for the cases and around the comparable time period for the matched controls was extracted. The traffic volume variable used in the analyses was the average traffic volume over this three hour period, expressed in vehicles per hour. For vehicle speed, the variable used in the analyses was the mean vehicle speed for the three hour period around the time of injury for the case and around the comparable time period for the controls, expressed in kilometres per hour. For parked vehicles, the variable "curb parked" was constructed by averaging the percentage of the curb that was parked, over a 100 metre distance, on both sides of the road, at sites of injury and control sites. The variables used in the analyses pertaining to the availability of safe areas for children's play were obtained from questionnaire items "Does your home have a yard or lawn where a child could play?" and "Is the play area completely separated from the street by a fence and a gate?".

Most of the variables on potential confounding factors were
based on questionnaire items and their construction requires no special comment. However the variables pertaining to socioeconomic position and ethnic group require some further explanation. Socioeconomic position was classified according to the New Zealand based Elley Irvine social class classification (Elley et al 1985). Both paternal and maternal occupations were classified according to this scale and the highest level of the two was chosen as the value of the socioeconomic position variable for each child. If neither parent had ever undertaken paid employment, the child was classified as "other" and for the purpose of the present analysis was included with the lowest socioeconomic group. The question relating to ethnic group in the interview was: "To which ethnic group does (name) belong?" The choices available were that of European, Maori, Samoan, Tongan, Cook Island, Fijian, Niuean, Chinese, Indian and other. For the purpose of data analysis three ethnic groups were constructed: Maori, Pacific Islander (Samoan, Tongan, Cook Island, Fijian, Niuean) and other (European, Chinese, Indian, other).

As indicated earlier in this chapter, pedestrian injuries in childhood can be divided into those occurring on public roads and those occurring on residential driveways. Since these two mechanisms of injury are likely to have distinct aetiologies with respect to some of the environmental risk factors, the identification of environmental risk factors requires that the two groups are analyzed separately. Initially however, risk factors were examined for all child pedestrian injuries both
traffic and non-traffic together. These analyses were based on the questionnaire data only and aimed to identify social, familial and personal risk factors as well as the risks associated with the absence of safe areas for children’s play. The results of these analyses are presented in chapter four. Chapter five presents the results of a validation study conducted in order to ascertain the validity of the questionnaire data on the availability of safe areas for children’s play.

In chapter six, risk factors for traffic pedestrian injuries are examined separately. As discussed earlier in this chapter, in order to examine the risks associated with variables related to the traffic environment it was necessary to use a matched design. Analyses in chapter six are therefore based on traffic pedestrian injury cases and their matched controls using conditional logistic regression modelling. Prior to undertaking matched analysis, the effect of matching was evaluated by calculating the effect estimates both preserving the matching and ignoring it (Rothman 1986). By determining whether the effect estimate from the matched analysis differs substantially from that obtained in the unmatched analysis, the need to retain the matching in the analysis can be determined.

Earlier in this chapter the problem of selecting appropriate comparison sites for injury sites was considered. Selection of comparison sites is particularly problematic for injuries
occurring at some distance from the homes of the cases. Since the validity of comparison site selection in this situation is open to question, analyses were also conducted on the subset of cases injured within 500 metres of their homes and their matched controls. These analyses are also presented in chapter six.

In chapter seven risk factors for non-traffic pedestrian injuries are examined. Since the site of injury for non-traffic pedestrian injuries is the residential driveway and the exposures of interest are not time dependent, there was no requirement to match for this component of the study. Environmental data were collected at the residential driveways of the cases and at the residential driveways of the controls. Because non-traffic pedestrian injuries account for only a small proportion of all child pedestrian injuries, in order to achieve greater power, the ratio of controls to cases was increased from 2:1 to 3:1 for this component of the study. This was accomplished by collecting environmental data at the residential driveways of controls who had previously been used as controls for traffic pedestrian injury cases. The primary focus of the analyses presented in chapter seven is on the risks associated with the absence of safe areas for children’s play, which in the context of driveway pedestrian injuries, pertains to the presence or absence of physical barriers between the play area and the driveway.

Analyses were undertaken using the SAS statistical software
package. In all analyses, univariate odds ratios have 95% confidence intervals calculated by the method of Cornfield (1956), except when cell numbers are small when the exact method was used (Breslow et al 1980). Multivariate odds ratios for the unmatched portions of the study were obtained from unconditional logistic regression modelling as were their confidence intervals. In all multivariate models continuous variables were categorised, with indicator terms constructed where appropriate to allow estimation of the effect at each level relative to a baseline category. Categorical indicator terms were also constructed for continuous confounding variables. For the estimation of exposure effects pertaining to the traffic environment, odds ratios were obtained by conditional logistic regression for matched data as were the 95% confidence intervals.

3.9 Ethical approval and consent.

Ethical approval for this study was obtained from the Auckland Area Health Board Research Ethics Committee and the University of Auckland Human Subjects Ethics Committee. Written consent was received from all study participants; the consent form was incorporated into the front page of the questionnaire but later detached so that all name identifiers were kept separate from stored questionnaires.
RESULTS AND DISCUSSION
RISK FACTORS FOR CHILD PEDESTRIAN INJURIES
CHAPTER 4. RISK FACTORS FOR CHILD PEDESTRIAN INJURIES

4.1 Introduction.

In this chapter risk factors for all child pedestrian injuries, both traffic and non-traffic are examined. First, univariate analyses are presented for a range of potential risk factors for child pedestrian injury. Subsequent analyses focus on the risks associated with the absence of a safe play area at the home, this being one of the major hypotheses that the Auckland Child Pedestrian Injury Study sought to address.

4.2 Results.

A total of 206 injured child pedestrians were identified by the surveillance system over the study period, 9 of whom were identified by surveillance at the coroner's office. This figure however does not represent the total number of child pedestrian deaths over the study period, since some children admitted to hospital may subsequently have died. Of the 206 identified cases, 160 (78%) were injured on public roads, 40 (19%) were injured in residential driveways, 4 (2%) were injured in car parks, and 2 (1%) children were injured in public parks. Of the 206 children identified, the parents of 200 agreed to participate in the study, a response rate of 97%.
A total of 406 eligible control children were identified over the study period. The parents of 400 of these children agreed to participate in the study, a response rate of 99%. In the selection of pre-school controls, if a home with a pre-school child was identified but the parents could not be contacted, a non response was recorded. The response rate for pre-school controls was almost identical to that for school aged controls.

The analyses presented in this chapter are therefore based on 200 participating cases and 400 participating controls, a case:control ratio of 1:2. Table 4.1 gives the distribution of cases and controls by age and sex. As would be expected given that controls were frequency matched to cases by age (0-4, 5-9, 10-14 years) and sex, the proportions of cases and controls in each age and sex category were almost identical.

4.2.1 Univariate analyses

Univariate odds ratios and 95% confidence intervals (CI) are presented in Tables 4.2 to 4.4 for a range of social and familial variables, for personal health related variables and for variables related to the home environment. Estimates based on unconditional logistic regression with the matching factors, age (under 5, 5-9, 10-14) and sex, as confounding variables, were initially conducted but this had little effect on the odds ratio estimates and therefore are not presented.
Table 4.1 Age and sex distribution for cases and controls.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (%)</th>
<th>Controls (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=200</td>
<td>n=400</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-4</td>
<td>72 (36)</td>
<td>134 (34)</td>
</tr>
<tr>
<td>5-9</td>
<td>83 (42)</td>
<td>178 (45)</td>
</tr>
<tr>
<td>10-14</td>
<td>45 (23)</td>
<td>88 (22)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>123 (62)</td>
<td>243 (61)</td>
</tr>
<tr>
<td>Female</td>
<td>77 (39)</td>
<td>157 (39)</td>
</tr>
</tbody>
</table>
There was a strong inverse relationship between the risk of pedestrian injury and socioeconomic position (Table 4.2). Children from families in the lowest socioeconomic stratum had a risk of pedestrian injury three times that of children from families in the highest socioeconomic stratum (OR=3.03 95%CI 1.79, 5.16). The risk of pedestrian injury for Pacific Island children was close to three times greater than that for children in the reference category (OR=2.97 95%CI 1.91, 4.61), with the risk for Maori children being between two and three times that of children in the reference category (OR=2.59 95%CI 1.64, 4.08). Children from single parent families (OR=1.99 95%CI 1.31, 2.98) and children from families with five or more children were also at a significantly increased risk of pedestrian injury (OR=2.35 95%CI 1.27, 4.35).

The presence of either a hearing or visual problem was associated with a near fourfold increase in the risk of injury, although due to the relatively low prevalence of these exposures, the precision of these estimates was low (Table 4.3). The presence of a health problem or a previous hospital admission for injury was not associated with a significantly increased risk.

Living in a multiple dwelling (OR=4.50 95%CI 2.39, 8.54), living in rental accommodation (OR=3.45 95%CI 2.38, 5.00) and having been resident at the present address for less than three months (OR=4.04 95%CI 1.66, 10.00) were associated with an increased risk of pedestrian injury (Table 4.4). Living in
a home where there is no yard or lawn where a child could play was associated with an increased risk of injury, although due to the very low numbers of such children the precision of this risk estimate was extremely low (OR=35.37 95%CI 2.03 615.9). None of the control children were exposed to this risk factor. The odds ratio estimate in this case was obtained by unconditional logistic regression using a correction of 0.5 in the zero cell. Children from homes where the play area is unfenced from the street (OR=1.95 95%CI 1.36, 2.79) were at increased risk, as were children from families without access to a car (OR=2.20 95%CI 1.43, 3.40).
Table 4.2 Numbers and odds ratios for social and familial variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (%)</th>
<th>Controls (%)</th>
<th>Crude OR (95% CI)</th>
<th>Adjusted OR* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=200</td>
<td>n=400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socioeconomic position</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I, II, III</td>
<td>28 (14)</td>
<td>108 (27)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>IV, V</td>
<td>84 (42)</td>
<td>180 (45)</td>
<td>1.80 (1.07, 3.03)</td>
<td>1.44 (0.84, 2.49)</td>
</tr>
<tr>
<td>VI and others</td>
<td>88 (44)</td>
<td>112 (28)</td>
<td>3.03 (1.79, 5.16)</td>
<td>1.41 (0.75, 2.66)</td>
</tr>
<tr>
<td>Ethnic group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maori</td>
<td>56 (28)</td>
<td>71 (18)</td>
<td>2.59 (1.64, 4.08)</td>
<td>1.93 (1.14, 3.28)</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>66 (33)</td>
<td>73 (18)</td>
<td>2.97 (1.91, 4.61)</td>
<td>1.92 (1.14, 3.24)</td>
</tr>
<tr>
<td>Other</td>
<td>78 (39)</td>
<td>256 (64)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Responsibility for child</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sole</td>
<td>62 (31)</td>
<td>74 (19)</td>
<td>1.99 (1.31, 2.98)</td>
<td>1.26 (0.79, 2.00)</td>
</tr>
<tr>
<td>Partner</td>
<td>138 (69)</td>
<td>326 (82)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Number of children in family</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;=2</td>
<td>100 (50)</td>
<td>219 (55)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>3-4</td>
<td>71 (36)</td>
<td>154 (39)</td>
<td>1.01 (0.69, 1.48)</td>
<td>0.81 (0.46, 1.40)</td>
</tr>
<tr>
<td>5+</td>
<td>29 (15)</td>
<td>27 (7)</td>
<td>2.35 (1.27, 4.35)</td>
<td>1.52 (0.69, 3.34)</td>
</tr>
</tbody>
</table>

* Adjusted for age, sex and variables in Tables 4.2 - 4.4
Table 4.3 Numbers and odds ratios for personal variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (%) n=200</th>
<th>Controls (%) n=400</th>
<th>Crude OR (95% CI)</th>
<th>Adjusted OR* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hearing problem</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>18 (9)</td>
<td>14 (4)</td>
<td>2.73 (1.26, 5.94)</td>
<td>3.83 (1.62, 9.08)</td>
</tr>
<tr>
<td>No</td>
<td>182 (91)</td>
<td>386 (97)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Visual problem</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9 (5)</td>
<td>4 (1)</td>
<td>4.66 (1.28, 20.94)</td>
<td>4.13 (1.08, 15.70)</td>
</tr>
<tr>
<td>No</td>
<td>191 (96)</td>
<td>396 (99)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Other health problem</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>10 (5)</td>
<td>17 (4)</td>
<td>1.19 (0.49, 2.80)</td>
<td>0.48 (0.17, 1.34)</td>
</tr>
<tr>
<td>No</td>
<td>190 (95)</td>
<td>383 (96)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Previous injury hospital admission</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>27 (14)</td>
<td>44 (11)</td>
<td>1.26 (0.73, 2.17)</td>
<td>0.97 (0.52, 1.80)</td>
</tr>
<tr>
<td>No</td>
<td>173 (87)</td>
<td>356 (89)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

* Adjusted for age, sex and variables in Tables 4.2 - 4.4
Table 4.4 Numbers and odds ratios for variables related to the home environment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (%)</th>
<th>Controls (%)</th>
<th>Crude OR (95% CI)</th>
<th>Adjusted OR* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple dwelling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>35 (18%)</td>
<td>18 (5%)</td>
<td>4.50 (2.39, 8.54)</td>
<td>2.90 (1.46, 5.76)</td>
</tr>
<tr>
<td>No</td>
<td>165 (83%)</td>
<td>382 (96%)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Rental accommodation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>114 (57%)</td>
<td>111 (28%)</td>
<td>3.45 (2.38, 5.00)</td>
<td>1.91 (1.21, 3.02)</td>
</tr>
<tr>
<td>No</td>
<td>86 (43%)</td>
<td>289 (72%)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Resident less &lt; 3 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>17 (9%)</td>
<td>9 (2%)</td>
<td>4.04 (1.66, 10.00)</td>
<td>3.65 (1.42, 9.38)</td>
</tr>
<tr>
<td>No</td>
<td>183 (92%)</td>
<td>391 (98%)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Presence of yard or lawn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>8 (4%)</td>
<td>0 (0%)</td>
<td>35.37 (2.03, 615.9)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>192 (96%)</td>
<td>400 (100%)</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Play area fenced off from street</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>119 (60%)</td>
<td>172 (43%)</td>
<td>1.95 (1.36, 2.79)</td>
<td>2.02 (1.36, 2.99)</td>
</tr>
<tr>
<td>Yes</td>
<td>81 (41%)</td>
<td>228 (57%)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Access to car</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>56 (28%)</td>
<td>60 (15%)</td>
<td>2.20 (1.43, 3.40)</td>
<td>0.94 (0.56, 1.57)</td>
</tr>
<tr>
<td>Yes</td>
<td>144 (72%)</td>
<td>340 (85%)</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

* Adjusted for age, sex and variables in Tables 4.2 - 4.4
Table 4.5 Distribution of cases and controls and odds ratios associated with the absence of a fenced play area by age group.

<table>
<thead>
<tr>
<th>Age group Exposure</th>
<th>0-4 years</th>
<th>5-9 years</th>
<th>10-14 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E+</td>
<td>E-</td>
<td>E+</td>
</tr>
<tr>
<td>Cases</td>
<td>34</td>
<td>49</td>
<td>56</td>
</tr>
<tr>
<td>Controls</td>
<td>38</td>
<td>85</td>
<td>27</td>
</tr>
<tr>
<td>OR</td>
<td>1.55</td>
<td>2.22</td>
<td>2.50</td>
</tr>
<tr>
<td>95%CI</td>
<td>(0.87, 2.78)</td>
<td>(1.29, 3.83)</td>
<td>(1.19, 5.25)</td>
</tr>
</tbody>
</table>

E+ = Fenced play area absent
E- = Fenced play area present
4.2.2 Stratified analysis.

In Table 4.5 the odds ratios associated with the absence of a fenced play area are examined across age strata. It is evident from the table that the odds ratio was lowest in the 0-4 age stratum (OR=1.55 95%CI 0.87, 2.78), intermediate in the 5-9 age stratum (OR=2.22 95%CI 1.29, 3.83) and greatest in the 10-14 age stratum (OR=2.50 95%CI 1.19, 5.25). The Breslow-Day test for homogeneity of the odds ratio gave \( X^2=1.217 \) DF=2 \( p=0.544 \) thus failing to reject the null hypothesis of an uniform odds ratio across age strata. The Mantel-Haenszel pooled odds ratio was 2.01 (95%CI 1.42, 2.84).

4.2.3 Multivariate analyses.

The risk of pedestrian injury associated with the absence of a fenced play area were then examined after controlling for potential confounding variables in a multiple logistic regression model. Variables incorporated into the model as potential confounders included all of the social and familial variables shown in Table 4.2, the personal variables shown in Table 4.3, the environmental variables shown in Table 4.4, and age and sex, the matching variables. In this analyses, as in the one presented in Table 4.4, the eight pedestrian injury cases living in homes without any play area whatsoever were included amongst the exposed group. The exposure "no play area fenced off from street" therefore includes both those living in homes without a play area and those living in homes with an
unfenced play area. The multivariate odds ratio associated with the absence of a fenced play area was 2.02 (95% CI 1.36, 2.99). This multivariate odds ratio (OR = 2.02) was very close to the univariate odds ratio (OR = 1.95), suggesting that there is little confounding by the variables included in the model.

Since it is implausible that a fenced play area could be aetiollogically important for all child pedestrian injuries, the analyses were repeated excluding cases injured on the school-home journey and cases injured in the residential driveway. The multivariate odds ratio associated with the absence of a fenced play area excluding these 89 cases was 1.73 (95% CI 1.08, 2.77).

For all of the social and familial variables the multivariate odds ratios were closer to the null value than were the univariate odds ratios, suggesting that these variables are highly correlated. The presence of either a hearing or a visual problem was associated with a fourfold increase in the risk of pedestrian injury. Most of the multivariate odds ratios for the environmental variables were also closer to the null value than were the univariate odds ratios. However strong risks remained for the exposures, resident less than three months (OR=3.65 95% CI 1.42, 9.38), living in a multiple dwelling (OR=2.90 95% CI 1.46, 5.76) and living in rental accommodation (OR=1.91 95% CI 1.21, 3.02).
4.3 Discussion.

In the following discussion section, as in the discussion sections of all the results chapters, only issues related to the validity and precision of the associations found are addressed. Inferences with respect to causation and implications for prevention have been reserved for chapter eight.

The aim of this study was to quantify the magnitude of the effects of a number of hypothesised risk factors on the incidence rate of child pedestrian injury. To achieve this a study base was specified, data on child pedestrian injury events arising in the study base were collected, the person time exposure of the study base was sampled and finally, effect estimates were calculated. Threats to the validity of effect estimation, or bias, may have been introduced at any of these stages.

In the Auckland Child Pedestrian Injury Study, the study base was a geographically and temporally defined segment of person time. This had the advantage that the distribution of exposures among the controls could be extrapolated to the study base to enable the calculation of population attributable risks. One of the prerequisites for validity with such a study base are that all cases (or a random sample of all cases) in the study base are ascertained and that controls randomly sample exposure in the study base (Wacholder et al
1992). Although an attempt was made to ascertain all child pedestrian injuries resulting in death or hospitalisation in the study base, some events may have been missed by the surveillance system. Nevertheless, provided the cases which were ascertained were a random sample of the totality of cases, no bias would have been introduced. Since there is no reason to believe that case finding by the surveillance system would have been dependant on exposure status and as few events are likely to have been missed, incomplete ascertainment would not appear to have threatened validity in this study.

Controls were a random sample of the study base selected from a sampling frame of all school children in the study region. With the possible exception of children from itinerant families, this sampling frame can be expected to include all children in the study base. Since school registers were used to select controls, children absent from school, for example as a result of illness, would still have been selected as controls.

A potentially more important source of bias is that resulting from non response. As a result of non response, the ratio of person time among the exposed and unexposed for the study participants might be different to that in the study base. However in view of the exceptionally high response rates for cases (97%) and controls (99%) in this study, the potential for bias due to non response would be minimal.
Confounding has been defined as the divergence between the effect estimate in the study base and the effect estimate in an "ideal person time" (Steineck et al 1992). In "ideal person time" there would be no difference in injury incidence between the exposed and unexposed, if the exposure were removed. In this study there would be no confounding if the incidence rate of pedestrian injury for children from homes without a fenced playing area was identical to the incidence rate of pedestrian injury for children from homes with a fenced playing area, if the exposure were removed. Since this ideal would have been unobtainable, data were collected on the factors which might have accounted for any difference in the incidence rate in this hypothetical situation and attempts were made to adjust for these effects in the multivariate analysis. A potential problem in this study however is confounding by "cautiousness". For example, parents whose homes have fenced play areas may be more aware of the risks of pedestrian injury, engaging in more preventive behaviours, than parents from homes without safe play areas, so that even if the exposed group were unexposed the incidence rates would not be identical. Capturing all of the elements contained within "cautiousness" in a study variable would be difficult and as a result, controlling for cautiousness as a confounder cannot readily be achieved.

Yet another potential threat to the validity of the results presented in this chapter concerns the accuracy of exposure measurement. Inaccurate exposure measurement may have resulted
in subjects being misclassified with respect to exposure categories. Misclassification is non differential when the sensitivity and specificity of exposure classification is the same for cases and controls. Misclassification is differential when the sensitivity and/or specificity of exposure classification varies according to case control status. Non differential misclassification, in most situations, will bias the odds ratio towards the null value, whereas differential misclassification may bias the odds ratio either towards or away from the null value (Copeland et al 1977). Because examining the risks associated with the absence of a safe play area was a primary aim of this study, an attempt was made to validate a sample of the questionnaire information to determine whether differential accuracy of parental recall would have introduced bias. The results of this validation study are presented in the next chapter. As will become evident in the next chapter, the validation study provided support for the validity of exposure measurement for the variable relating to the absence of a fenced play area. Nevertheless is still possible that misclassification of potential confounders may have limited the extent to which confounding was controlled in multivariate the analyses.

In the analyses presented in this chapter risk factors were examined for all child pedestrian injuries, both traffic and non-traffic. It was therefore not possible to control for potential confounders such as traffic volume and vehicle speed. However in chapter six risk factors for traffic
pedestrian injuries will be examined separately and the potential for confounding by such factors will be addressed.
VALIDATION STUDY
CHAPTER 5. VALIDATION STUDY

5.1 Introduction.

In case-control studies, subjects may be misclassified with respect to exposure to a risk factor for disease. Misclassification is non differential when the sensitivity and specificity of exposure classification is the same for cases and controls. Misclassification is differential when the sensitivity and/or specificity of exposure classification varies according to case control status (Copeland et al 1977). For dichotomously measured exposures, non differential misclassification will bias the odds ratio towards the null value, whereas differential misclassification may bias the odds ratio either towards or away from the null value. In studies where the exposures of interest are determined during interviews with the study subjects, differential recall accuracy between cases and controls may lead to differential exposure misclassification and bias in the estimation of the odds ratio. Although differential recall is a potent threat to validity in many case-control studies, its presence is rarely examined (Neugebauer et al 1990). Because the examination of the risks associated with the absence of a fenced play area was a primary aim of this study, an attempt was made to validate the information collected on this variable and examine whether differential recall may have introduced bias. In this chapter the results of this validation study are
5.2 Methods.

Subjects for the validation study were the first one hundred cases and the first one hundred controls participating in the Auckland Child Pedestrian Injury Study. Parents of cases and controls completed the main study interviewer administered questionnaire, which included questions about the presence of a play area at the child's home and the presence of fences separating the play area from both the driveway and the road. Parents were later asked if a research officer could visit their homes to make further measurements of aspects of the home environment. During this visit the presence or absence of complete separation of the children's play area from the road and the driveway was ascertained. The research officer's observations constituted the "gold standard" against which parental reports were compared. Wherever possible the research officer was blind as to whether the home was that of a case or a control. Case-control differences in recall accuracy were evaluated conditional on exposure as determined by the research officer's assessment. For each variable the "sensitivity of recall" was defined as the proportion of parents reporting exposure in the questionnaire amongst those for whom the research officer documented exposure. The "specificity of recall" was defined as the proportion of parents reporting no exposure in the questionnaire amongst those for whom the research officer documented no exposure.
Case-control differences in sensitivity and specificity were analyzed using 95% confidence intervals for differences in proportions (Fleiss 1973).

To examine the influence of recall accuracy on the calculated effect estimates, the odds ratios calculated using the questionnaire data were compared with the odds ratios calculated using the research officer's data by calculating the ratio of odds ratios (ROR) (Drews et al 1990). ROR was defined as the odds ratio based on questionnaire data divided by the odds ratio based on the research officer's data. The accuracy of recall for the variable related to the fencing of the driveway was examined separately for the subset of cases (N=26) who were injured in the driveway.

Finally, the misclassification rates obtained were used to adjust the odds ratio estimate for the absence of a fenced play area (as calculated in the previous chapter). The direct method described by Marshall (1990) was used to adjust the odds ratio.

5.3 Results.

The sensitivity and specificity of recall for the variables pertaining to the fencing of the play area from the road and from the driveway, for the one hundred cases and one hundred controls are shown in Table 5.1. Overall case-control differences in the sensitivity and specificity of recall were
small with the ratio of odds ratios (ROR) being close to unity.

Table 5.2 shows the sensitivity and specificity of recall for the variable related to the fencing of the driveway for the 26 cases who were injured in the driveway and all controls. The odds ratio based on the questionnaire data (OR=3.03) overestimated the risks associated with the absence of a fence separating the driveway from the play area when compared to the gold standard (OR=1.92), with an ROR of 1.59.

The validation study data in Table 5.3 can be used to estimate the odds ratio for "absence of a fenced play area", after correction for misclassification. Using the direct method for estimating true exposure proportions as described by Marshall, the true proportion of cases exposed (PE cases), correcting for misclassification is given by (Appendix 4):

\[
PE \text{ cases} = \frac{54}{63} \times \frac{119}{200} + \frac{6}{38} \times \frac{81}{200} \\
= 0.5739
\]

The true proportion of controls exposed (PE controls), correcting for misclassification (PE controls) is given by:

\[
PE \text{ controls} = \frac{33}{41} \times \frac{172}{400} + \frac{6}{60} \times \frac{228}{400} \\
= 0.4031
\]

The corresponding odds ratio, corrected for misclassification is given by:
A comparison of the uncorrected odds ratio (OR=1.95) with the misclassification corrected odds ratio (OR=1.99) shows that the former was minimally biased towards the null.
Table 5.1: Sensitivity and specificity of recall by case control status.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases</th>
<th>Controls</th>
<th>Case-control difference</th>
<th>Ratio of odds ratios (ROR)**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=100</td>
<td>n=100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Play area not fenced off from street</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.78</td>
<td>0.87</td>
<td>-0.09 (-0.25, +0.07)*</td>
<td>1.05 (2.44/2.32)</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.90</td>
<td>0.85</td>
<td>+0.05 (-0.09, +0.19)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Play area not fenced off from drive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.68</td>
<td>0.85</td>
<td>-0.17 (-0.39, +0.05)</td>
<td>1.28 (1.89/1.47)</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.93</td>
<td>0.91</td>
<td>+0.02 (-0.07, +0.11)</td>
<td></td>
</tr>
</tbody>
</table>

* 95% confidence interval.
** ROR = odds ratio questionnaire/odds ratio direct observation.
Table 5.2: Sensitivity and specificity of recall for driveway cases and all controls.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases</th>
<th>Controls</th>
<th>Case-control difference</th>
<th>Ratio of odds ratios (ROR)**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=26</td>
<td>n=100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Play area not fenced off from drive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.50</td>
<td>0.87</td>
<td>-0.37 (-0.74,-0.004)*</td>
<td>1.59 (3.03/1.92)</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.89</td>
<td>0.86</td>
<td>+0.03 (-0.15,+0.210)</td>
<td></td>
</tr>
</tbody>
</table>

* 95% confidence interval.
** ROR = odds ratio questionnaire/odds ratio direct observation.
Table 5.3 Validation study data for "absence of fenced play area".

<table>
<thead>
<tr>
<th></th>
<th>Direct observation</th>
<th></th>
<th>Validation study</th>
<th>Full study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>exposed</td>
<td>unexposed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interview Cases</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>exposed</td>
<td>54</td>
<td>9</td>
<td>63</td>
<td>119</td>
</tr>
<tr>
<td>unexposed</td>
<td>6</td>
<td>32</td>
<td>38</td>
<td>81</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>41</td>
<td>101</td>
<td>200</td>
</tr>
<tr>
<td>Controls Cases</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>exposed</td>
<td>33</td>
<td>8</td>
<td>41</td>
<td>172</td>
</tr>
<tr>
<td>unexposed</td>
<td>6</td>
<td>54</td>
<td>60</td>
<td>228</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>62</td>
<td>101</td>
<td>400</td>
</tr>
</tbody>
</table>
5.4 Discussion.

The gold standard used in this validation study comprised direct measurement by a research officer who was blind as to whether the home was that of a case or a control. Comparison of all child pedestrian injury cases with all controls provided no evidence for differential recall. Overall the sensitivity and specificity of parental recall was high. However the sensitivity of recall for the question related to the fencing of the driveway was significantly lower for cases injured in driveways than for the controls. This had a substantial effect on the magnitude of the calculated odds ratio, such that the odds ratio based on the misclassified data overestimated the protective effect associated with the presence of a fence separating the driveway from the play area. There are several possible explanations for these findings.

Parents of cases in this study were most often interviewed in hospital, whereas controls were interviewed in their own homes. Since the questions are related to aspects of the home environment it would be easier for parents of controls to provide accurate responses. However if this was the case, one would expect the sensitivity for the responses in Table 5.1 to be as low as the responses for the driveway cases in Table 5.2.

A more plausible explanation is that the parents of the
children who were injured in driveways overstated the extent to which their driveways were unfenced. A previous study of driveway pedestrian injuries in Auckland found that children injured in driveways are most often injured by a parent or relative reversing out of the drive (Roberts et al 1993 b). In such situations parents who have injured their own child appear to over report the extent to which their driveway was unfenced. A large proportion of these injuries involve children living in government housing so that the responsibility for providing fences and therefore fault in the case of injury may be perceived to lie with the government rather than the householder (Roberts et al in press).

These results suggest that for driveway related pedestrian injuries, exposure information should be collected by direct observation. However for the traffic pedestrian injuries, the validation sub-study presented in this chapter demonstrates that the use of exposure information collected by interviewer administered questionnaire is unlikely to have introduce significant bias and that the small amount of bias introduced was towards the null.
RISK FACTORS FOR TRAFFIC PEDESTRIAN INJURIES
CHAPTER 6. RISK FACTORS FOR MOTOR VEHICLE TRAFFIC PEDESTRIAN INJURIES

6.1 Introduction.

Pedestrian injuries in childhood can be divided into two broad categories based on the location of injury. The majority of child pedestrian injuries occur on public roads and are classified as "motor vehicle traffic accidents" by the ICD 9 E coding system (WHO 1977). The remainder, classified as "motor vehicle non-traffic accidents", occur off public roads, most often when a child is reversed over in a residential driveway. In this chapter risk factors for motor vehicle traffic child pedestrian injuries are examined. Specifically, the risks associated with traffic volume, vehicle speed, parked vehicles and the availability of safe areas for children's play, are determined. As discussed in chapter three, in order to examine the risks associated with variables related to the traffic environment, it was necessary to use a matched design. Therefore the analyses in this chapter are based on traffic pedestrian injury cases and their matched controls using conditional logistic regression. Risk factors for non-traffic child pedestrian injuries will be examined in the next chapter.
6.2 Results.

Of the 206 children injured as pedestrians over the study period, 160 (78\%) were injured on public roads. The parents of 156 of these children agreed to participate in the study, a response rate of 98\%. The site of pedestrian-motor vehicle collision was identified for all of the 156 participating cases. Two controls were selected for each participating case, a total of 312 controls. These 312 controls were randomly selected from the 400 controls participating in the study. The overall response rate for the control group was 99\%. Each "case site" was matched with two corresponding "control sites" as described in chapter three. The analyses presented below are therefore based on 156 traffic pedestrian injury cases and 312 matched controls, a case:control ratio of 1:2. The age and sex distribution of the cases and controls are shown in Table 6.1. It is evident that for children under five years matching by sex was not as close as had been anticipated. This discrepancy arose because the frequency matching was based on the totality of cases rather than frequency matching traffic and non-traffic separately.

6.2.1 Univariate analyses

Table 6.2 presents effect estimates for traffic volume, vehicle speed, parking density and absence of a fenced play area, both preserving the matching and ignoring it.
Table 6.1 Age and sex distribution for cases and controls.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (%) n=156</th>
<th>Controls (%) n=312</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-4</td>
<td>34 (22)</td>
<td>18 (6)</td>
</tr>
<tr>
<td>5-9</td>
<td>78 (50)</td>
<td>200 (64)</td>
</tr>
<tr>
<td>10-14</td>
<td>44 (28)</td>
<td>94 (30)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>95 (61)</td>
<td>192 (62)</td>
</tr>
<tr>
<td>Female</td>
<td>61 (39)</td>
<td>120 (39)</td>
</tr>
</tbody>
</table>
Table 6.2 Univariate odds ratios calculated in unmatched and matched analyses for traffic volume, vehicle speed, parking density and absence of fenced play area.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unmatched analysis</th>
<th>Matched analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cases (%)</td>
<td>Controls (%)</td>
</tr>
<tr>
<td>n=156</td>
<td>n=312</td>
<td></td>
</tr>
<tr>
<td>Traffic volume (vehs/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;250</td>
<td>47 (30)</td>
<td>228 (73)</td>
</tr>
<tr>
<td>250-499</td>
<td>25 (16)</td>
<td>34 (11)</td>
</tr>
<tr>
<td>500-749</td>
<td>19 (12)</td>
<td>17 (5)</td>
</tr>
<tr>
<td>&gt;750</td>
<td>65 (42)</td>
<td>33 (11)</td>
</tr>
<tr>
<td>Mean Speed (km/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;40</td>
<td>21 (14)</td>
<td>73 (23)</td>
</tr>
<tr>
<td>40-49</td>
<td>52 (33)</td>
<td>91 (29)</td>
</tr>
<tr>
<td>&gt;=50</td>
<td>83 (53)</td>
<td>148 (47)</td>
</tr>
<tr>
<td>Curb parked (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>109 (70)</td>
<td>266 (85)</td>
</tr>
<tr>
<td>5-9</td>
<td>13 (8)</td>
<td>27 (9)</td>
</tr>
<tr>
<td>&gt;=10</td>
<td>34 (22)</td>
<td>19 (6)</td>
</tr>
<tr>
<td>Play area fenced off from street</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>151 (48)</td>
<td>161 (52)</td>
</tr>
<tr>
<td>No</td>
<td>97 (62)</td>
<td>59 (38)</td>
</tr>
</tbody>
</table>
Overall, the effect estimates calculated when the matching was ignored were closer to the null value. This was particularly evident for traffic volume. It implies that there was a correlation between the matching factors and the exposures and indicates that a matched analyses should be undertaken.

In univariate (matched) analyses there were strong and significant risks associated with high traffic volumes. Sites with a traffic volume greater than 750 vehicles per hour were associated with a thirteen fold increase in the risk of pedestrian injury relative to the baseline (OR=13.0 95%CI 6.71, 25.20). Sites with a mean vehicle speed greater than 40 kph were associated with a significantly increased risk (OR=1.96 95%CI 1.08, 3.53), although there was no evidence of increasing risk over exposure categories. There was also a significantly increased risk at sites where more than 10% of the curb was parked (OR=4.48 95%CI 2.37, 8.45). There was a significantly increased risk associated with the absence of a fenced play area (OR=2.00 95%CI 1.31, 3.07). However when the analysis was repeated excluding the 52 cases injured on the way to and from school, the odds ratio associated with the absence of a fenced play area was reduced (OR=1.57 95%CI 0.96, 2.58).

6.2.2 Multivariate analyses

Table 6.3 shows multivariate odds ratios for the variables traffic volume, vehicle speed, parking density and the absence
of a fenced play area. Overall there was little difference between the effect estimates obtained in the univariate matched analysis (Table 6.2) and the multivariate matched analysis, suggesting that the risk factors are largely independent of one another. Table 6.4 shows multivariate odds ratios for traffic volume, vehicle speed, parking density and the absence of a fenced play area after controlling for age, sex, all social and familial variables and all variables related to the home environment. Once again, there was little difference between the effect estimates obtained in univariate matched analysis (Table 6.2) and in the multivariate matched analysis, suggesting that the risk factors are largely independent of the variables included in the model. When the analysis was repeated excluding the 52 cases injured on the way to and from school, the odds ratios associated with the absence of a fenced play area fell to 1.34 (95%CI 0.73, 2.46). The odds ratios for traffic volume, vehicle speed and parking density were essentially unchanged.
Table 6.3 Multivariate odds ratios (matched analyses) for traffic volume, vehicle speed, parking density and absence of fenced play area, after adjusting for each of the other three variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>(95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic volume (vehs/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;250</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>250-499</td>
<td>4.78</td>
<td>(2.01, 11.40)</td>
</tr>
<tr>
<td>500-749</td>
<td>7.62</td>
<td>(2.92, 19.90)</td>
</tr>
<tr>
<td>≥750</td>
<td>15.70</td>
<td>(7.09, 34.80)</td>
</tr>
<tr>
<td>Mean Speed (km/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;40</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>40-49</td>
<td>2.82</td>
<td>(1.22, 6.50)</td>
</tr>
<tr>
<td>≥50</td>
<td>1.21</td>
<td>(0.53, 2.81)</td>
</tr>
<tr>
<td>Curb parked (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>5-9</td>
<td>1.66</td>
<td>(0.65, 4.27)</td>
</tr>
<tr>
<td>≥10</td>
<td>4.27</td>
<td>(1.83, 9.95)</td>
</tr>
<tr>
<td>Play area fenced off from street</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1.66</td>
<td>(0.96, 2.84)</td>
</tr>
</tbody>
</table>
Table 6.4 Multivariate odds ratios (matched analyses) for traffic volume, vehicle speed, parking density and absence of fenced play area, controlling for age, sex, social and familial variables and variables related to the home environment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>(95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic volume (vehs/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 250</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>250-499</td>
<td>5.09</td>
<td>(1.85, 14.00)</td>
</tr>
<tr>
<td>500-749</td>
<td>7.46</td>
<td>(2.59, 21.50)</td>
</tr>
<tr>
<td>≥ 750</td>
<td>10.30</td>
<td>(4.26, 24.80)</td>
</tr>
<tr>
<td>Mean Speed (km/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 40</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>40-49</td>
<td>2.91</td>
<td>(1.11, 7.68)</td>
</tr>
<tr>
<td>≥ 50</td>
<td>1.22</td>
<td>(0.48, 3.14)</td>
</tr>
<tr>
<td>Curb parked (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 5</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>5-9</td>
<td>1.87</td>
<td>(0.61, 5.70)</td>
</tr>
<tr>
<td>≥ 10</td>
<td>4.54</td>
<td>(1.52, 13.60)</td>
</tr>
<tr>
<td>Play area fenced off from street</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1.84</td>
<td>(0.98, 3.44)</td>
</tr>
</tbody>
</table>
Table 6.5 shows multivariate odds ratios for the variables of interest for the 93 cases who were injured within 500 metres of their home and their matched controls. The odds ratio point estimates for traffic volume were similar to those obtained in the analysis of all cases, although as would be expected, the precision of the estimates was much lower. The odds ratios for the vehicle speed variable increased substantially at both levels of exposure but only reached statistical significance at the 0.05 level for the middle exposure category. There were increased odds ratios associated with both levels of parking density, although these did not reach significance at the 0.05 level. The risk associated with the absence of a fenced play area was of a similar magnitude to that obtained in the analysis of all cases, but did not reach significance at the 0.05 level.
Table 6.5 Multivariate odds ratios for traffic volume, vehicle speed, parking density and the absence of a fenced play area for the 93 cases injured within 500 metres of their home and matched controls.

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>(95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic volume (vehs/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;250</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>250-499</td>
<td>5.97 (1.89, 18.90)</td>
<td></td>
</tr>
<tr>
<td>500-749</td>
<td>7.03 (2.01, 24.60)</td>
<td></td>
</tr>
<tr>
<td>&gt;=750</td>
<td>9.78 (3.40, 28.10)</td>
<td></td>
</tr>
<tr>
<td>Mean Speed (km/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;40</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>40-49</td>
<td>6.00 (1.70, 21.20)</td>
<td></td>
</tr>
<tr>
<td>&gt;=50</td>
<td>3.07 (0.83, 11.40)</td>
<td></td>
</tr>
<tr>
<td>Curb parked (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>5-9</td>
<td>2.32 (0.66, 8.09)</td>
<td></td>
</tr>
<tr>
<td>&gt;=10</td>
<td>3.09 (0.86, 11.10)</td>
<td></td>
</tr>
<tr>
<td>Play area fenced off from street</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1.99 (0.97, 4.07)</td>
<td></td>
</tr>
</tbody>
</table>

* Variables included in multivariate model were traffic volume, vehicle speed, parking density, absence of a fenced play area, socioeconomic position, ethnic group, age and sex.
6.2.3 Tests for dose response.

There are a range of definitions of dose response of which one of the most rigorous is that every increment in exposure is associated with a positive increment in risk (Maclure et al 1992). To evaluate this hypothesis, the odds ratios at each category of exposure must be contrasted with those at the next lower category. If each of the "incremental odds ratios" is greater than one with the lower bounds of the 95% confidence intervals falling above one, then, using the descriptive terminology suggested by Maclure, the data can be said to "provide evidence for" an increasing dose response relation. If the incremental odds ratios are greater than one but the lower bounds of the 95% confidence intervals include one, the data can be said to "conform to" an increasing dose response relation. In Table 6.6, the incremental odds ratios and 95% confidence intervals are presented for traffic volume, vehicle speed and parking density. For traffic volume, all of the incremental odds ratios were greater than one although the lower bounds of the 95% confidence intervals included one. For vehicle speed the incremental odds ratio for highest exposure category was less than one. For the parking density variable, both of the incremental odds ratios were greater than one, although the confidence intervals for the middle exposure level included one. Therefore for traffic volume and parking density the data "conform to" an increasing dose response, whilst there is no evidence of a monotonic increasing (or decreasing) dose response relation for vehicle speed.
Table 6.6 Incremental odds ratios for traffic volume, vehicle speed and parking density.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Incremental OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic volume (vehs/hr)</td>
<td></td>
</tr>
<tr>
<td>&lt;250</td>
<td>1.00</td>
</tr>
<tr>
<td>250-499</td>
<td>4.47 (2.16, 9.25)</td>
</tr>
<tr>
<td>500-749</td>
<td>1.61 (0.62, 4.16)</td>
</tr>
<tr>
<td>&gt;=750</td>
<td>1.81 (0.79, 4.11)</td>
</tr>
<tr>
<td>Mean Speed (km/hr)</td>
<td></td>
</tr>
<tr>
<td>&lt;40</td>
<td>1.00</td>
</tr>
<tr>
<td>40-49</td>
<td>1.96 (1.08, 3.53)</td>
</tr>
<tr>
<td>&gt;=50</td>
<td>0.98 (0.64, 1.50)</td>
</tr>
<tr>
<td>Curb parked (%)</td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>1.00</td>
</tr>
<tr>
<td>5-10</td>
<td>1.22 (0.60, 2.49)</td>
</tr>
<tr>
<td>&gt;=10</td>
<td>3.66 (1.51, 8.88)</td>
</tr>
</tbody>
</table>
6.3 Discussion.

As discussed in chapter four, incomplete ascertainment of cases is unlikely to have resulted in significant bias in this study. Similarly, in view of the very high response rates for both cases (98%) and controls (99%), non response is also unlikely to have introduced significant bias. Potentially more potent threats to the validity of the results presented in this chapter are the problems of misclassification and confounding.

In preliminary analyses the effect of the duration of the exposure measurement period for traffic volume was examined. A range of different measurement periods were evaluated, each with the collision time at the mid point of the measurement period. The motivation for evaluating a range of time windows for exposure measurement was uncertainty as to whether measurement error in traffic volume estimation over a short, but logically more appropriate period, would introduce more or less exposure misclassification than would a possibly more stable volume estimate over a longer, but less relevant period. The period of traffic volume aetiologically related to the occurrence of a child pedestrian–motor vehicle collision is likely to be the traffic volume at the instant that the child enters the roadway, effectively an induction time of zero. Ideally, measurement error may have been minimised by making repeated volume measurements over a very short period around the time of injury and taking as the relevant exposure
information the average of these. However this would have involved considerable extra cost.

It was found that varying the length of the exposure measurement period had a dramatic effect on the magnitude of the odds ratio (Roberts et al 1993 d). Overall there was a trend towards decreasing odds ratios with increasing length of the exposure measurement period. It was evident in these analyses that the decrease in the odds ratio, as the exposure measurement period lengthened, was almost entirely due to changes in the classification of case sites, suggesting that the misclassification was differential. Of note, differential misclassification may have resulted even from non differential exposure measurement error, as might occur with an excessively short measurement period. Flegal et al (1991) observed that two conditions must be met for this type of misclassification to occur. Both of these conditions are fulfilled in this study. First, the probability of injury is likely to be related to the exposure in a continuous fashion rather than categorically, and second, the probability of misclassification will vary with the exposure level, being greatest close to the cut point. Similarly, the inclusion of irrelevant exposure information, as a form of non differential measurement error, might also have resulted in differential misclassification, the degree and direction depending on the position of the cut point. With a high cut point, inclusion of irrelevant exposure information would result in a greater degree of misclassification for cases than for controls,
because the true exposure values for the cases will be closer to the cut point.

Because differential misclassification can bias the odds ratio towards or away from the null, deciding which exposure period involves the least measurement error and the minimum of bias, is problematic. In the analyses presented in this chapter a three hour exposure measurement period was selected, although as there was no gold standard measurement for comparison, the decision to use this particular time period remains somewhat arbitrary. However whereas in the preliminary analyses traffic volume was dichotomised into exposed and unexposed, in the analyses presented in this chapter, the risks associated with traffic volume were evaluated over multiple exposure levels. The use of narrower categories would reduce the extent to which the probability of misclassification varies within a category so that the potential for differential misclassification bias would have been reduced.

For traffic volume and vehicle speed, exposure classification was based on measurements made on the same weekday as the injury and at the same time of the day, but one week later. Although it was possible to demonstrate that traffic volume and speed are relatively stable characteristics (Roberts et al in press), differences between the conditions at the time of injury and at the time of measurement would inevitably have resulted in some degree of exposure misclassification. Similarly, inaccuracies in parental reporting of the time of
injury may also have resulted in exposure misclassification. For vehicle speed, the exposure measure chosen in this study was the mean vehicle speed for the three hour period around the time of injury. Again this is only a crude proxy for a more relevant measure such as the speed of the impacting vehicle. Nevertheless the use of the mean speed may be defended as being the more relevant measure from a public health perspective since this is the parameter which is routinely measured in neighbourhood traffic studies.

There is also the potential for misclassification in relation to the parking density variable. The variable "curb parked" was created by averaging the parking densities on both sides of the street at sites of pedestrian injury and control sites. Had it been possible to ascertain accurately from which side of the road the child was walking before being struck, then this may have provided a more aetiologically relevant measure. If so, taking the average density of parking over both sides may again have resulted in exposure misclassification and bias.

A further methodological issue which needs to be addressed is the choice of cut points in the creation of exposure categories. For some variables, such as traffic volume, the choice of cut points had little effect on the magnitude of the odds ratios. However for speed, preliminary analyses demonstrated that the choice of cut point had a much greater influence on the magnitude of the odds ratio. In the case of
speed, the particular cut points chosen for the analyses presented in this chapter were chosen to represent the most meaningful divisions (eg residential area speed limit of 50 kph), but also taking into account the distribution of subjects over exposure categories.

Confounding would be present if there was a difference in injury incidence between the exposed and unexposed, if the exposure were removed (Steineck et al 1992). In relation to the risks associated with traffic volume it is possible that sites with high traffic volumes would have a greater incidence of child pedestrian injury even if volumes were not high, because more children cross at such sites. For example, shopping areas may have high traffic volumes but they 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 indeed may even chose to play in quiet streets. Nevertheless when the analysis was limited to children injured within 500 metres of their home and their matched controls, there was still a markedly elevated pedestrian injury risk for children living in neighbourhoods with high traffic volumes. Restricting the analysis to the immediate neighbourhoods of cases and controls in this way would be expected to limit the extent to which children’s road crossing varies.

The amount of road crossing may also have confounded the association with vehicle speed. This may explain the 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. Due to the method of control selection in this study, fast roads may have been selected as control sites but because they are crossed less frequently would be less likely to become case sites. This confounding essentially arises due to the way the study base was specified. It might have been possible to avoid it had "person time road crossing" been sampled as opposed to just "person time". The risk estimates for high vehicle speed in this study may therefore be under estimates.
RISK FACTORS FOR NON-TRAFFIC PEDESTRIAN INJURIES
CHAPTER 7. RISK FACTORS FOR NON-TRAFFIC PEDESTRIAN INJURIES

7.1 Introduction.

The majority of pedestrian injuries in childhood are sustained when a child is struck by a rapidly moving vehicle on a public roadway. However for children younger than five years, non-traffic pedestrian injuries, most often involving a child reversed over in a residential driveway, account for the majority of deaths and hospitalisations (Brison et al 1988). To date there have been no controlled epidemiologic studies of driveway related child pedestrian injuries. As a result there are few well established countermeasures. In this chapter risk factors for driveway related child pedestrian injuries are examined. As in previous chapters, the major analytic focus concerns the estimation of the risks associated with the availability of safe areas for children's play. In the context of driveway related pedestrian injuries, this pertains to the presence or absence of physical barriers between the play area and the driveway.

7.2 Results.

Of the 206 children injured as pedestrians over the study period, 40 (19%) were injured in residential driveways. The parents of 38 of these children agreed to participate in the study, a response rate of 95%. Three controls were selected
for each identified case, a total of 120 controls. The parents of 117 of these controls agreed to participate in the study, a response rate of 98%. The age and sex distribution of the 38 cases and 117 controls is shown in table 7.1. It is evident from this table that cases were younger than controls and that a somewhat greater proportion of cases were male compared with controls.

7.2.1 Univariate analyses

Univariate odds ratios and 95% confidence intervals for a range of social and familial variables and for variables related to the home environment are presented in Tables 7.2 and 7.3. Univariate odds ratios have confidence intervals calculated by the method of Cornfield except for the socioeconomic position variable where the exact method was used because cell numbers were small. There was an inverse association between the risk of driveway related pedestrian injury and socioeconomic position. The risk of injury for children from families in the lowest socioeconomic group was close to six times that of children in the reference category (OR=5.81 95%CI 1.45, 33.21), although the precision of this point estimate is low. The risk of injury for Maori children was over four times that of children in the reference category (OR=4.08 95%CI 1.42, 11.78) and the risk for Pacific Island children was close to three times that of children in the reference category (OR=2.85 95%CI 1.05, 7.79). Children from families with more than two children under five years were
also at increased risk (OR=6.40 95%CI 2.05, 20.49). Odds ratios for the personal health related variables described in previous chapters were not examined for driveway injuries because the numbers of subjects in this component of the study was low and these exposures were rare.
Table 7.1 Age and sex distribution of (non-traffic) cases and controls.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (%)</th>
<th>Controls (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=38</td>
<td>n=117</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 3</td>
<td>25 (66)</td>
<td>51 (44)</td>
</tr>
<tr>
<td>&gt;=3</td>
<td>13 (34)</td>
<td>66 (56)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>23 (61)</td>
<td>64 (55)</td>
</tr>
<tr>
<td>Female</td>
<td>15 (39)</td>
<td>53 (45)</td>
</tr>
</tbody>
</table>
Table 7.2 Numbers and odds ratios for social and familial variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (%)</th>
<th>Controls (%)</th>
<th>Crude OR (95% CI)</th>
<th>Adjusted OR** (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Socioeconomic position</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I, II, III</td>
<td>3 (8)</td>
<td>31 (27)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>IV, V</td>
<td>17 (45)</td>
<td>54 (46)</td>
<td>3.25 (0.83, 18.51)*</td>
<td>2.44 (0.49, 12.03)</td>
</tr>
<tr>
<td>VI and others</td>
<td>18 (47)</td>
<td>32 (27)</td>
<td>5.81 (1.45, 33.21)*</td>
<td>1.91 (0.33, 11.04)</td>
</tr>
<tr>
<td><strong>Ethnic group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maori</td>
<td>11 (29)</td>
<td>14 (12)</td>
<td>4.08 (1.42, 11.78)</td>
<td>3.13 (0.80, 12.17)</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td>11 (29)</td>
<td>20 (17)</td>
<td>2.85 (1.05, 7.79)</td>
<td>1.22 (0.33, 4.44)</td>
</tr>
<tr>
<td>Other</td>
<td>16 (42)</td>
<td>83 (71)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Responsibility for child</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sole</td>
<td>10 (26)</td>
<td>21 (18)</td>
<td>1.63 (0.63, 4.18)</td>
<td>0.63 (0.19, 2.09)</td>
</tr>
<tr>
<td>Partner</td>
<td>28 (74)</td>
<td>96 (82)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Number of children (under 5 years)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; = 3 children</td>
<td>11 (29)</td>
<td>7 (6)</td>
<td>6.40 (2.05, 20.49)</td>
<td>3.24 (0.91, 11.57)</td>
</tr>
<tr>
<td>&lt; = 2 children</td>
<td>27 (71)</td>
<td>110 (94)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

* Exact confidence intervals.
** Adjusted for age, sex and variables in Tables 7.2 and 7.3.
Table 7.3 Numbers and odds ratios for variables related to the home and driveway environment.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cases (%)</th>
<th>Controls (%)</th>
<th>Crude OR (95% CI)</th>
<th>Adjusted OR** (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=38</td>
<td>n=117</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple dwelling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>8 (21)</td>
<td>7 (6)</td>
<td>4.19 (1.25, 14.20)</td>
<td>2.29 (0.56, 9.36)</td>
</tr>
<tr>
<td>No</td>
<td>30 (79)</td>
<td>110 (94)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Rental accommodation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>25 (66)</td>
<td>32 (84)</td>
<td>5.12 (2.18, 12.09)</td>
<td>4.00 (1.37, 11.69)</td>
</tr>
<tr>
<td>No</td>
<td>13 (34)</td>
<td>85 (73)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Resident &lt; 3 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>4 (11)</td>
<td>2 (2)</td>
<td>6.76 (0.91, 76.58)*</td>
<td>2.02 (0.21, 19.81)</td>
</tr>
<tr>
<td>No</td>
<td>34 (89)</td>
<td>115 (98)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Access to car</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>11 (29)</td>
<td>15 (13)</td>
<td>2.77 (1.04, 7.33)</td>
<td>1.87 (0.56, 6.27)</td>
</tr>
<tr>
<td>Yes</td>
<td>27 (71)</td>
<td>102 (87)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Shared driveway</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>12 (32)</td>
<td>25 (21)</td>
<td>1.70 (0.70, 4.12)</td>
<td>1.23 (0.38, 3.99)</td>
</tr>
<tr>
<td>No</td>
<td>26 (68)</td>
<td>92 (79)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Play area fenced from driveway</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>20 (53)</td>
<td>39 (33)</td>
<td>2.22 (0.99, 5.00)</td>
<td>2.43 (0.91, 6.49)</td>
</tr>
<tr>
<td>Yes</td>
<td>18 (47)</td>
<td>78 (67)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Driveway width</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 3.0 m</td>
<td>15 (39)</td>
<td>53 (45)</td>
<td>0.79 (0.35, 1.77)</td>
<td>0.52 (0.18, 1.56)</td>
</tr>
<tr>
<td>&lt;= 3.0 m</td>
<td>23 (61)</td>
<td>64 (55)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Driveway length</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 20 m</td>
<td>28 (74)</td>
<td>67 (57)</td>
<td>2.09 (0.87, 5.10)</td>
<td>3.19 (1.07, 9.56)</td>
</tr>
<tr>
<td>&lt;= 20 m</td>
<td>10 (26)</td>
<td>50 (43)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Driveway gradient</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Down to road</td>
<td>21 (55)</td>
<td>54 (46)</td>
<td>1.44 (0.65, 3.21)</td>
<td>0.85 (0.31, 2.38)</td>
</tr>
<tr>
<td>Up or flat to road</td>
<td>17 (45)</td>
<td>63 (54)</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

* Exact confidence interval.
** Adjusted for age, sex and variables in Tables 7.2 and 7.3
Living in a multiple dwelling (OR=4.19 95%CI 1.25, 14.20) living in rental accommodation (OR=5.12 95%CI 2.18, 12.09) and having no access to a car (OR=2.77 95%CI 1.04, 7.33) were associated with a significantly increased risk of driveway related pedestrian injury. Living in a home where the play area was unfenced was associated with a twofold increased risk, although this did not reach significance at the 0.05 level (OR=2.22 95%CI 0.99, 5.00).

7.2.2 Stratified analysis

Table 7.4 presents the distribution of cases and controls and the odds ratios associated with an unfenced driveway across age and sex strata. Examination of stratum specific effect estimates did not suggest effect modification by either age or sex. The Breslow-Day test for homogeneity of odds ratios over strata gave $X^2=0.249$ p=0.62 across age strata and $X^2=0.028$ p=0.81 across sex strata, thus failing to reject the null hypothesis of a uniform odds ratio across strata. The Mantel-Haenszel pooled odds ratios were essentially identical to the crude odds ratio suggesting no confounding by age or sex.
Table 7.4 Distribution of cases and controls and odds ratios associated with an unfenced driveway across age and sex strata.

<table>
<thead>
<tr>
<th>Age/Sex</th>
<th>&lt; 3 years</th>
<th>≥3 years</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure</td>
<td>E+</td>
<td>E-</td>
<td>E+</td>
<td>E-</td>
</tr>
<tr>
<td>Cases</td>
<td>14</td>
<td>17</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>Controls</td>
<td>11</td>
<td>34</td>
<td>7</td>
<td>44</td>
</tr>
<tr>
<td>OR</td>
<td>2.54</td>
<td>1.71</td>
<td>2.17</td>
<td>2.48</td>
</tr>
<tr>
<td>95% CI</td>
<td>(0.95, 6.79)</td>
<td>(0.51, 5.72)</td>
<td>(0.82, 5.77)</td>
<td>(0.77, 7.80)</td>
</tr>
<tr>
<td>Pooled OR</td>
<td>2.18</td>
<td></td>
<td>2.29</td>
<td></td>
</tr>
<tr>
<td>95% CI</td>
<td>(1.02, 4.64)</td>
<td></td>
<td>(1.09, 4.84)</td>
<td></td>
</tr>
</tbody>
</table>

E+ = Unfenced driveway present
E- = Unfenced driveway absent
* Test based confidence intervals.
7.2.3 Multivariate analyses

The risks associated with an unfenced driveway were examined after controlling for potential confounding variables in a multiple logistic regression model. Variables incorporated into the model as potential confounders included all of the social and familial variables shown in Table 7.2, all of the environmental variables shown in Table 7.3 and age and sex. The multivariate odds ratio associated with an unfenced driveway was 2.43 (95%CI 0.91, 6.49). This multivariate odds ratio (OR = 2.43) was close to the univariate odds ratio (OR = 2.22), suggesting that there was little or no confounding by the variables included in the model.

All of the multivariate odds ratios for the social and familial variables were closer to the null value than were the univariate odds ratios. Similarly, apart for the odds ratio for an unfenced driveway, controlling for potential confounders had the effect of reducing the magnitude of the odds ratios for the variables related to the home environment. Nevertheless, strong (although imprecise) associations remained for the variables multiple dwelling (OR=2.29 95%CI 0.56, 9.36), rental accommodation (OR=4.00 95%CI 1.37, 11.69), resident less than 3 months (OR=2.02 95%CI 0.21, 19.81) and a driveway length of more than 20 metres (OR=3.19 95%CI 1.07, 9.56).
7.2.4 Population attributable risks

Since there was no matching in the selection of pre-school controls, it is reasonable to assume that the exposure prevalence among the controls is likely to be representative of the exposure prevalence in the study base. Population attributable risks can therefore be estimated. The population attributable risk associated with an unfenced driveway was 28.9% (95% CI 10.6, 58.5).
7.3 Discussion.

Cases in this study were all children killed or injured as pedestrians in residential driveways, in the Auckland region, during the study period. Controls were a random sample of the child population. The same surveillance system was used for ascertaining "non-traffic" pedestrian injury cases in this study as was used in the study of "traffic" pedestrian injuries described in the previous chapter. Although it is possible that a small number of driveway cases were missed by the surveillance system, this is unlikely. Moreover, incomplete ascertainment would only introduce selection bias if the exposure prevalence among those included was different from among those not included. Since there is no reason to suspect this, incomplete case ascertainment is unlikely to have resulted in significant bias. In addition, response rates for both cases and controls were very high so that even if the exposure prevalence among non respondents was different from that among respondents, no major bias would be expected.

Exposure classification for the environmental variables in this study was based on the direct observations of a research officer rather than parental questionnaires. The validation study reported in chapter five had suggested that parents of children injured in driveways may have over reported the extent to which their driveways were unfenced. As a result, the use of parental questionnaires overestimated the risks associated with unfenced driveways. However by making
independent observations the possibility of recall bias was eliminated. Whenever possible the research officer was blind to whether the driveway was the site of an injury or a control site. Nevertheless sometimes this was not possible and since the research officer was aware of the study hypotheses the possibility of "interviewer bias" remains.

Confounding arises when the unexposed subjects in the study base have a different injury incidence than the exposed subjects would have had if the effect of the exposure were removed. In the context of this study it is possible that children from homes with fenced driveways might have a lower incidence of driveway pedestrian injury than would those from homes without fences, quite apart from the effect of the fencing. For example, parents from the homes with fenced driveways may be more aware of the problem of driveway injuries and consequently more cautious whilst reversing out of the driveway. The fencing may be a result of this increased awareness. Confounding by "cautiousness" is a potential bias in this study which cannot readily be avoided or controlled.

The main weakness of this component of the study is that, as a result of the small number of driveway injury cases, the precision of estimation is low. In order to achieve greater precision, the ratio of controls to cases was increased from 2:1 to 3:1 for the non-traffic component of the study. Increasing the number of cases studied by expanding the study either geographically or temporally would have afforded
greater precision, however resource constraints did not allow for this.
CONCLUSIONS
CHAPTER 8. CONCLUSIONS

8.1 Environment and injury: association or causation?

In the analyses presented in the preceding chapters the contribution of four potentially modifiable environmental risk factors for child pedestrian injury were examined: traffic volume, vehicle speed, parked vehicles and the availability of safe areas for children's play. The primary aim of the preceding chapters has been to assess the presence and magnitude of the associations between these exposures and the risk of child pedestrian injury. In this chapter the associations found are considered in the context of causal inference. Implications for the prevention of child pedestrian injuries are then discussed.

8.1.1 Traffic volume

There was a strong association between traffic volume and the risk of child pedestrian injury. The risk of pedestrian injury at sites with the highest traffic volumes was over ten times that for the least busy sites. Similarly children living in neighbourhoods with the highest traffic volumes had a risk of pedestrian injury nearly ten times greater than that of children living in the least busy neighbourhoods. The strong association with traffic volume remained after controlling for potential confounding factors in multivariate models.
This strong association between the risk of injury and traffic volume is consistent with the results of a previous North American case-control study of child pedestrian injuries, although the magnitude of the risks obtained in this study were greater. Mueller et al obtained an adjusted odds ratio of 3.1 (95% CI 0.9, 10.8) for neighbourhoods with the highest traffic volumes. The analyses presented in appendix 4 however provide one possible explanation for the difference in the magnitude of the effect estimates. Specifically, the use of a 24 hour exposure measurement period in the study by Mueller may have lead to an underestimation of the effect of traffic volume. The results obtained in the current study are also consistent with the ecological data. In New Zealand, government restrictions on car use in the aftermath of the 1974 energy crisis were associated with a 46.4% reduction in the child pedestrian mortality rate.

Because the examination of the risks associated with the traffic environment required a matched design, it was not possible to calculate population attributable risks for exposure to high traffic volume. However the strength of the association is such that if even a comparatively modest proportion of the child population were exposed, then a high proportion of injuries may be attributable to this risk factor.

In chapter six, analyses were conducted to examine whether a "dose response" relation existed between traffic volume and
the risk of pedestrian injury. These analyses employed a considerably more rigorous definition of dose response than is conventionally used. It was demonstrated that all of the incremental relative risks were greater than unity although the lower bounds of the 95% confidence limits included unity. Using the descriptive terminology suggested by Maclure, these data can be said to "conform to" an increasing dose response (Maclure et al 1992). However, in these analyses traffic volume was evaluated over four exposure levels. As a result the number of cases and controls at each exposure level would be comparatively small. When traffic volume was evaluated over three exposure levels, all of the lower bounds of the 95% confidence intervals for the incremental relative risks were greater than unity.

That a causal relation exists between high traffic volume and the risk of child pedestrian injury is undoubtedly plausible. The typical mechanism of pedestrian injury in childhood involves the sudden entry into the roadway of a child, unseen by the driver of the vehicle involved (Snyder et al 1971). In such situations it is reasonable to expect that the greater the traffic volume the greater the probability of a collision. However, whilst a causal relation seems plausible at the individual level, at the population level there are data which may, at first sight, appear to conflict with this assertion. Over the past two decades, child pedestrian mortality rates in both Britain and the USA have fallen, despite an almost exponential increase in traffic volume. This decline cannot be
readily explained by the effect of child pedestrian education programmes nor a reduction in the case fatality rates (Roberts 1993 c). It would seem logical that if the total volume of traffic increases, more children would be exposed to conditions of high traffic volume and the incidence of child pedestrian injury would increase. There is however a plausible explanation for this apparent paradox. Concomitant with the increase in traffic volume there has been marked decline in children’s traffic exposure. As the volume of road traffic has increased, streets have become more dangerous and increasingly children have been kept away from them. A British study, which examined changes in children’s independent mobility over the past two decades, found that whereas in 1971, 80% of seven and eight year old children were allowed to travel to school unaccompanied, in 1990 the figure was 9% (Hillman et al 1990). The decline in incidence would not be compatible with high traffic volume being a sufficient cause of child pedestrian injury, nevertheless it is readily compatible with high traffic volume being a component cause.

It could be argued that efforts to establish whether a causal relation exists between traffic volume and the risk of child pedestrian injury are superfluous. By definition vehicles are a necessary cause of pedestrian-motor vehicle collisions. However the research question at the heart of this thesis goes further. By categorising the continuous variable traffic volume into multiple levels of exposure, the research question becomes re-defined. Exposure to the highest level of traffic
volume is neither necessary nor sufficient for the occurrence of child pedestrian injury. The aim of this study was to examine the extent to which high traffic volume explains the distribution of child pedestrian injury occurrence (Rose 1985). Starting from the conceptual framework of Rothman’s model of causal constellations, it follows that the strength of a risk factor is determined by the relative prevalence of the component causes (Rothman 1986). The high risks associated with conditions of high traffic volume suggest that other component causes are prevalent so that high traffic volume differentiates children at high risk of injury from those at low risk. This stands in stark contrast to the results of studies which have examined the contribution of personal and behavioral risk factors to the occurrence of child pedestrian injury (Pless et al 1989). The most striking finding in these studies is the lack of strong risk factors identified. This implies that the exposures examined are comparatively widespread and consequently of little discriminatory value.

8.1.2 Vehicle speed

There were increased risks of pedestrian injury for sites with high vehicle speeds, although the data did not conform to a monotonic increasing dose response relationship. The highest risks were found in the middle speed category. There are two possible explanation for this pattern of point estimates. First it is possible that the pattern of effect estimates is merely a manifestation of low precision in the highest speed
category. In which case the point estimates in the highest speed categories might diverge from an increasing dose response relation only because of random error. However it is also possible that the data are an accurate reflection of an underlying nonlinear relation. It is possible that the risk of pedestrian injury increases with increasing vehicle speed, until at very high speeds, there are behavioural changes such that, although streets in the highest speed categories may be more dangerous to cross, because they are perceived as dangerous they are crossed less often. Because of the method of control site selection in this study, such fast sites may be selected as control sites but if they were crossed much less often they would be less likely to become case sites. This would essentially amount to confounding by children's road crossing. It is interesting to observe that the same pattern of point estimates remained when the analysis was restricted to children injured within 500 metres of their homes and their matched controls, although the risks were much higher in both exposure categories. If there is confounding by "road crossing" then the risks associated with high vehicle speeds estimated in this study are likely to be underestimates.

Only one case-control study has examined the association between vehicle speed and the risk of child pedestrian injury. Mueller et al found that there was an increase in the risk of injury with increasing posted speed limit. Sites with a posted speed limit of greater than 40 mph were associated with a six
fold increase in risk (OR=6.0 95%CI 1.4, 26.9). However after controlling for traffic volume the strength of this association was much reduced (OR=3.4 95%CI 0.6, 18.9). That high vehicle speed is a risk factor for greater injury severity in a pedestrian motor vehicle collision was demonstrated in the Pedestrian Injury Causation Study (Pitt et al 1990). Pitt (1990) found a mean Injury Severity Score difference of 11.02 between the lowest and the highest travel speed categories. In the present study, as in the case-control study by Mueller, it was not possible to separate out risk factors for the occurrence of a child pedestrian motor vehicle collision and risk factors for increased injury severity given that a collision has occurred, since becoming a case depends on both of these factors. Nevertheless the results of all three studies are consistent, the effects are strong and the findings are plausible.

8.1.3 Parked vehicles

Strong associations were found between the risk of child pedestrian injury and the density of on street parking. Sites where more than 10% of the curb was parked were associated with a fourfold increase in the risk of pedestrian injury. This association remained after controlling for potentially confounding factors in a multivariate model. On investigation for a dose response relation, the risks associated with parked vehicles were found to "conform to" an increasing dose response, with all of the incremental odds ratios being
greater than unity, but with the lower bounds of the 95% confidence intervals including the null value. To date, only one other controlled study has examined the risks associated with on street parking, the case-control study of Mueller et al. In an analysis limited to children injured outside their own homes and their matched controls, Mueller et al estimated an odds ratio of 2.2 (95% CI 0.6, 8.4) for sites where more than 50% of the curb was parked. However, this result was in univariate analyses, so that the possibility of confounding by traffic volume or other variables remains open to question. Nevertheless the proposition that parked vehicles may increase the risk of child pedestrian injury by obscuring the driver’s view of the child as s/he enters the roadway is supported by the current data.

8.1.4 Safe areas for children’s play

Case-control studies conducted in North American and Britain have found that children living in homes without a play area are at an increased risk of pedestrian injury. Mueller et al estimated an odds ratio of 5.3 (95% CI 2.6, 11.0) for children living in homes without a play area and Backett et al estimated an odds ratio of 2.56 (95% CI 1.37, 4.79) for children in homes "without any play amenities". The results of the present study are consistent with these findings. Children living in homes without a play area were at a significantly increased risk of pedestrian injury (OR=35.37 95% CI 2.03, 615.95). However because none of the 400 control children were
exposed to this risk factor, the precision of the estimate obtained in this study was very low. Regardless, the very low prevalence of the exposure in the population, would mean that this risk factor, although strong, is unlikely to be important at the population level. Possibly more important is the risk associated with an unfenced play area. As described in chapters four and six, children from homes without a fenced play area were found to be at a significantly increased risk of pedestrian injury (OR=2.00 95%CI 1.31, 3.07). This increased risk remained after controlling for potential confounding variables (OR=1.84 95%CI 0.98, 3.44), in particular after controlling for traffic volume. However the observation that the risks associated with the absence of a play area were reduced when children injured on the way to and from school were excluded from the analysis casts further doubt on a causal association. It is not plausible that the absence a fenced play area would be aetiologicaly related to the occurrence of a pedestrian injury whilst walking to or from school. One would expect that if the absence of a play area were aetio logically related to the occurrence of a pedestrian injury, then the risks would be increased after excluding outcomes that were aetio logically unrelated.

To date, only one case-control study has examined this association. Mueller et al found an odds ratio of 1.3 (95%CI 0.7, 2.6) associated with "no fenced yard at residence". However because of the small size of this study the precision of estimation was low and the ability to control for potential
confounding factors was limited.

The absence of a fence separating the driveway from the play area was associated with an increased risk of driveway related pedestrian injury (OR=2.22 95%CI 0.99, 5.00). Although the odds ratio point estimate was somewhat imprecise, it remained unchanged after controlling for potential confounding variables (OR=2.43 95%CI 0.91, 6.49). Since no other published studies have examined this association the criteria of consistency clearly cannot be satisfied. The finding is however plausible and the concept that fences may prevent children gaining access to the residential driveway is analogous to the argument that fences prevent children from gaining access to domestic swimming pools (Carey 1993). In view of the relatively high population attributable risk of 28.9% (95%CI 10.6, 58.5), the prospect of fencing domestic driveways as a prevention strategy deserves further attention, in particular a consideration of feasibility and cost effectiveness.

8.2 Implications for prevention.

There has been a great deal of debate in the epidemiologic literature about the extent to which policy recommendations should accompany epidemiological research findings. On the one hand are those who argue that making policy recommendations compromises a researchers ability to critically self evaluate the epidemiologic evidence (Rothman 1993). On the other are
those who argue that enforcing a schism between research and policy denies or at least diminishes the important contribution that epidemiology can make to public health (Teret 1993). In this thesis an attempt has been made to reconcile these views. Following each segment of data analysis an attempt has been made to critically evaluate the research findings. Only issues pertaining to the validity and precision of the associations are considered. For many of the potential biases an argument has been made that the effects are likely to be minimal and insignificant. For others, for example confounding by "cautiousness" and confounding by "road crossing", no defence can be made and the possibility of bias remains open to question. However in this concluding chapter the next step has been taken. The associations found have been evaluated in relation to criteria for causation (Hill 1965). When judged in this way, these criteria are clearly fulfilled for traffic volume and are also satisfied in the main for vehicle speed and parking density. For the absence of a fenced play area there is some evidence which casts doubt on a causal interpretation. In the final pages of this thesis the potential public health implications of the findings will be discussed.

In the second chapter of this thesis the relative merits of education verses environmental change as strategies for the prevention of child pedestrian injury were contrasted. It was argued that the paucity of evidence to support the efficacy of educational approaches to prevention justified a closer
examination of the risks associated with environmental factors. This study has identified a number of environmental risk factors for child pedestrian injury.

The results suggest that a high density of on street parking increases the risk of child pedestrian injury. However there are some reasons why it may not be appropriate to suggest that this risk factor should form the basis of an intervention strategy, without further information. First, if residents were encouraged to park in driveways rather than on the road this may increase the incidence of driveway related pedestrian injuries. Second, reducing the density of on street parking may result in higher vehicle speeds, since the perceived road width would increase. However these results do support the suggestion that curb parking be restricted at specific crossing locations (Rivara 1990). This might appropriately be investigated in a controlled community intervention trial.

The results of this study also provide strong evidence to support strategies aimed at reducing traffic volumes and vehicle speeds in residential areas. It remains to be considered how this might be achieved.

The British epidemiologist Geoffrey Rose distinguished two types of preventive strategy, the high risk strategy and the population strategy (Rose 1981). A high risk approach to the prevention of child pedestrian injury might involve targeting interventions to neighbourhoods with high rates of child
pedestrian injury. These interventions might involve traffic management strategies to divert traffic away from residential roads onto the urban arterial and traffic calming methods to reduce vehicle speeds on residential streets. An area analysis of child pedestrian injury in Auckland revealed several geographical areas where pedestrian injury morbidity rates were higher than the regional average (Roberts et al 1992b). Typically these were the most socioeconomically disadvantaged areas. Targeting the implementation of such schemes to the most socioeconomically disadvantaged areas would greatly increase the cost effectiveness of this intervention.

However the population approach to prevention offers some powerful advantages, as outlined below. This would involve changes in transportation policy to encourage a shift from the private passenger car to bus, rail or air travel for longer journeys, with cycling or walking for shorter journeys. An essential prerequisite would be the provision of comprehensive public transport network that was safe, affordable, clean and convenient (Roberts 1993e). The shift towards public transport could be facilitated by transferring motoring cost from car ownership to car usage by increasing petrol taxes and introducing mileage related road tax and car insurance. An increase in car parking charges in inner city areas would discourage commuters from driving to work. The potential for this approach was illustrated at the time of the energy crisis when government restrictions on car use were associated with a significant reduction in child pedestrian mortality rates.
(Roberts et al 1992c). However this strategy is also likely to provide other public health advantages, in particular a reduction in road vehicle related mortality rates. There are twenty times more deaths, per passenger kilometre travelled, with car travel than with rail or air travel and seven times more deaths than with bus or coach travel (The Public Health Alliance 1991). Changing transportation modes from the private passenger car to alternative forms of travel might therefore be expected to reduce road death rates.

Injury is not the only adverse public health consequence of a car oriented transport system. Physical inactivity is an important risk factor for both cardiovascular disease and stroke. British civil servant who cycled regularly were shown to have a 50% reduction in the number of coronary events (Morris et al 1990), and brisk walking has been shown to reduce the risk of myocardial infarction (Shaper et al 1991). It has been estimated that a 43% reduction in cardiovascular mortality might result if regular physical exercise were taken up by the New Zealand population (Scragg et al 1987). However present car oriented transport policies discourage both cycling and walking. The risk of serious injury is a powerful disincentive to cycling and an increasingly hostile urban living environment makes walking unappealing. Other potential benefits of a modal shift away from the private passenger car would include a reduction in the emission of greenhouse gases and improved access to health care for low income families without access to a car.
Sir Austin Bradford Hill (1965) argued that in weighing up the case for action the potential consequences of the decision to act must be considered. In the case-control study presented in this thesis it is possible that due to unrecognised confounders, the associations between pedestrian injury risk and traffic volume are spurious. However if the consequences of action are a healthier urban living environment and a more equitable access to health care and recreational opportunities then the evidence may already be sufficient for action.
REFERENCES
REFERENCES


APPENDICES
APPENDIX 1

Letters
The Principal  
Name of School  
Address  

Dear  

I would like to introduce the Auckland Child Pedestrian Injury Study and seek the cooperation of your school for its conduct. This study is funded by the Health Research Council of New Zealand and has the support of the Ministry of Education, the Auckland Primary Principals and the Auckland School Boards of Trustees Association.

Pedestrian accidents are the leading cause of death and serious injury in New Zealand school children. The aim of this study is to identify the causes of these accidents in order to develop effective prevention strategies. To this end, the parents of all children injured in pedestrian accidents in Auckland over the next two years will be interviewed and a number of traffic and roadway measurements made at the site of the accidents. Similar interviews and measurements will be made for a group of children who have not been involved in accidents, for purposes of comparison. This is the component of the study for which we require your schools assistance. It would entail providing access to the class registers so that up to four children could be randomly selected from them by the study interviewers. The parents of these children would then be sent a letter inviting them to take part in the study. I have enclosed a copy of the information sheet that is provided to all study participants.

One of the study team will contact you next week to discuss this. If you have any questions I would be pleased to discuss them with you.

Yours sincerely  

Dr Ian Roberts  
Principal Investigator
Dear

We were glad to hear that (name) has now been discharged from hospital following a pedestrian accident. Each year in New Zealand over 400 children are admitted to hospitals as a result of these accidents. Because pedestrian accidents are such an important child health problem we are conducting a study to find out more about the causes of these accidents so that they can be prevented.

The study is funded by the Health Research Council of New Zealand and has the support of the Ministry of Education and the Auckland Schools Trustees Association. The results of the study will be important in preventing pedestrian accidents to children both in New Zealand and overseas.

The study involves an interview with one of our trained interviewers and lasts about half an hour. During the interview questions will be asked about the accident, about where you live and about your family. The information is strictly confidential and the study has been approved by the Ethics Committee.

Our research interviewer Binki Taua will contact you to arrange a suitable time to see you. I hope that you are able to help us with this study as we depend on your goodwill for its success.

Yours sincerely

Dr Ian Roberts
Department of Community Health
Dear

We recently found out that your daughter (name) died in a pedestrian accident. We would like to extend our sympathy for your loss. We know this may be a difficult time to contact you, but we would very much appreciate your help.

Each year in New Zealand over thirty children are killed and over 400 children are seriously injured in pedestrian accidents. Close to a quarter of these accidents happen when children are run over in the driveway. Because pedestrian accidents are such an important child health problem we are conducting a study to find out more about the causes of these accidents so that they can be prevented.

The study involves an interview with one of our trained interviewers and lasts about half an hour. During the interview questions will be asked about the accident, about where you live and about your family. The information is strictly confidential and the study has been approved by the Ethics Committee.

Our research interviewer Binki Taua would like to contact you in a few days to discuss whether you are willing to help us with the study. If you would like to know more or if you think it will be difficult for her to contact you, please phone our office on 3737-599 extension 6346 so that she can arrange a suitable time to contact you.

Thank you for your assistance.

Yours sincerely

Dr Ian Roberts
Department of Community Health
Dear

Your child (name) has been randomly selected from a list of Auckland school children to take part in the Auckland Child Pedestrian Accident Study. By looking at the differences between families with children who have had pedestrian accidents and families with children who have not, like yours, we will be able to find out more about the causes of these accidents and how to prevent them.

The study is funded by the Health Research Council of New Zealand and has the support of the Ministry of Education and the Auckland Schools Trustees Association. The results of the study will be important in preventing road accidents to children both in New Zealand and overseas.

The study involves an interview with one of our trained interviewers and lasts about half an hour. During the interview questions will be asked about where you live and about your family. The information will be strictly confidential and the study has been approved by the Ethics Committee.

Our research interviewer Binki Taua will contact you shortly to arrange a suitable time to see you. I hope that you are able to help us with this study as we depend on your goodwill for its success.

Yours sincerely

Dr Ian Roberts
Department of Community Health
Dear Householder

We would be grateful if you could assist us with the Auckland Child Pedestrian Accident Study. By comparing families with children who have had pedestrian accidents with families who have not, like yours, we can find out more about the causes of these accidents and how to prevent them.

If you have a child younger than five years in your household you would be able to help us. Your help would involve a brief interview with one of our trained interviewers and lasts about half an hour. During the interview questions will be asked about where you live and about your family. The information will be strictly confidential and the study has been approved by the Ethics Committee.

Our research interviewer Judy Rudd will try to contact you shortly to arrange a time to see you. If you wish to help or else if you can not because you do not have a child under five years in your household, could you phone 4791822 (evenings). Thank you for your assistance.

Yours sincerely

Dr Ian Roberts
Department of Community Health
Dear

Thank you for helping us with the Auckland Child Pedestrian Accident Study. The information you have given will help us find ways to prevent pedestrian accidents to children in the future.

We will produce a full report of the study findings, when the study finishes in 1994. A summary of the findings will be sent to you at that time.

Once again thank you for your help with this study.

Yours sincerely

Dr Ian Roberts  
Department of Community Health

Binki Taua  
Research Interviewer
APPENDIX 2

Questionnaire
AUCKLAND CHILD PEDESTRIAN INJURY STUDY

QUESTIONNAIRE

Injury Prevention Research Centre
Department of Community Health
University of Auckland
Auckland, New Zealand
Ph: (09) 3737 999 ext 6346
Fax: (09) 3770 956

Supported by the Health Research Council of New Zealand.
Auckland Child Pedestrian Injury Study

Information Leaflet

Child Pedestrian Accidents - A Major Health Problem

Each year in New Zealand over 400 children are hospitalised as a result of pedestrian accidents. The purpose of this study is to find out more about the causes of these accidents so that they can be prevented. The results of this study are likely to be important in preventing child pedestrian accidents in New Zealand and overseas.

The Study Participants

All parents of children younger than fifteen years who have been admitted to Auckland hospitals because of pedestrian accidents will be invited to take part in this study.

For the purpose of comparison some children who have not been injured will be randomly selected from schools in Auckland. Everyone taking part in this study has done so voluntarily and the study depends on your goodwill for its success.

If You Decide to Participate

We would like to invite you to take part in this study. If you decide to take part, it will involve answering some questions about the accident, about where you live and about your family. These questions will take about forty five minutes to answer. The information will be strictly confidential and the study has been approved by the Auckland Area Health Board Ethics Committee.

Finally

If you decide to participate you are free to change your mind at any time. Whatever you decide the care your child receives from the hospital staff will not be affected. The study staff will contact you in the next few days to see if you would like to take part in the study and arrange a suitable time to see you.

Please feel free to talk about taking part in the study with your family, friends or doctor before deciding. If you have any questions you can ask:

Dr Ian Roberts
Research Co-ordinator
Injury Prevention Research Centre
Department of Community Health
School of Medicine
Phone 3737 999 ext 6346
AUCKLAND AREA HEALTH BOARD ETHICS COMMITTEE

CONSENT FORM

<table>
<thead>
<tr>
<th>Language</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>English</td>
<td>I wish to have an interpreter</td>
</tr>
<tr>
<td>Maori</td>
<td>E hiahia ana koe i tetahi tangata</td>
</tr>
<tr>
<td>Samoan</td>
<td>Oute manaʻo e iai se faʻamatala upu</td>
</tr>
<tr>
<td>Tongan</td>
<td>'Oku fiemaʻu ha fakatonulea</td>
</tr>
<tr>
<td>Cook Island</td>
<td>Ka inangaro au i tetai tangata</td>
</tr>
<tr>
<td>Niuean</td>
<td>Fia manako au ke fakaaoaga</td>
</tr>
</tbody>
</table>

(Delete one)

Yes | No

Yes | No

AUCKLAND CHILD PEDESTRIAN INJURY STUDY

I have read/had explained to me the Subject Information Sheet for the above research study to be performed by: Dr Roberts and Dr Norton.

I agree to participate in this study. I have had an opportunity to ask questions. I understand I may withdraw my permission at any time without giving any reason. A decision not to participate or to withdraw will not affect my child's future treatment.

Subject Name:

Signature:

Date:

Confirmation of Informed Consent

In my opinion consent was given freely and with understanding.

Witness Name:

Signature:

Date:

* The Witness should not be the investigator and should preferably be a person principally concerned for the patients welfare such as a relative. If a relative is not accessible then a friend, hospital chaplain, or justice of the peace may substitute.
CASE QUESTIONNAIRE

To be completed prior to interview

Child's name

Address

Telephone no

Care giver's name

Address if different from above

ACPIS ID NUMBER .............
CASE QUESTIONNAIRE

Interviewer

Date interview started

Date interview completed

Consent obtained:  Y       N

Reason for non consent

Relationship of respondent to child

Mother = 1  
Father = 2  
Other = 3, specify

Sex (circle):  Male    Female

Date of birth

Age

Ethnicity:  European = 1  Maori = 2  Samoan = 3  Tongan = 4

Cook Island = 5  Fijian = 6  Niuean = 7  Chinese = 8

Indian = 9  Other = 10

Child’s status :  Case = 1  Control = 2

The following questions are about the accident:

1. On which day of the week was it?
   6. Saturday  7. Sunday

2. What was the date?

   (Day Month Year)

3. What was the time of the accident? (24Hrs)

4. Do you know where the accident happened?  Yes/No
Name of street ____________________________
Identifying characteristics ____________________________

5. Did you see the accident? Yes/No
6. Can you give a brief account of it? 

Action
1. Playing in street
2. Walking in street
3. Crossing the street
4. Darting into the street
5. Playing/walking on footpath
6. Playing/walking on driveway
7. Playing/walking in car park
8. Other, specify

Site
1. On pedestrian crossing
2. Near crossing
3. Intersection
4. Mid block
5. Driveway
6. Car park
7. Other

Vehicle
1. Forward straight
2. Forward turning right
3. Forward turning left
4. Reversing

7. Was anyone with him/her at the time of the accident? Yes/No

If yes, specify relationship to child ____________________________
and give age ____________________________

8. Can you think of anything that might have contributed to the accident?

________________________________

How might this accident have been prevented?

(If child is younger than five years and does not attend preschool go to Q16).

9. Did the accident happen on a school/preschool day? Y/N
If no go to question 16) If yes did it happen when s/he was

1. Walking to school
2. Walking from school
3. Out of school during the lunch break
4. Playing outside after school
5. Playing outside before school
6. Other specify ____________________________

10. If the accident happened on the way to or from school was s/he

1. Walking alone
2. Walking with school friends
3. Walking with younger brother or sister.
4. Walking with older brother or sister
5. Walking with an adult
6. Getting in/out of the vehicle that took him/her to school

11. How many streets would s/he have crossed on the way to and from school? Total no __

12. What time did the school day end? ____________________________

13. Was there anyone at home when s/he arrived
   If yes, what was the age of the oldest person ____________

14. Was s/he wearing or carrying anything to make him/her seen more easily on the way to or from school?
   If yes, specify ____________________________

15. Was s/he wearing or carrying anything to make him/her seen more easily after school?
   If yes, specify ____________________________

16. What type of vehicle was involved in the accident?

   1. Car
   2. Van
   3. Truck
   4. Bus
   5. Motorbike
   6. Utility
   7. Don’t Know

17. Did the vehicle stop after the accident?

   1. Yes
   2. No
   3. Don’t know

18. How did s/he get to hospital?

   1. Ambulance
   2. Private transport
   3. Other
   4. Don’t know

19. Which one of the following best describes the weather conditions at the time of the accident?
20. Which of the following best describe the lighting at the time of the accident?

1. Bright sun
2. Overcast
3. Twilight
4. Dark with streetlight
5. Dark without streetlight

The following questions are about your home and family

21. Which of the following best describes your current housing? (show card)

1. separate house (not joined to another house)
2. two flats/houses joined together
3. three or more flats or houses joined together
4. flat or house attached to a business or shop
5. caravan cabin or tent
6. emergency housing/refuge
7. other (specify)

If flats, on which level are you living?
Ground/First/Second/Third

22. Is this rented or owned?

1. Rented privately
2. Rented (State)
3. Owned
4. Living with relatives
5. Other, specify

23. How many people were staying in your home on the day of the accident/yesterday?

24. How many children (less than fifteen years old) were staying?

25. How many children under five years old were there?

26. How long have you been staying at this address?

1. More than 3 months
2. Less than 3 months

27. Do you use a car during the day?

Yes/No

28. Does your home have a driveway?

Yes/No

29. What sort of vehicle most often uses the driveway?

1. Car
2. Van, Ute, Truck or Bus
3. Other, specify
30. Does your home have a yard or lawn where a child could play? Yes/No
(If no, go to question number 34)

31. Is the main (most often used) children's play area in front (bordering the street) or behind (separated from the street by the house) the house? Draw plan here if required

32. Is the play area completely separated from the street by:
   A fence and a gate? Yes/No
   A fence but no gate? Yes/No
   If yes, is the fence taller than 1.2 metres? Yes/No
   (If no go to Q. 33)
   Does the gate have a latch? Yes/No
   If yes, where on the gate is the latch? Inside/Outside/Top
   Is the gate usually closed? Yes/No
   Is the gate self closing? Yes/No

33. Is the play area completely separated from the driveway by:
   A fence and a gate? Yes/No
   A fence but no gate? Yes/No
   If yes, is the fence taller than 1.2 metres? Yes/No
   (If no go to Q. 34)
   Does the gate have a latch? Yes/No
   If yes, where on the gate is the latch? Inside/Outside/Top
   Is the gate usually closed? Yes/No
   Is the gate self closing? Yes/No

34. How far is it from your home to the nearest park or playground?
   1. Less than 5 mins walk
   2. Between 5 and 10 mins walk
   3. Between 10 and 20 mins walk
   4. More than 20 mins walk

35. How many streets would have to be crossed to get to the nearest park or playground?
36. On how many days has (child) used it in the past fortnight? __

37. Which school/preschool does your child attend

   Name ____________________________

   Address __________________________

Pedestrian education

47. How did your child learn about crossing streets? __ / __

   1. Parents taught child to cross
   2. Taught at school to cross
   3. Taught self to cross
   4. Parents taught never to cross alone
   5. Other specify

48. At what age would you say that children could safely cross on their own?

   1. A quiet neighbourhood street __
   2. A busy neighbourhood street __
   3. A main street at the traffic lights __
   4. A main street without traffic lights __

Health status

49. Do you think your child hears normally? Yes/No

   If no, specify ____________________________

50. Do you think your child sees normally? Yes/No

   If no, specify ____________________________

51. Does your child have any health problems that might make them more likely to have an accident? Yes/No

   If yes specify ____________________________

52. Has s/he ever been admitted to hospital before for any type of injury including falls, burns and poisoning? Yes/No

53. Has s/he ever been treated at an Accident and Emergency Dept/Clinic for any type of injury including burns and poisoning? Yes/No

   No of times __________

Thank you, the questionnaire is nearly complete, the last few questions are about yourself. Remember all the information you give in this questions is completely confidential.
Demographic data

54. In what year were you born? 

55. What is your marital status?
   1. Married/De Facto relationship
   2. Single: never married
   3. Single: separated divorced widowed

56. Do you have sole responsibility for your children or do you share this responsibility with a partner? 
   Sole/Partner

57. How old were you when you (mother) left school? 
   After you left school did you get the opportunity to attend university or technical college? 
   Yes/No
   Are you a graduate of a university or technical college? 
   Yes/no

58. How old were you when you (father) left school? 
   After you left school did you get the opportunity to attend university or technical college? 
   Yes/No
   Are you a graduate of a university or technical college? 
   Yes/no

59. Which of the following best describe your (mother) present working position?
   1. Full time paid employment
   2. Part time paid employment
   3. Receiving benefit
   4. Full time work in the home
   5. Other work, specify

60. Could you describe as fully as possible your present or most recently paid job?

61. Which of the following best describe your (father) present working position?
   1. Full time paid employment
   2. Part time paid employment
   3. Receiving benefit
   4. Full time work in the home
   5. Other work, specify

62. Could you describe as fully as possible your present or most recently paid job?

To be coded by interviewer.

Mother NZCO 

Mother EI 

Father NZCO 

Father EI 

THANK YOU THE QUESTIONNAIRE IS NOW COMPLETE
AUCKLAND CHILD PEDESTRIAN INJURY STUDY

QUESTIONNAIRE

Injury Prevention Research Centre
Department of Community Health
University of Auckland
Auckland, New Zealand
Ph: (09) 3737 999 ext 6346
Fax: (09) 3770 956

Supported by the Health Research Council of New Zealand.
Auckland Child Pedestrian Injury Study
Information Leaflet (Control)

Child Pedestrian Accidents - A Major Health Problem

Each year in New Zealand over 400 children are hospitalised as a result of pedestrian accidents. The purpose of this study is to find out more about the causes of these accidents so that they can be prevented. The results of this study are likely to be important in preventing child pedestrian accidents in New Zealand and overseas.

The Study Participants

All parents of children younger than fifteen years who have been admitted to Auckland hospitals because of pedestrian accidents will be invited to take part in this study.

For the purpose of comparison some children who have not been injured will be randomly selected from schools in Auckland. Everyone taking part in this study has done so voluntarily and the study depends on your goodwill for its success.

If You Decide to Participate

We would like to invite you to take part in this study. If you decide to take part, it will involve answering some questions about where you live and about your family. These questions will take about thirty minutes to answer. The information will be strictly confidential and the study has been approved by the Auckland Area Health Board Ethics Committee.

Finally

If you decide to participate you are free to change your mind at any time. The study staff will contact you in the next few days to see if you would like to take part in the study and arrange a suitable time to see you.

Please feel free to talk about taking part in the study with your family, friends or doctor before deciding. If you have any questions you can ask:

Dr Ian Roberts
Research Co-ordinator
Injury Prevention Research Centre
Department of Community Health
School of Medicine
Phone 3737-999 ext 6346
AUCKLAND AREA HEALTH BOARD ETHICS COMMITTEE

CONSENT FORM

(Delete one)

English: I wish to have an interpreter
Maori: E hiaha ana koe i tetahi tangata hei whaka Maori nga koreo
Samoan: Oute mana‘o e iai se fa‘amata la upu
Tongan: ‘Oku fiema‘u ha fakatonulea
Cook Island: Ur i inangaro au i tetai tangata
Niuean: Fia manako au ke faka aoga e tagata fakahokohoko vagahau

Yes No
Ae Kao
Io Leai
Io Ikai
Ae Kare

AUCKLAND CHILD PEDESTRIAN INJURY STUDY

I have read/had explained to me the Subject Information Sheet for the above research study to be performed by: Dr Roberts and Dr Norton.

I agree to participate in this study. I have had an opportunity to ask questions. I understand I may withdraw my permission at any time without giving any reason. A decision not to participate or to withdraw will not affect my child’s future treatment.

Subject Name:
Signature:
Date:

Confirmation of Informed Consent

In my opinion consent was given freely and with understanding.

Witness Name:*
Signature:
Date:

* The Witness should not be the investigator and should preferably be a person principally concerned for the patients welfare such as a relative. If a relative is not accessible then a friend, hospital chaplain, or justice of the peace may substitute.
CONTROL QUESTIONNAIRE

To be completed prior to interview

Child’s name

Address

Telephone no

Care giver’s name

Address if different from above

ACPIS ID NUMBER .............
CONTROL QUESTIONNAIRE

Introducer

Date interview started

Date interview completed

Consent obtained: Y N

Reason for non consent

Relationship of respondent to child

- Mother = 1
- Father = 2
- Other = 3, specify

Sex (circle): Male Female

Date of birth Age

Ethnicity: European = 1 Maori = 2 Samoan = 3 Tongan = 4
- Cook Island = 5 Fijian = 6 Niuean = 7 Chinese = 8
- Indian = 9 Other = 10

Child’s status Case = 1 Control = 2

The following questions are about your home and family

21. Which of the following best describes your current housing? (show card)

1. separate house (not joined to another house)
2. two flats/houses joined together
3. three or more flats or houses joined together
4. flat or house attached to a business or shop
5. caravan cabin or tent
6. emergency housing/refuge
7. other (specify)

If flats, on which level are you living? Ground/First/Second/Third
22. Is this rented or owned?
   1. Rented privately
   2. Rented (State)
   3. Owned
   4. Living with relatives
   5. Other specify ________

23. How many people were staying in your home on the day of the accident/yesterday? ________

24. How many children (less than fifteen years old) were staying? ________

25. How many children under five years old were there? ________

26. How long have you been staying at this address?
   1. More than 3 months
   2. Less than 3 months

27. Do you use a car during the day? Yes/No

28. Does your home have a driveway? Yes/No

29. What sort of vehicle most often uses the driveway?
   1. Car
   2. Van, Ute, Truck or Bus
   3. Other, specify ________________

30. Does your home have a yard or lawn where a child could play? Yes/No
    (If no, go to question number 34)

31. Is the main (most often used) children’s play area in front (bordering the street) or behind (separated from the street by the house) the house?
    Draw plan here if required
    Front/Behind

32. Is the play area completely separated from the street by:
    A fence and a gate? Yes/No
    A fence but no gate? Yes/No
    If yes, is the fence taller than 1.2 metres? Yes/No
    (If no go to Q.33)
    Does the gate have a latch? Inside/Outside/Top
    If yes, where on the gate is the latch? Yes/No
    Is the gate usually closed? Yes/No
    Is the gate self closing? Yes/No
33. Is the play area completely separated from the driveway by

<p>| | |</p>
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<thead>
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<tr>
<td></td>
<td>artillery &amp; a gate?</td>
</tr>
<tr>
<td></td>
<td>A fence but no gate?</td>
</tr>
<tr>
<td>If yes, is the fence taller than 1.2 metres?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>(If no go to Q 34)</td>
<td></td>
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<tr>
<td>Does the gate have a latch?</td>
<td>Yes/No</td>
</tr>
<tr>
<td>If yes, where on the gate is the latch?</td>
<td>Inside/Outside/Top</td>
</tr>
<tr>
<td>Is the gate usually closed</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Is the gate self closing?</td>
<td>Yes/No</td>
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</table>

34. How far is it from your home to the nearest park or playground?

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<thead>
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<tbody>
<tr>
<td>1.</td>
<td>Less than 5 mins walk</td>
</tr>
<tr>
<td>2.</td>
<td>Between 5 and 10 mins walk</td>
</tr>
<tr>
<td>3.</td>
<td>Between 10 and 20 mins walk</td>
</tr>
<tr>
<td>4.</td>
<td>More than 20 mins walk</td>
</tr>
</tbody>
</table>

35. How many streets would have to be crossed to get to the nearest park or playground?

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36. On how many days has (child) used it in the past fortnight?

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37. Which school/preschool does your child attend?

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<tbody>
<tr>
<td>Name</td>
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<tr>
<td>Address</td>
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The following questions refer to the most recent full school/preschool day that your child attended.

38. How did s/he get to school?

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</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Walked alone</td>
</tr>
<tr>
<td>2.</td>
<td>Walked with school friends</td>
</tr>
<tr>
<td>3.</td>
<td>Walked with younger brother or sister</td>
</tr>
<tr>
<td>4.</td>
<td>Walked with older brother or sister</td>
</tr>
<tr>
<td>5.</td>
<td>Walked with an adult</td>
</tr>
<tr>
<td>6.</td>
<td>By car, bus or other vehicle</td>
</tr>
<tr>
<td>7.</td>
<td>By bike</td>
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</table>

39. How many streets would s/he have crossed on the way to and from school?

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</table>

40. Did s/he go out of the school grounds during the lunch break?

<p>| | |</p>
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</tbody>
</table>
41. How did s/he get home from school?
   1. Walked alone
   2. Walked with school friends
   3. Walked with younger brother or sister
   4. Walked with older brother or sister
   5. Walked with an adult
   6. By car, bus or other vehicle
   7. By bike

42. Was s/he wearing or carrying anything to make him/her seen more easily on the way to or from school? Yes/No
   If yes, specify

43. Was s/he wearing or carrying anything to make him/her seen more easily after school? Yes/No
   If yes, specify

44. What time did the school day end?

45. What time did s/he arrive home?

46. Was there anyone at home when s/he arrived
   Yes/No
   If yes, what was the age of the oldest person

Pedestrian education

47. How did your child learn about crossing streets?  
   1. Parents taught child to cross
   2. Taught at school to cross
   3. Taught self to cross
   4. Parents taught never to cross alone
   5. Other specify

48. At what age would you say that children could safely cross on their own?
   1. A quiet neighbourhood street
   2. A busy neighbourhood street
   3. A main street at the traffic lights
   4. A main street without traffic lights
Health status

49. Do you think your child hears normally?  Yes/No
    If no, specify________________________________________________________

50. Do you think your child sees normally?  Yes/No
    If no, specify________________________________________________________

51. Does your child have any health problems that might make him/her more likely to have an accident?  Yes/No
    If yes specify ______________________________________________________

52. Has s/he ever been admitted to hospital before for any type of injury including falls, burns and poisoning?  Yes/No

53. Has s/he ever been treated at an Accident and Emergency Dept/Clinic for any type of injury including burns and poisoning?  Yes/No
    No of times____________________

Thank you, the questionnaire is nearly complete, the last few questions are about yourself. Remember all the information you give in this questions is completely confidential.

Demographic data

54. In what year were you born? ______________________

55. What is your marital status?  ______________________
    1. Married/Defacto relationship
    2. Single: never married
    3. Single: separated divorced widowed

56. Do you have sole responsibility for your children or do you share this responsibility with a partner? Sole/Partner

57. How old were you when you (mother) left school?  ______
    After you left school did you get the opportunity to attend university or technical college?  Yes/No
    Are you a graduate of a university or technical college?  Yes/no

58. How old were you when you (father) left school?  ______
    After you left school did you get the opportunity to attend university or technical college?  Yes/No
    Are you a graduate of a university or technical college?  Yes/no
59. Which of the following best describe your (mother) present working position?

1. Full time paid employment  
2. Part time paid employment  
3. Receiving benefit  
4. Full time work in the home  
5. Other work, specify ____________________________

60. Could you describe as fully as possible your present or most recently paid job?

________________________________________________________________________

61. Which of the following best describe your (father) present working position?

1. Full time paid employment  
2. Part time paid employment  
3. Receiving benefit  
4. Full time work in the home  
5. Other work, specify ____________________________

62. Could you describe as fully as possible your present or most recently paid job?

________________________________________________________________________

To be coded by interviewer.

Mother NZCO _______ Mother El  
Father NZCO _______ Father El  

THANK YOU THE QUESTIONNAIRE IS NOW COMPLETE
APPENDIX 3

Environmental data collection instruments
Case Control Study of Child Pedestrian Injury

Environmental Data Collection - Roadway

ACPIS No ............ Date .................................. Time (24 hours) ......................
(day month year)


Name of Street : ........................................ Map number: ........... Grid reference:

Identifying Characteristics:


1. Reway condition : 1. Dry 2. Wet


3. Reway function : a. Arterial b. Collector c. Local through road d. Local non through road
e. Other, specify..............................

4. Posted speed limit : 1) <50 2) 50 3) 60 4) 70 5) L50 6) 100

5. Traffic calming measures ? yes / no

If yes, specify........................................


7. Lanes : Dir ............ Number ...... Width ......... metres

 Dir ............ Number ...... Width ......... metres

8. Gradient : Flat

 Dir ............ Up Down a. Less than 3 %
b. 3 % to 5 % c. Greater than 5 %


 b. Flush (painted) Width................ metres

c. Centreline Width............. cm
d. None
e. Other Specify...........................................

 Width............. metres

10. Verge : a. none b. one c. both Dir ............ Width ......... metres

 b. both Dir ............ Width ......... metres

11. Footpath : a. none b. one c. both Dir ............ Width ......... metres

 b. both Dir ............ Width ......... metres


14. Intensity of R/side dev:  
   a. High  
   b. Moderate  
   c. Low

15. Intersection within 50 metres?  
   Type of int.?  
   a. Signalised  
   b. Give Way  
   c. Stop  
   d. No signs or controls

16. Pedestrian crossing within 100 metres (both directions)?  
   Type of crossing?  
   a. Signal (Excl)  
   b. Signal (Pllle)  
   c. Zebra (Ext)  
   d. Zebra (No ext kerbs)

17. Bus stop within 100 metres?  
   yes / no

18. Intervisibility distance - 1 m (driver's eye height) and 600 mm (object height)  
   For distances less than 100 m, measure to nearest 10 m  
   100 to 200 m, measure to nearest 20 m  
   over 200 m, state over 200 m (nearest 20 m if speed limit over 50 km/hr)  
   a. At kerb  
      Dir.........  
      Inv. Dist. .............  
      Dir.........  
      Inv. Dist. .............  
   b. At centreline  
      Dir.........  
      Inv. Dist. .............  
      Dir.........  
      Inv. Dist. .............

19. On street parking:  
   Measure 50 metres in both directions from the index point. Measure the number of complete vehicles parked in this distance. Repeat for other side. If index point is at an intersection then the distance is measured along the direction of the main traffic flow. Record the percentage of parking space utilized by the vehicles.  
   North ................ %  
   South ................ %  
   East.................. %  
   West.................. %

20. Data downloaded from vehicle classifier.  
   Volume:  
   Total (24 hour) traffic volume .................  
   Three hour traffic volume  
      hour .................  
      volume .................  
   Speed:  
   Average (24 hour vehicle speed) .................  
   Three hour vehicle speed  
      hour .................  
      speed .................
### Case Control Study of Child Pedestrian Injury

**Environmental Data Collection - Driveway**

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<th>Date</th>
<th>Time (24 hours)</th>
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Site details: .................................................................

Map number: .............. Grid reference: ..............


1. Shared driveway? yes/no

2. Type of driveway: 1. Sealed 2. Unsealed


4. Number of cars in driveway ..............

5. Width of driveway: .............. metres

6. Length of driveway: .............. metres

7. Gradient of driveway: 1. Flat to st 2. Down to st...........% 3. Up to st...........%

Is main play area completely separated from the street by a fence and gate? yes/no

If yes, is the fence taller than 1.2 metres yes / no

does the gate have a latch yes / no

latch on inside or outside or top inside / outside / top

is the gate closed yes / no

is the gate self closing yes / no

Is main play area completely separated from the driveway by a fence and gate? yes/no

If yes, is the fence taller than 1.2 metres yes / no

does the gate have a latch yes / no

latch on inside or outside or top inside / outside / top

is the gate closed yes / no

is the gate self closing yes / no

Visibility for vehicles exiting driveway (5 m back from sidewalk, 600 mm object height)

Left: Vis. distance: ..............metres Obstruction: ............................................................

Right: Vis. distance: ..............metres Obstruction: ............................................................
5000 Series Recorder
Users’ Manual
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1. Introduction

1.1 Essential Information - please read this

The 5000 Series Recorder has been designed with ease of operation in mind. Operating the recorder in accordance with the following instructions should ensure trouble-free data collection.

During normal operation, a special power-saving feature is invoked. The effect of this is that the Liquid Crystal Display goes blank if no buttons have been pushed for approximately two minutes. To restore the display, simply press the button marked: -

'\#' (hash symbol)

When the battery is disconnected, the 5000 Series Recorder will remember all configured parameters such as site number, recording interval, site configuration, etc. plus the time and date. The recorder can be left for up to 5 years without power, your parameters being stored in a non-volatile memory powered by a miniature battery contained on the recorders' CPU board, while a real-time clock circuit maintains the correct time and date.

A built-in battery voltage monitor is provided. To ensure reliable operation, replace the battery when the indicated voltage is 5.5 v or less.

All configurable parameters are protected by a password. The user may view any parameter (including battery voltage) without entering the password, but no parameters may be altered without first entering the correct password. Invalid entries are ignored.

1.2 5000 Series recorder options

The 5000 Series Recorder is available with the following options:

Model 5000 Standard 2 tube counter/classifier

Model 5010 2 tube counter/classifier with inbuilt Solar Panel
APPENDIX 4

Methodological issues
Effect of Exposure Measurement Error in a Case-Control Study of Child Pedestrian Injuries

Ian Roberts and Trevor Lee-Joe

We examined the effect of the duration of the exposure measurement period on the odds ratio in a case-control study of traffic flow and the risk of child pedestrian injury. Varying the length of the measurement period resulted in differential exposure misclassification and bias in the odds ratio. Differential misclassification may have arisen from measurement error in traffic flow estimation over a short period or from inclusion of irrelevant exposure information with a longer measurement period. (Epidemiology 1993;4:477-479)

Keywords: epidemiologic methods, misclassification, bias, injuries, traffic accidents, case-control study, child.

Exposure misclassification is an important source of bias in case-control studies. When an exposure measure is constructed by categorizing a continuous variable, measurement error in the continuous variable may result in misclassification of the exposure into the respective categories. If the probability of the outcome is related to the continuous exposure as opposed to the category, misclassification may be differential even when the measurement error is independent of outcome status.

For a continuous variable, measurement error resulting in exposure misclassification may be introduced if the period of exposure measurement is excessively short and the exposure is variable. Even if the exposure is measured over a longer period, exposure misclassification may also result from the inclusion of exposure information outside of the time window that is etiologically related to the outcome. In this report, we examine the effect of varying exposure measurement periods in a case-control study of traffic flow and the risk of child pedestrian injuries.

Methods
The units of observation in this study were roadway locations. All children, younger than 15 years, killed or hospitalized as a result of a pedestrian-motor vehicle collision in the Auckland region, were identified through a monitoring system at the region’s hospitals and the coroner. The median age of these children was 6 years. The Auckland region has a predominantly urban population of 889,170, of whom approximately 209,000 are under 15 years. The exact locations of the collisions were determined during parental interviews with trained interviewers, or from police records if the location was unknown to the parent. These sites constituted the “case sites” for case-control comparison. We chose control sites by first selecting a group of age- and sex-matched control children. 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 injured child. These sites were identified from detailed maps of the region. Two control sites were chosen for each injury site. We selected control children by randomly selecting a school from a list of all schools in the region, with a sampling probability in proportion to the number of children on the school roll, and then randomly selecting a child from the school roll.

We measured a 24-hour bi-directional traffic flow profile at case and control sites using GK-5000 traffic counters, positioned as near as possible to the site. If the case site was an intersection, we measured traffic flow on the street the vehicle was traveling along immediately before collision. For controls at intersections, we randomly selected one of the intersecting streets. For cases, measurements were made on the same day of the week as the injury, usually 1 week
motor vehicle collision is likely to be the traffic flow at the instant that the child enters the roadway, effectively an induction time of zero. Ideally, we might have minimized measurement error by making repeated flow measurements over a very short period around the time of injury and taking as the relevant exposure information the average of these. This procedure, however, would have involved considerable extra time and cost.

Our results show a trend toward a decreasing odds ratio as the exposure period lengthens. This decrease is almost entirely due to changes in the classification of case sites, suggesting that the misclassification is differential. Differential misclassification may have resulted from nondifferential exposure measurement error, as might occur with an excessively short measurement period, since both conditions required for this type of misclassification are fulfilled. First, the probability of injury is likely to be related to the continuous exposure level rather than the category, and second, the probability of misclassification will vary with the exposure level, being greatest close to the cutpoint. Similarly, the inclusion of irrelevant exposure information might also result in differential misclassification, the degree and direction depending on the position of the cutpoint. With a high cutpoint, inclusion of irrelevant exposure information might be expected to result in a greater degree of misclassification for cases than for controls, because the true exposure values for the cases will be closer to the cutpoint. This argument illustrates that an inappropriate induction

<table>
<thead>
<tr>
<th>Exposure Period</th>
<th>Cases</th>
<th>Controls</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>&gt;800</th>
<th>&lt;800</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td>22</td>
<td>8</td>
<td>10.71</td>
<td>3.74-31.62</td>
<td>16</td>
<td>7</td>
<td>6.86</td>
<td>2.28-21.26</td>
</tr>
<tr>
<td>3 hours</td>
<td>25</td>
<td>8</td>
<td>14.45</td>
<td>5.00-43.29</td>
<td>20</td>
<td>7</td>
<td>10.20</td>
<td>3.44-31.40</td>
</tr>
<tr>
<td>6 hours</td>
<td>22</td>
<td>8</td>
<td>10.71</td>
<td>3.74-31.62</td>
<td>17</td>
<td>8</td>
<td>6.55</td>
<td>2.28-19.36</td>
</tr>
<tr>
<td>12 hours</td>
<td>19</td>
<td>8</td>
<td>7.99</td>
<td>2.79-23.51</td>
<td>13</td>
<td>7</td>
<td>4.97</td>
<td>1.62-15.72</td>
</tr>
<tr>
<td>24 hours</td>
<td>14</td>
<td>7</td>
<td>5.56</td>
<td>1.82-17.42</td>
<td>5</td>
<td>4</td>
<td>2.71</td>
<td>0.58-13.11</td>
</tr>
</tbody>
</table>

Results
We measured traffic flow for 41 injury sites and 82 control sites. Odds ratios and 95% confidence intervals for the different exposure periods are shown in Table 1. There was a trend toward decreasing odds ratios with increasing length of the exposure measurement period. This trend was evident for both exposure definitions.

Discussion
Our motivation for evaluating a range of time windows for exposure was uncertainty as to whether measurement error in traffic flow estimation over a short, but logically more appropriate, period would introduce more or less exposure misclassification than would a possibly more stable flow estimate over a longer, but less relevant, period. The period of traffic flow etiologically related to the occurrence of a child pedestrian later. For controls, measurements were made on the same day of the week as the injury of the case to which the control was matched. We dichotomized traffic flow, expressed as vehicles per hour, to indicate exposed and unexposed. We used two different cutpoints, as shown in Table 1. The resulting definitions of high flow were similar to those in a previous study. We evaluated a range of exposure periods, each with the collision time at the midpoint of the period. We conducted unmatched analyses so that misclassification due to measurement error could be determined from inspection of the 2 × 2 tables.

<table>
<thead>
<tr>
<th>TABLE 1. Distribution of Subjects, Odds Ratio Estimates, and 95% Confidence Intervals for “High Traffic Flow” with Varying Exposure Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure Period</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>1 hour</td>
</tr>
<tr>
<td>Cases</td>
</tr>
<tr>
<td>Controls</td>
</tr>
<tr>
<td>3 hours</td>
</tr>
<tr>
<td>Cases</td>
</tr>
<tr>
<td>Controls</td>
</tr>
<tr>
<td>12 hours</td>
</tr>
<tr>
<td>Cases</td>
</tr>
</tbody>
</table>

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Differential misclassification can bias the odds ratio toward or away from the null, so that determining which exposure period in this study involves the least measurement error, and consequently the minimum of bias, is problematic. Nevertheless, the results demonstrate the magnitude of the bias that may result from measurement error. A previous case-control study of traffic flow and the risk of child pedestrian injury compared mean weekday traffic volume for injury sites and control sites and estimated an odds ratio of 3.5 (95% confidence interval = 1.0–11.8) for sites with a mean daily traffic volume greater than 15,000 vehicles. In view of the difference in the effect estimates between the 3- and 24-hour exposure periods in this study, it is possible that this figure may be an underestimate.

Some degree of exposure misclassification is inevitable in epidemiologic studies. The magnitude of the bias demonstrated here underscores the importance of examining the effect of different measurement assumptions.

References

Validation Study Methods

Table 1. Data for validation studies. \( E \) is true exposure status, \( X \) measured exposure status

<table>
<thead>
<tr>
<th>Measured exposure ( X )</th>
<th>Validation True exposure ( E )</th>
<th>Total</th>
<th>(Remainder)*</th>
<th>Primary study</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x )</td>
<td>( e ) a</td>
<td>( n_x )</td>
<td>( R_x = N_x - n_x )</td>
<td>( N_x )</td>
</tr>
<tr>
<td>( x^- )</td>
<td>( e^- ) c</td>
<td>( n_x^- )</td>
<td>( R_{x^-} = R - R_x )</td>
<td>( N_{x^-} )</td>
</tr>
<tr>
<td></td>
<td>( n_e )</td>
<td>( n )</td>
<td>( R = N - n )</td>
<td>( N )</td>
</tr>
</tbody>
</table>

\[
P_D = \frac{a}{n_x} \left( \frac{N_x}{N} \right) + \frac{c}{n_{x^-}} \left( \frac{N_{x^-}}{N} \right)
\]
APPENDIX 5

Publications
Child pedestrian mortality and traffic volume in New Zealand

Ian Roberts, Roger Marshall, Robyn Norton

Pedestrian injuries are a leading cause of childhood mortality. The analysis of trends in pedestrian death rates may provide information on the determinants of the incidence of these injuries. We have examined the relation between child pedestrian mortality and traffic volume in New Zealand from 1967 to 1987.

Methods and results
Child (aged <15 years) pedestrian death rates (ICD code E814-7) were calculated by using National Health Statistics Centre mortality data for 1967 to 1987. A traffic volume index, based on data from traffic counters on urban highways throughout New Zealand, and the number of registered vehicles were obtained from the Ministry of Transport.

There was an annual average of 32·5 pedestrian deaths over the study period (3·7/100 000 children yearly). From 1967 to 1975 there was a 57·1% increase in traffic volume and a 69·7% increase in the death rate. Between 1975 and 1981 traffic volume increased by only 5·2% and death rates fell by 46·4%. After 1982 traffic volume rose by 27·6% and death rates by 53·7% (see figure). The number or registered vehicles increased steadily by 91·3% between 1967 and 1987.

The trend in child pedestrian death rates was examined by Poisson regression modelling. Death rate was the dependent variable and traffic volume index (V), number of registered vehicles (R), and year (Y) the explanatory variables. The expected death rate (P) was modelled by a log linear equation, of the form: log F = β0 + β1V + β2Y + β3R. After fitting the model only the variables V (β0 = 3·089, SE 0·929; p = 0·0009) and

Y (β1 = -0·095, SE 0·025; p = 0·0002) were significant. The number of registered vehicles (R) was not significant in the model (p = 0·244) or in a model with only R and Y (p = 0·102). When rates were modelled with the unusual year 1976 excluded the coefficients were essentially unchanged. The relation between the death rates, traffic volume, and rates predicted by the model are shown in the figure.

Comment
A definite decline in child pedestrian death rates occurred between 1975 and 1981, a period in which there was very little growth in traffic volume. The energy crisis of 1974, which was accompanied by a fourfold increase in the price of petrol, was probably important in determining the growth in traffic volume. As a result of the crisis the New Zealand government introduced "careless days" (when each car was required to be off the road for one day each week) and a ban on weekend petrol sales, which lasted until August 1980. That the pedestrian death rates fell, as opposed to having levelling off in line with the plateau in traffic volume, suggests that the safety of the transport system was also improving during the period.

The results of modelling support these findings. A positive coefficient was derived for traffic volume, showing that death rates increase when traffic volume increases. A negative coefficient was derived for year, showing that, after controlling for traffic volume, death rates decline over time.

The impressive fall in death rates that occurred between 1975 and 1981 suggests that limiting the future growth in traffic volume has the potential significantly to reduce child pedestrian mortality. This would require public policy changes that strengthen the public transport system, discourage the use of private vehicles, promote cycling, and encourage the use of rail, river, and sea transport by freight. Ultimately the impetus for reducing the growth in traffic volume may come from an increasing awareness of the health effects of road traffic apart from injury. With cities in Britain, North America, and Australia having recently experienced episodes of photochemical pollution, the environmental effects of motorisation are increasingly becoming the focus of attention.

We thank Professor Robert Beaglehole for critical comments on the manuscript.

Cardiac rehabilitation programmes: are women less likely to attend?

Hannah M McGee, John H Horgan

Cardiac rehabilitation programmes offer valuable secondary prevention after myocardial infarction and other cardiac events. Research attests to the effectiveness of rehabilitation programmes—for example, in decreasing death rates after myocardial infarction. However, the evidence is based almost exclusively on male patients under 70. Though the positive impact of exercise training by female cardiac patients has been documented, women are perceived as being less motivated to attend structured programmes especially those entailing vigorous exercise.

Some studies have noted higher drop out rates for women. Oldridge and colleagues noted a higher one year drop out rate from a cardiac rehabilitation programme for female (18/28; 64%) than male (65/153; 42%) patients after myocardial infarction or coronary artery surgery in the 1970s. A study of similar patients in the early 1980s found a female drop out rate of 18-9% (7-9% in men) and a lower programme attendance record for women (77% v 87%) (n = 37 women, 227 men).
Table 1  Major causes of injury admission for Auckland children aged 0–14 years, 1982–87

<table>
<thead>
<tr>
<th>Causes of injury</th>
<th>ICD9 E code</th>
<th>No.</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (all injuries)</td>
<td>E800–999</td>
<td>13735</td>
<td>100.0</td>
</tr>
<tr>
<td>Accidental falls</td>
<td>E880–888</td>
<td>4137</td>
<td>30.1</td>
</tr>
<tr>
<td>Other accidents</td>
<td>E916–928</td>
<td>3347</td>
<td>24.4</td>
</tr>
<tr>
<td>Motor vehicle and traffic accidents</td>
<td>E810–819</td>
<td>1476</td>
<td>10.7</td>
</tr>
<tr>
<td>Other road vehicle accidents</td>
<td>E826–829</td>
<td>890</td>
<td>6.5</td>
</tr>
<tr>
<td>Accidental poisoning</td>
<td>E850–869</td>
<td>738</td>
<td>5.4</td>
</tr>
<tr>
<td>Late effects of accidental injury</td>
<td>E929</td>
<td>703</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Total injury morbidity

Refer to Fig. 1. Several pockets of high (SMR > 1.5) morbidity are discernible in the central urban area and in south Auckland. The two eastern waterfront areas with high SMR corresponding to central Auckland (a) and Orakei (b) are separated from another band of particularly high rates (Onehunga, Penrose, Mt Wellington) by an area of low morbidity centred on Remuera (c). Average rates are seen throughout the whole of south Auckland with the exception of the eastern suburbs. Low rates predominate on the North Shore especially the east coast where morbidity rates are less than three-quarters the regional average.

Pedestrian injury morbidity

Refer to Fig. 2. There are two main zones of high pedestrian injury morbidity. The largest extends from the south-eastern corner of the central urban area down into south Auckland, with a second area of high rates occurring around central Auckland. Rates are above average throughout most of south Auckland, with the exception of the eastern suburbs. Pedestrian injury morbidity rates are below average on the North Shore.

Motor vehicle occupant injury morbidity

Refer to Fig. 3. Motor vehicle occupant injury morbidity is characterized by higher than average rates in the west, the central urban area and in south Auckland. Rates are particularly low throughout the North Shore and the north-western suburbs.

Correlation with unemployment rates

Unemployment rates were significantly correlated with all childhood injury morbidity measures. Table 2 shows the Spearman rank correlation coefficients for the morbidity measures and census area unit unemployment rates.
An area analysis of child injury morbidity in Auckland

I. ROBERTS,\(^1\) R. MARSHALL,\(^2\) R. NORTON\(^3\) and B. BORMAN\(^3\)

\(^1\)Auckland Injury Prevention Research Centre, \(^2\)Department of Community Health, University of Auckland, Auckland and \(^3\)Health Statistical Services, Department of Health, Wellington, New Zealand

Abstract The geographical distribution of child injury morbidity in Auckland between 1982 and 1987 was examined. Analysis of total injury, pedestrian injury and vehicle occupant injury, with the census area unit as the basic spatial entity revealed distinct variations in child injury morbidity by census area unit. Morbidity rates were above average in parts of the central urban area and South Auckland and below average on the North Shore. Total injury morbidity and pedestrian injury morbidity rates were strongly correlated with census area unit unemployment rates, which were used as a measure of socio-economic deprivation. Geographical areas with high rates of child injury morbidity, to which injury prevention resources can be directed, were identified. In particular, the results suggest that injury prevention programmes should be targeted at socio-economically disadvantaged communities.

Key words: childhood injuries; ecological analysis; occupant; pedestrian.

For New Zealand children between the ages of 1 and 14 years, injuries are the leading cause of death and the second leading cause of hospitalization.\(^1,2\) Of all childhood deaths, pedestrian injuries and motor vehicle occupant injuries are the leading causes.\(^3\) For many childhood injuries, effective prevention strategies are available but are not implemented. It has been estimated that with the implementation of 12 currently available prevention strategies 29% of child injury deaths could be prevented.\(^3\) Improved access to injury prevention resources for parents of children at high risk of injury might be expected to lead to higher levels of implementation. The identification of geographical areas where child injury rates are highest would enable injury prevention programmes and resources to be allocated preferentially to areas where the need is greatest. This study examines the geographical variations in childhood injury morbidity in Auckland. Maps are presented on total injury morbidity, pedestrian injury and motor vehicle occupant injury.

METHODS

Records of all admissions to public hospitals in the Auckland region for childhood (<15 years) injury (E800–999) were obtained for the period 1982–87 from Health Statistical Services. Each hospital admission was recorded with a census area unit domicile code indicating where the child was usually resident. These census area units form the basic spatial entity for the area analysis. The census area unit boundaries were not changed during the study period. One hundred and sixty-six census area units were used to define the Auckland region. For each recorded hospital admission, information on year of injury, age and ICD9 E code was available. Denominator data to compute hospital morbidity rates were obtained by linear interpolation using 1981 and 1986 census data. Age standardized rates were computed, taking the age structure of all Auckland children as the standard. Standardized morbidity ratios (SMR), showing an excess (SMR>1) or deficit (SMR<1) from the Auckland regional average were then computed and mapped. Maps were produced using the SAS computer mapping procedure GMAP.\(^4\) The SMR levels <0.75, 0.75–1, 1–1.25, 1.25–1.5, >1.5 are represented in all maps.

Subgroup analyses of pedestrian (E814) and motor vehicle occupant morbidity (E810–19 excluding E814) were also performed. However, because of relatively few admissions per census area unit, a statistical method to handle inherent random variability was used. The method is described in detail elsewhere.\(^5\) Briefly, age specific estimates of morbidity at each unit were obtained using a weighted average of the rate at the unit and its adjacent neighbours.

Finally, the extent to which the observed morbidity patterns reflect patterns of socio-economic deprivation was explored using census area unit unemployment rates as the deprivation measure. Spearman rank correlation coefficients were calculated between the standardized injury morbidity ratios and the census area unit unemployment rate at the time of the 1981 census.

RESULTS

There were a total of 13735 childhood injury admissions to all Auckland public hospitals over the 6 year period, of which 702 were pedestrian injuries and 774 were vehicle occupant injuries. The major causes of injury admission are shown in Table 1.
Unemployment rates were used in this study as an index of socio-economic deprivation. A recent British study found that unemployment rates were strongly correlated with other purposely developed indices of deprivation, with Spearman rank correlation coefficients of 0.799 for the Jarman index and 0.874 for Townsend's material deprivation index. The strong correlations observed between injury morbidity and unemployment rates suggest therefore that the observed morbidity patterns reflect those of socio-economic disadvantage in Auckland. Since hospital admission might be influenced by factors apart from injury severity, it is also possible that the observed patterns reflect differential admission by socio-economic status. However, the strong association between socio-economic disadvantage and pedestrian injury is consistent with other studies. A Montreal study found that the rate of pedestrian and bicycle injury to children living in the poorest neighbourhoods was four times that of those living in the wealthiest neighbourhoods, although the reasons for this remain obscure. The importance of environmental factors was shown in a North American study which found that the risk of pedestrian injury to children living in neighbourhoods with high traffic volumes was three times that of children living in low volume areas. The weaker associations observed for vehicle occupant injuries in this study might be related to lower vehicle ownership in disadvantaged areas.

In establishing causal relationships ecological studies can be directed. For example, child passenger restraints are a known effective prevention strategy. A recent study found that child restraints were approximately 60% effective in preventing injuries to the skull and brain. The challenge for injury prevention lies in increasing their utilization. By directing injury prevention programmes to areas with high occupant injury morbidity rates, utilization rates might be improved.

The impact of poverty and disadvantage on child health has already been documented. The results of this study suggest that childhood injuries show similar socio-economic inequalities. Further studies are required to identify and determine the relative importance of the environmental and behavioural determinants of these inequalities, so that prevention strategies can be designed appropriately. Child injury prevention strategies should be aimed at socio-economically disadvantaged communities. Paediatricians as advocates for children have a responsibility to act to prevent the perpetuation of these inequalities.

ACKNOWLEDGEMENTS

The permission of the Director General of Health to publish this paper is acknowledged.
REFERENCES

International trends in pedestrian injury mortality

I G Roberts

Abstract
Trends in pedestrian injury mortality for children aged 0-4 and 5-14 for England and Wales, Denmark, Sweden, the USA, and New Zealand were examined from 1968 onwards. While there has been a reduction in the pedestrian mortality in all these countries, there are striking international differences in the extent of these reductions. Denmark has achieved the greatest fall in mortality with the smallest decrease seen in New Zealand. Countries which have experienced major decreases in pedestrian mortality are distinguished by having placed greater emphasis on environmentally based prevention strategies rather than pedestrian skills education.

Pedestrian injuries are a leading cause of childhood mortality. Each year in England and Wales approximately 230 children are killed in pedestrian-motor vehicle collisions. For the children who survive the injuries are often severe. A North American study found that 24% of children involved in pedestrian motor vehicle collisions required hospital admission. Serious head injury is common with high levels of residual disability.

Over the past two decades a number of different approaches to the prevention of child pedestrian injuries have been tried in different countries. Usually these strategies are implemented at the national level as part of a countries road safety policy, for example, the Green Cross Code in the UK. International comparisons of child pedestrian fatality rates may therefore provide some insight into the relative efficacy of the different strategies adopted. In this study international trends in child pedestrian mortality are examined and these trends are considered in relation to the types of preventive strategy employed.

Methods
Pedestrian injury mortality rates (ICD 9 E code 814.7) for children aged 0-4 and 5-14 were obtained for England and Wales, Denmark, Sweden, the USA, and New Zealand from 1968 until the most recent year for which these data were available. Data for England and Wales were obtained from the Office of Population Censuses and Surveys, for Denmark from the Danish Council for Road Safety Research, for Sweden from Statistics Sweden, for the USA from the Centers for Disease Control, and for New Zealand from Health Statistical Services published data. To reduce the influence of random variability and give a clearer impression of overall trends, three year moving averages were calculated and shown graphically. Specific year comparisons were made for 1987, the most recent year for which data were available for all the countries studied.

Results
The trends in pedestrian injury mortality for children aged 0-4 and 5-14, for England and Wales, Denmark, Sweden, the USA, and New Zealand are shown in the figure. For children aged 0-4 there were marked international differences in mortality rates with New Zealand having the highest rates and Sweden the lowest. By comparison with Sweden in 1987 the pedestrian mortality rate in New Zealand was 13.3
times higher, in the USA 6·0 higher, in England and Wales 5·3 times higher, and in Denmark 3·6 times higher (see table 1). A similar pattern of decline was observed in all five countries over the study period with a marked decline in the early to mid-1970s, a slight increase after 1976 and a further major decline between 1978 and 1982. Between 1968 and 1987 the largest absolute reduction in mortality rates was in Denmark with a reduction of 5·6/100 000. The smallest absolute reduction was seen in New Zealand with a reduction of 0·4/100 000. Sweden experienced the greatest percentage reduction in mortality rates (91%) followed by Denmark (84%), England and Wales (67%), the USA (57%), and New Zealand (9%).

For children aged 5–14 years there were again conspicuous international differences in mortality rates with England and Wales having the highest rates and Sweden the lowest. By comparison with Sweden in 1987 the mortality rate in England and Wales was 2·3 times higher, in New Zealand 2·1 times higher, in the USA 1·9 times higher, and in Denmark 1·3 times higher (see table 2). There has been a steady decline in mortality rates in all five countries since 1968, although the decline for children aged 5–14 years was less pronounced than that for the 0–4 year age group. Between 1968 and 1987 the greatest absolute reduction in mortality rates was seen in Denmark with a reduction of 6·2/100 000. The smallest absolute reduction was in New Zealand with a reduction of 0·8/100 000. Denmark showed the greatest percentage reduction in mortality rates (79%) followed by Sweden (68%), the USA (40%), England and Wales (39%), and New Zealand (24%).

### Table 1: Pedestrian mortality in children 0–4 years in 1987

<table>
<thead>
<tr>
<th>Country</th>
<th>Rate/100 000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>0·3</td>
</tr>
<tr>
<td>Denmark</td>
<td>1·1</td>
</tr>
<tr>
<td>England and</td>
<td>1·6</td>
</tr>
<tr>
<td>Wales</td>
<td>1·8</td>
</tr>
<tr>
<td>USA</td>
<td>2·3</td>
</tr>
<tr>
<td>New Zealand</td>
<td>4·0</td>
</tr>
</tbody>
</table>

### Table 2: Pedestrian mortality in children 5–14 years in 1987

<table>
<thead>
<tr>
<th>Country</th>
<th>Rate/100 000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>1·2</td>
</tr>
<tr>
<td>Denmark</td>
<td>1·6</td>
</tr>
<tr>
<td>England and</td>
<td>2·8</td>
</tr>
<tr>
<td>Wales</td>
<td>2·3</td>
</tr>
<tr>
<td>USA</td>
<td>2·5</td>
</tr>
</tbody>
</table>

**Discussion**

The examination of trends in mortality is sometimes complicated by changes in classification conventions for the cause of death. However although in this study cause of death was classified according to the 8th revision of the International Classification of Diseases from 1968 to 1978 and the 9th revision subsequently, the code for pedestrian injury remained unchanged between these revisions. Furthermore for events as unequivocal as pedestrian-motor vehicle collisions it is unlikely that the external cause of injury would be classified differently in different countries. It is therefore reasonable to assume that valid international comparisons can be made for the time period studied.

The data show that although there has been a fall in child pedestrian mortality for children of all ages, there are marked international differences in the extent of these reductions with substantial differences in the most recent mortality rates. In 1987, if England and Wales had experienced the same pedestrian mortality rate as Sweden, there would have been 130 fewer child pedestrian deaths.

While it would be inappropriate to attribute the international differences in pedestrian mortality rates to any specific prevention programme some 'broad brush' inferences may be justified. The most striking difference between Denmark and Sweden, countries which have made impressive strides in the reduction of pedestrian mortality, and New Zealand and Britain, where reductions have been less impressive, is the greater emphasis given to environmental approaches to prevention in the former countries as opposed to educationally based prevention strategies in the latter. Although all countries have employed both environmental and educational measures to some extent, legislative changes in Denmark and Sweden, which gave greater priority to pedestrians, resulted in a balance of strategies weighted more towards environmental change in these countries. In particular Denmark, which changed its ranking from having the highest mortality rates in 1970 to being second only to Sweden in 1988, made a major commitment to a programme of environmental change which resulted in lower vehicle speeds in urban areas. Specifically, local streets were designated as 'living areas' with speed limits of either 30 km/hour or 15 km/hour and give way rules reversed to give priority to pedestrians. Compliance with speed limits was encouraged by traffic calming measures such as speed humps. In addition, major roads passing through towns were also modified with the introduction in the 1980s of 'environmentally adapted through roads' which again used traffic engineering measures to reduce speed. These projects had a dramatic effect on safety and were also popular with residents. Similarly in Sweden, environmental modifications were implemented according to the SCAFT environmental planning guidelines which emphasised the importance of separating pedestrians from traffic.

By contrast in New Zealand and Britain the major thrust of preventive strategy comprised attempts of change child behaviour through pedestrian skills training programmes. These programmes, however, have proved to be of limited value. Although a small scale evaluation in New Zealand did demonstrate changes in behaviour after pedestrian skills education, few programmes internationally have been shown to lead to reduced injury rates. Indeed there is evidence to suggest that the fall in pedestrian mortality which occurred in New Zealand between 1974 and 1982 was due to the reduced growth in traffic volume after the oil crisis, rather than being the result of education campaigns.

The international differences in pedestrian mortality cannot be taken as evidence for the efficacy of environmental prevention strategies as there may be other confounding factors, such as international differences in children's exposure to traffic, that account for them. Nevertheless, they do provide some support for the view that greater emphasis should be given to environmental approaches in future prevention efforts. These approaches will require expertise outside the domain of the paediatrician, in particular that of town planners and civil engineers. However paediatricians have an integral part to play in forging the interdisciplinary coalitions required to achieve these goals.

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Council of Road Safety Research, Yvonne Lonn of Statistics Sweden, Richard Waxweiler of the Centers for Disease Control, and the National Health Statistics Centre for providing the data.

has been a greater decline in the T4 lymphocyte count. An aseptic meningitis occurs in some patients at the time of seroconversion approximately two to six weeks after the acquisition of infection [1] but in our patient occurred many years after infection as others have described [1]. Cerebral toxoplasmosis commonly occurs early in the course of AIDS and patients frequently survive for months to years [8,12,13]. In contrast primary CNS lymphoma, progressive multifocal leukencephalopathy and clinically significant AIDS dementia commonly occur late in the course of AIDS and have a poor prognosis [1,3,5].

Acknowledgements: Dr N Anderson, neurologist, provided helpful advice on the investigation and management of many of these patients. Mrs D Black, the medical typist.

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Child pedestrian injury 1978-87

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Abstract

Object: to report the incidence of child pedestrian injury in New Zealand and review prevention strategies.


Results: over the ten year period, there was an annual average of 30 deaths (3.6/100,000 per year) and 411 hospitalisations (49/4/100,000 per year) for child pedestrian injury. There has been no significant reduction in the fatality or hospital morbidity rate over this time. Pedestrian fatality rates are highest for boys and for children in the youngest age groups. Hospitalisation rates are over 2.5 times higher for Maori children than for non-Maori children.

Conclusions: child pedestrian injury is an important public health problem in New Zealand for which there are few established prevention strategies. Controlled studies aimed at the identification of modifiable environmental factors are required.

NZ Med J 1992; 105: 512

Introduction

The establishment of both the New Zealand Health Goals and Targets for the year 2000 [1] and the Priorities for Child Health in New Zealand [2] provides a focus for public health efforts for the coming decade. The reduction of preventable death and disability from motor vehicle crashes is one of the ten health goals, with child safety and the prevention of injuries one of the ten child health priorities. For New Zealand children, between the ages of one and fourteen years, pedestrian injuries are the leading cause of death. In the following article we report the incidence of child pedestrian injury in New Zealand, and review strategies for prevention.

Methods

National Health Statistics Centre (now Health Statistical Services) mortality and hospital morbidity data from 1978-87 were examined to identify all deaths and hospital discharges for pedestrian injury (International Classification of Diseases E codes 814.7 and 822.7), in children between the ages of 0 and 14 years. Mortality and hospital morbidlty rates per 100,000 population were calculated using National Health Statistics Centre population estimates. Ninety-five percent confidence intervals were calculated assuming a Poisson distribution [3,4].

Results

Mortality: over the ten years from 1978-87 there were 300 fatal pedestrian injuries to children aged 0-14 years, an average of 30 deaths per year (Table 1) [3]. There was no significant change in the pedestrian death rates over this period, with an average annual death rate of 3.6 deaths per 100,000 children.

Boys accounted for 59.0% of the deaths with a fatality rate significantly higher than that for girls. Over 80% of the fatalities were sustained by children younger than 10 years, with rates significantly higher than those in the age group 10-14 years. Mortality rates were similar for Maori and non-Maori children.

Of the 300 pedestrian deaths, 265 (88.3%) were coded as traffic deaths (ICD9 E814.7), that is, deaths occurring on streets or on roads and 35 (11.7%) were coded as non traffic deaths (ICD9 E892.7), that is, deaths occurring on driveways, car parks or lanes.

Morbidity: between 1978 and 1987 there were a total of 4110 hospital discharges for child pedestrian injury, an average of 411 discharges per year (Table 2) [4]. There was no significant change in the rates of hospitalisation over this period, with an average annual hospital discharge rate of 4.9 discharges per 100,000 population.

Boys accounted for 62.6% of the discharges with a discharge rate approximately 50% higher than that for girls. The peak age for hospitalisation was between 5-9 years, with this age group accounting for 41.7% of the total discharges. The discharge rate for Maori children was over 2.5 times higher than that for non-Maori children.

Of the 4110 hospital discharges, 3793 (92.3%) were coded as traffic events and 316 (7.7%) were coded as nontraffic events.

Discussion

Pedestrian injury is the leading cause of road crash death in New Zealand children, accounting for 44% of road crash deaths in children between the ages of one and fourteen years. In 1987, there were 2.5 times more deaths from pedestrian injuries in this age group, than from leukaemia, the leading childhood malignancy, four times more deaths than from asthma and five times more deaths than from all infectious diseases combined [9]. The child pedestrian fatality rate for New Zealand of 3.6/100,000 per year is significantly higher than the rates for both the USA (2.8/100,000) [9] and the UK (2.6/100,000) [6].

The finding that rates of pedestrian injury are significantly higher for boys than girls, has been observed in other countries [7]. However the reason for this remains obscure. Howarth et al found that exposure to risk as pedestrians, in terms of the number of roads crossed and traffic density, was similar for boys and girls and suggested that the different rates may reflect sex determined differences in behaviour [8]. The rate
of hospitalisation was highest for children aged 5-9 years, however the fatality rate was highest for the 0-4 age group, reflecting the high case fatality rate for this group [7].

The high rate of pedestrian injury hospitalisation for Maori children, at nearly three times that for nonMaori children, is particularly striking. An Auckland study of admissions to the department of critical care medicine for child pedestrian injury also found that the admission rate for Maori children was three times higher than that for nonMaori children [9]. This suggests that the ethnic differences in hospitalisation rates are likely to reflect actual differences in injury occurrence rather than differential admission criteria. The finding that pedestrian mortality rates differ little between nonMaori and Maori children is therefore surprising, but might reflect misclassification of ethnicity in mortality statistics, as has been reported previously [10].

Over the ten years from 1978-87 both mortality and hospital morbidity rates have changed little, suggesting that pedestrian injury will continue to be a major child health problem if efforts are not directed at prevention. In New Zealand, the most preventable have been directed at changing child behaviour through pedestrian skills training programmes. Although some of these programmes have been shown to lead to changes in observed behaviour, few programmes internationally and none of those currently taught in New Zealand have been shown to reduce injury rates [11,12]. With close to half of the fatalities and over one-third of the hospitalisations in the 0-4 age group, a more appropriate target for education programmes might be changing parental expectations of children’s abilities in traffic [13].

Overall prevention strategies include modifying driver behaviour and changing vehicle design [14,15]. However there is little evidence to suggest that either of these approaches is likely to be effective [16,17]. Of all the possible intervention strategies, those directed at the environment have been suggested as having the greatest potential to reduce injury rates [18,19]. The reduced injury rates seen in Scandinavian cities in which town planning has reduced the traffic volume and speed in residential areas [20], provides support for this approach. Further support comes from suggestions that the strong inverse relationship between risk of pedestrian injury and socioeconomic area of residence relates to the higher traffic flows, greater vehicle speeds and lack of alternatives to playing in the street that are found in poor areas [21,22]. However, to date, there have been few controlled studies of the risks associated with environmental factors.

In summary, child pedestrian injury is an important public health problem in New Zealand for which there are few well established prevention strategies. Controlled studies aimed at the identification of modifiable environmental factors are required. This information might then lead to development of interventions that will reduce preventable death and disability from pedestrian injury by the year 2000.

Acknowledgements: the authors wish to thank Steve Marshall of the Otago injury prevention research unit for extracting data from National Health Statistics Centre data files. We also thank Dr Imre Asher for her comments on the manuscript.

Correspondence: Dr Ian Roberts, Auckland Injury Prevention Research Centre, Department of Community Health, University of Auckland School of Medicine, Private Bag, Auckland.

Table 1.—Fatal pedestrian injuries in children in New Zealand 1978-87

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>%</th>
<th>Rate/100 000 population (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total males</td>
<td>1777</td>
<td>59.0</td>
<td>4.2 (3.6, 4.9)</td>
</tr>
<tr>
<td>Total females</td>
<td>129</td>
<td>41.0</td>
<td>3.0 (2.4, 3.6)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-4</td>
<td>136</td>
<td>45.3</td>
<td>5.3 (4.5, 6.3)</td>
</tr>
<tr>
<td>5-9</td>
<td>114</td>
<td>39.0</td>
<td>4.1 (3.4, 4.9)</td>
</tr>
<tr>
<td>10-14</td>
<td>50</td>
<td>16.7</td>
<td>1.7 (1.2, 2.2)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NonMaori</td>
<td>256</td>
<td>85.3</td>
<td>3.5 (3.1, 4.1)</td>
</tr>
<tr>
<td>Maori</td>
<td>44</td>
<td>14.7</td>
<td>4.1 (2.9, 5.4)</td>
</tr>
<tr>
<td>Cause</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MV traffic</td>
<td>265</td>
<td>88.0</td>
<td>2.2 (2.8, 3.6)</td>
</tr>
<tr>
<td>MV nontraffic</td>
<td>35</td>
<td>12.0</td>
<td>0.4 (0.3, 0.6)</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td>25</td>
<td></td>
<td>3.9 (2.7, 5.5)</td>
</tr>
<tr>
<td>1979</td>
<td>21</td>
<td></td>
<td>3.7 (2.5, 5.0)</td>
</tr>
<tr>
<td>1980</td>
<td>23</td>
<td></td>
<td>4.0 (2.7, 5.5)</td>
</tr>
<tr>
<td>1981</td>
<td>13</td>
<td></td>
<td>3.7 (2.6, 5.3)</td>
</tr>
<tr>
<td>1982</td>
<td>21</td>
<td></td>
<td>2.5 (1.7, 3.8)</td>
</tr>
<tr>
<td>1983</td>
<td>22</td>
<td></td>
<td>2.7 (1.7, 4.0)</td>
</tr>
<tr>
<td>1984</td>
<td>12</td>
<td></td>
<td>3.9 (2.7, 5.5)</td>
</tr>
<tr>
<td>1985</td>
<td>12</td>
<td></td>
<td>3.6 (2.3, 5.2)</td>
</tr>
<tr>
<td>1986</td>
<td>19</td>
<td></td>
<td>3.6 (2.3, 5.2)</td>
</tr>
<tr>
<td>1987</td>
<td>19</td>
<td></td>
<td>4.3 (2.9, 6.0)</td>
</tr>
<tr>
<td>Total</td>
<td>300</td>
<td></td>
<td>3.6 (3.2, 4.0)</td>
</tr>
</tbody>
</table>

Table 2.—Hospital discharges for pedestrian injury in children in New Zealand 1978-87

<table>
<thead>
<tr>
<th>Category</th>
<th>N</th>
<th>%</th>
<th>Rate/100 000 population (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total males</td>
<td>2572</td>
<td>62.6</td>
<td>60.6 (58.2, 62.9)</td>
</tr>
<tr>
<td>Total females</td>
<td>1537</td>
<td>37.4</td>
<td>37.5 (35.0, 39.8)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-4</td>
<td>1409</td>
<td>34.3</td>
<td>55.3 (52.5, 58.3)</td>
</tr>
<tr>
<td>5-9</td>
<td>1714</td>
<td>41.7</td>
<td>62.0 (59.0, 64.9)</td>
</tr>
<tr>
<td>10-14</td>
<td>987</td>
<td>24.0</td>
<td>32.9 (31.0, 35.1)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maori</td>
<td>1196</td>
<td>29.1</td>
<td>110.3 (104.5, 117.1)</td>
</tr>
<tr>
<td>NonMaori</td>
<td>2914</td>
<td>70.9</td>
<td>40.3 (38.8, 41.5)</td>
</tr>
<tr>
<td>Cause</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MV traffic</td>
<td>3793</td>
<td>92.3</td>
<td>45.6 (44.2, 47.1)</td>
</tr>
<tr>
<td>MV nontraffic</td>
<td>316</td>
<td>7.7</td>
<td>3.8 (3.4, 4.2)</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td>646</td>
<td></td>
<td>52.4 (47.7, 57.3)</td>
</tr>
<tr>
<td>1979</td>
<td>416</td>
<td></td>
<td>45.0 (43.5, 55.8)</td>
</tr>
<tr>
<td>1980</td>
<td>478</td>
<td></td>
<td>56.2 (51.3, 61.5)</td>
</tr>
<tr>
<td>1981</td>
<td>380</td>
<td></td>
<td>45.2 (40.7, 50.0)</td>
</tr>
<tr>
<td>1982</td>
<td>395</td>
<td></td>
<td>47.4 (42.7, 52.2)</td>
</tr>
<tr>
<td>1983</td>
<td>362</td>
<td></td>
<td>43.8 (39.4, 48.6)</td>
</tr>
<tr>
<td>1984</td>
<td>485</td>
<td></td>
<td>59.4 (54.3, 64.9)</td>
</tr>
<tr>
<td>1985</td>
<td>375</td>
<td></td>
<td>46.4 (41.8, 50.1)</td>
</tr>
<tr>
<td>1986</td>
<td>399</td>
<td></td>
<td>50.3 (45.5, 55.6)</td>
</tr>
<tr>
<td>1987</td>
<td>355</td>
<td></td>
<td>45.2 (40.6, 50.1)</td>
</tr>
<tr>
<td>Total</td>
<td>4110</td>
<td></td>
<td>49.4 (47.9, 51.0)</td>
</tr>
</tbody>
</table>
accurate bookkeeping and performance within budget.

Another issue to be resolved is the time after accident at which assessment and rehabilitation should take place. A balance is required between excessive investment in unnecessarily expensive (seeing all subjects early after injury or illness), and seeing people later on, by which time abnormal illness behaviours could have become established. We would suggest at between eight to 13 weeks after injury.

Benefits from this type of programme include an accurate assessment of the workers' medical problems, and an accurate functional assessment as well as an accurate prescription of the type of work which the worker could handle. We assume that the increased physical fitness will reduce the likelihood of reinjury, especially in workers with repeated injuries. Further research is required in this area. Other benefits in a future centre include an early decision that a worker could not return to paid employment, so that compensation decisions could be made early, and a new life style developed.

This study addressed the problem of a small group of people with long times off work, and demonstrated a successful outcome with positive cost benefit performance. It is possible to generalise from this selected group to the general population of injured workers, it would be possible to calculate benefits on a national scale. If 20 rehabilitation centres were established nationally, each with an operating budget of $500 000 the estimated cost would be $10 million. With a BCR of 1.5:1 and a 10% discount rate, net savings in the first year would be $5 million in ECR payments. This would accumulate to $52 million by five years, and $90 million by 10 years. We recommend that the ACC invest in such rehabilitation centres and reap the expected benefits, both visible and invisible, and reduce pain and suffering among injured people.

Acknowledgments: this project was funded by the Accident Compensation Corporation of New Zealand, and carried out in association with the injury prevention research group of the University of Otago. The authors would like to thank Professor Margaret Lectist of the University of Otago and Mr Murray Johnson of the ACC for their support, and Mr Paul Hansen for his construction of the computerised Swestuass.

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Critical injuries in paediatric pedestrians
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Abstract
Data are presented on all sixty-four children who were injured as pedestrians and admitted to the department of critical care medicine, Auckland Hospital over a four year period. Median age was six years, with a male:female ratio of 1:6:1:0. Admission rates were 3.1 and 3.0 times higher for Maori and Pacific Island children, respectively, than for children of European origin. Fifty-two percent of injuries occurred between 3 pm and 7 pm. Median injury severity score (ISS) was 29, and 55% of patients had an ISS of 16 or more. Life threatening injuries were most common to the head, whilst less severe injuries, commonly fractures, were to the limbs. The combination of head and lower limb injury was seen in 53% of patients. Twenty-nine patients had 34 operative procedures: 16 orthopaedic, six neurosurgical, four laparotomies and eight wound debridement and closure. Eighty-one percent of the patients received ventilatory support and nine patients (14%) died, all from brain injuries. Pediatric injury is an important child health problem in New Zealand and studies aimed at the identification of factors that place children at risk for these injuries are needed.

NZ Med J 1991; 104: 247-8

Introduction
In New Zealand children aged between one and 14 years, injuries are the leading cause of death and the second leading cause of hospital admission [1,2]. In 1987 motor vehicle crashes were responsible for 26 percent of all deaths in this age group and pedestrian injuries accounted for nearly half of these [1]. This paper describes a series of critically injured paediatric pedestrians and identifies patient characteristics, patterns of injury and use of resources.

Methods
The department of critical care medicine's computerised prospective trauma registry was used to access data on all injured child pedestrians (<15 yr) admitted to the department between 1986 and 1989. The department is the main intensive care facility for children within the Auckland Area Health Board (AAHB) region, which in 1986 had a predominantly urban population of 889,170 of whom approximately 208,650 were under 15 years of age [1]. Data collected included age, sex, ethnicity, time of injury, nature of injuries, mortality, specific intensive care treatment modalities used, operative procedures and length of intensive care stay.

Ambulance officers reports were used to collect data on mechanism of injury and hospital records were used to determine length of hospital stay. Ethnic specific admission rates were calculated for the Auckland Area Health Board by excluding transfers from other regions and using 1986 census data [2]. Ninety-five percent confidence intervals were calculated using the data from four years and assuming a Poisson distribution.

For each subject, an injury severity score (ISS) was calculated during admission [3] using the 1980 revision of the abbreviated injury scale (AIS) [4]. Under this system the body is divided into six regions (head, face, thorax, abdomen, extremities and external). Each injury is assigned an AIS grade from 1 (no injury) to 6 (unsurvivable injury) and the most severe injury in each region determines the AIS grade for that region. The ISS is calculated as the sum of squares of the AIS grades for the three most severely injured regions, with the exception that patients with AIS 6 injuries are automatically assigned an ISS of 75.

Results
There were 484 admissions to Auckland Area Health Board hospitals for child pedestrian injury over the four years from 1986 to 1989. Sixty-four (13%) were admitted to the department of critical care medicine. These cases comprised 34% of all departmental paediatric trauma admissions over this period (Figure 1). There were three patients transferred to Auckland from other regions; two were from Northland and one from Waikato.

The median age of these 64 patients was six years. There were 40 boys and 24 girls. Boys outnumbered girls at all ages, with an overall male:female ratio of 1:6:1:0. There were 24 children of European origin, 20 Maori children, 15 Pacific Island children and five others. Ethnic specific admission rates for the AAHB were 4.2 (2.6-6.3)/100 000 children of European origin per year, 13.2 (7.9-20.6)/100 000 Maori children per year and 12.7 (7.1-20.9)/100 000 Pacific Island children per year.

Excluding transfers, all patients were admitted to the department within 24 hours of injury. Precise time of injury was available for 61 patients. All timed injuries occurred between 7 am and 11 pm and 52% occurred between 3 pm and 7 pm.
7 pm. In 59 cases, injury occurred when the child was struck by the front or side of the vehicle and in five cases the child was reversed over at slow speed.

Figure 2 shows the distribution of ISS for the 64 patients. The median ISS for all patients was 29 (range 4-75).

Survivors had a median ISS of 29 (range 4-59) and nonsurvivors had a median ISS of 38 (range 25-75). The number of patients with injuries of each AIS grade in each body region is shown in Table 1. The head was the region that sustained the majority (83%) of the critical (AIS5) and severe (AIS4) injuries. Fifty-two percent of the serious injuries (AIS3) were to the extremities most commonly a fracture of the femur and 29% were to the thorax most commonly lung contusion or pneumothorax.

Table 1. Number of children who had injuries of each AIS grade of severity in each body region

<table>
<thead>
<tr>
<th>Body Region</th>
<th>AIS Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>0  1  2  3  4  5  6  7  8</td>
</tr>
<tr>
<td>Face</td>
<td>0  1  2  3  4  5  6  7  8</td>
</tr>
<tr>
<td>Thorax</td>
<td>0  1  2  3  4  5  6  7  8</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0  1  2  3  4  5  6  7  8</td>
</tr>
<tr>
<td>Extremities</td>
<td>0  1  2  3  4  5  6  7  8</td>
</tr>
<tr>
<td>External</td>
<td>0  1  2  3  4  5  6  7  8</td>
</tr>
</tbody>
</table>

There were 31 patients (48%) with injuries of AIS grade 3 or worse in two or more body regions and twelve patients (19%) with injury of this severity in three or more body regions. Of the 49 patients with head injuries of AIS grade 4 or worse, 24 (49%) had serious (AIS3) injury or worse in another body region. The combination of head and lower limb injury was seen in 53% of patients.

Fifty-two patients (81%) received ventilatory support. Of these patients all but two had serious (AIS3) or worse injury to the head, eleven of whom had serious or worse injury to both the head and thorax. Twenty-nine patients (45%) had 34 operative procedures: 16 orthopaedic, six neurosurgical, four laparotomies and eight wound debridement and closure. The six neurosurgical procedures comprised four decompressive craniotomies and two elevations of depressed fractures.

Nine patients (14%) died. All deaths resulted from AIS5 or AIS6 brain injuries. Median length of departmental stay for these patients was one day. Median length of stay for survivors, before transfer to other hospital departments, was three days (range 1-26). Median length of acute hospital stay for these patients was 14 days (range 3-185).

Discussion

The results of this study indicate that the typical injured child pedestrian is a six year old boy injured between 1500 and 1900, who has sustained a brain injury often in conjunction with a fractured femur. The predominance of males seen in this study has also been documented in other studies [5], although the reasons for this remain obscure.

Both census and hospital ethnicity data used in this paper are based on parent reported ethnicity. Descendent and not single origin census statistics were used as the denominators for the calculation of Maori and Pacific Island rates. The effect of choosing descent populations as the denominator would be to underestimate the rates for these populations [7]. The true rates for these groups may be even higher than we have documented.

Very few of the injuries reported would have occurred during the hours of darkness, as only 16% of timed incidents occurred after 7 pm. Other studies have shown that few child pedestrian injuries occur at night and that the majority are on well lighted urban arterial roads suggesting improvements in street lighting would have minimal impact in reducing these injuries [6].

As might be expected given the nature of the population studied, the severity of injury in these patients is high. Ninety-five percent of this sample had major trauma defined as an ISS of 16 or more. Although pedestrian injury represents only approximately 4% of all paediatric trauma admitted to hospitals in Auckland [Streat SF, Cron PD, McEachan J, Judson JA, unpublished], pedestrians represent 34% of departmental paediatric trauma, reflecting the greater severity of pedestrian injuries compared with other types of trauma. Serious head injury was common, with 84% of patients having sustained AIS3 or worse injury and only 30% had neurosurgically remediable lesions was low, with only four decompressive craniotomies. The high number of patients with head injuries in this series reflects the importance of motor vehicle trauma as a cause of paediatric head injury. A recent study showed that 31% of all brain injury in school aged children was motor vehicle related [8].

Lower limb injuries were a feature in many of our patients. Ashton [9] reviewed pedestrian impact dynamics and found that vehicle bumper contact was the main cause of serious lower limb injury, the location of injury depending on bumper height relative to pedestrian height. Although this was the predominant mechanism of injury with the child struck by the front or side of the vehicle, in five patients injuries resulted when the child was reversed over at slow speed, often in a driveway. Brison et al [10] found this was an important mechanism of pedestrian injury in young children and most often involved a light truck or van driven by a family member. The relatively low numbers of such cases seen in this series may reflect the fact, as indicated by Brison [10], that many of these children are killed immediately.

The injuries suffered by the nine patients who died were either unsurgically remediable (AIS6) or critical (AIS5) and it is unlikely that improvements in trauma care could have prevented their deaths. Most deaths from blunt trauma occur at the site of injury [11], further emphasising the importance of primary prevention.

Pedestrian injury is an important cause of death and disability in children, perhaps even more so in New Zealand than in other countries [13]. Any major reductions in the morbidity and mortality from child pedestrian injury will require preventive efforts. Analytical studies aimed at identifying patterns of injury and at place children at risk for these injuries are clearly needed.

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Non-traffic child pedestrian injuries

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Abstract  All non-traffic child pedestrian deaths and injuries resulting in hospitalization in the Auckland region over a 5 year period were identified from coroner’s and hospital records. There were eight deaths (0.77/100,000 children per year) and 91 hospital admissions (8.7/100,000 children per year). Close to half (48%) of the non-traffic pedestrian injury admissions had been misclassified as traffic pedestrian injuries. Eighty-seven per cent of the non-traffic pedestrian injury deaths and 93% of the injuries occurred in residential driveways, most often involving a child run over by a reversing vehicle. Further studies are required to determine the most effective strategies for the prevention of non-traffic child pedestrian injuries.

Key words: childhood injuries; non-traffic mortality; pedestrian.

Pedestrian injuries are the leading cause of death in New Zealand children after the first year of life.¹ Each year in New Zealand approximately 30 children are killed (3.6/100,000 children per year) and 410 seriously injured (49.4/100,000 children per year) in pedestrian motor vehicle collisions.² The majority of these collisions occur on public highways and are classified as 'traffic accidents' by the International Classification of Diseases (ICD) E coding system. The remainder, classified as 'non-traffic accidents' occur off the public highway and account for 12% of child pedestrian fatalities in New Zealand.¹ While there have been several detailed descriptions of traffic pedestrian injuries to children,²,³,⁴ much less is known about the circumstances of non-traffic child pedestrian injuries. The purpose of this study was to document the circumstances of children killed or sustaining injuries that required hospital admission as a result of non-traffic pedestrian injuries.

METHODS

The coroner’s records of all children (<15 years) who died as a result of trauma in the Auckland region over the 5 year period 1986–90 were searched to identify all child pedestrian deaths. Based on the description of the circumstances of death in these records, all non-traffic collision pedestrian deaths were identified. Data were recorded on age, sex, location and circumstances of injury, time of injury and cause of death.

In addition, the medical records of all children admitted to hospitals in the Auckland region as a result of pedestrian injury over the same 5 year period were identified by a computer search of the Auckland Area Health Board hospital admission data base. The search identified all pedestrian injury admissions, both traffic (E814.7) and non-traffic (E822.7) as a previous report had indicated that a significant proportion of non-traffic deaths were misclassified as traffic deaths, a bias that might also be present for morbidity data.⁴ Based on the descriptions of the circumstances of injury in the medical records, all non-traffic pedestrian injury admissions were identified. Data were recorded on age, sex, location of injury, vehicle and driver factors, time of injury and duration of hospital stay.

The study region had a predominantly urban population with 208,650 children at the time of the 1986 census. Mortality and hospital morbidity rates were calculated using these 1986 census figures. Ninety-five per cent confidence intervals were calculated assuming a Poisson distribution.

RESULTS

There were 75 child pedestrian deaths over the 5 year period of which eight (10.7%) were non-traffic, resulting in a non-traffic pedestrian injury fatality rate of 0.77 (0.3–1.5)/100,000 children per year. The median age for fatalities was 15 months (range: 0.5–7 years). There were five girls and three boys. Seven of the eight children were fatally injured by a reversing vehicle in a driveway and one child was struck by a forward moving vehicle in a car park. All deaths occurred between 10 a.m. and 6 p.m. The primary cause of death was brain injury in six cases and traumatic rupture of the liver in two.

There were 590 pedestrian injury admissions over the 5 year period of which 47 (8%) were coded as non-traffic. However examination of the medical records of the remaining 543 pedestrian injury admissions, revealed a further 44 non-traffic pedestrian injuries which had been classified incorrectly. Therefore the total number of non-traffic pedestrian injury admissions was 91 (15.4%), generating a hospital admission rate of 8.7 (7.0–10.7)/100,000 children per year.

For the 91 non-traffic pedestrian injury admissions the median age was 25 months (range: 0.5–14 years). There were 53 boys and 38 girls. The location of injury was a driveway in 85 cases.
LEADING ARTICLE

Transport and public health

Travel is an integral part of New Zealand life. The most recent household travel survey estimated a national annual household travel volume of 36,390 million kilometres. Travel is beneficial and health promoting in that it provides access to recreation, employment and social support networks. However there are adverse public health consequences of travel, the most tangible being transport related injuries. The adverse health effects of travel depend largely on the mix of the transport system, which is strongly influenced by transport and other government policies. For example, it has been estimated that a marked decline in public transport patronage between 1988 and 1991, bus patronage in Auckland fell by 34% and rail and ferry patronage fell by 19%. However, in terms of transport safety the private passenger car represents one of the most dangerous transport options. Per passenger kilometre there are twenty times more deaths with car travel than with rail or air travel and seven times more deaths than from bus or coach travel. The public health corollary for New Zealand is an average of 780 people killed on the roads each year, 51% of whom are in the 1-29 year age group. This road death rate is considerably higher than that of other comparable countries.

Whilst the health promoting aspects of car travel are experienced by car users, the detrimental effects are experienced by the whole community but particularly, children, the economically disadvantaged and the elderly. For New Zealand children, pedestrian injuries are the leading cause of death after the first year of life with an average of thirty children killed and over 400 seriously injured each year. Ironically, pedestrian injuries disproportionately affect children from those communities which derive the least benefit from car travel. In Auckland 25% of Maori households have no access to a car compared to 13% for non Maori; however child pedestrian injury rates are three times higher for Maori children than for non Maori. Socioeconomically disadvantaged children are at particularly high risk. In Auckland, the census area unemployment rate is a strong predictor of the child pedestrian injury rate. Overseas studies have shown that poor children are exposed to a three times higher risk of pedestrian injury than are the least poor. The elderly are also particularly vulnerable as pedestrians, the number of injuries per road crossing being similar to that of school children.

Injury is not the only adverse health consequence of the present car-oriented transport system. Physical inactivity is an important risk factor for both cardiovascular disease and cancer. People who drive less tend to walk less and have been shown to have a fifty per cent reduction in the number of coronary events and brisk walking has been shown to reduce the risk of myocardial infarction. It has been estimated that a 43% reduction in cardiovascular mortality might result if regular physical exercise such as cycling or walking were taken up by the New Zealand population. However present car oriented transport policies discourage both cycling and walking. The risk of serious injury is a powerful disincentive to cycling and an increasingly hostile urban transport environment makes walking unappealing. Extrapolating from road mortality statistics and household travel survey data, it can be calculated that there are over five times more deaths per kilometre of cycling than of travelling by car. In Britain, where transport policy is also strongly car oriented, it has been shown that the years of life lost through cycle injury, outweigh the life years gained through improved cardiovascular health. In New Zealand less than four percent of all trips are made by bicycle compared to the Netherlands where up to half of all trips are made by bicycle. One of the main reasons for this difference is considered to be the strong governmental support for cycling in the Netherlands, with widespread provision of cycle routes and cycle parking facilities.

Paradoxically the increased personal mobility for car users results in a decrease in mobility for children, those who cannot afford a car, and the elderly. A British study found that between 1971 and 1990 there had been a decrease in the proportion of children walking to school of approximately 20% with a concomitant increase in the proportion going by car. Overall there had been a marked reduction in children's independent mobility. The main reason for parental reluctance to allow their children to walk unaccompanied was traffic danger. Whilst similar data are not available for New Zealand children, traffic volume has increased during the same period by an even greater amount. The mobility of older New Zealanders also becomes curtailed as travel destinations become more spread out and public transport options reduced. Whereas 19% of the population 15 - 60 years do not hold a driving licence, 34% of the population over sixty years are not licensed to drive. Given present population trends, the year 2031 one in every four New Zealanders will be aged sixty or over, representing a significant segment of the population dependent on public transport.

Although air pollution from road traffic is a major health problem for cities in the northern hemisphere, New Zealand's urban centres have relatively clean air in relation to WHO air quality guidelines. This is due more to the geographic good fortune than design. Nevertheless it is no longer adequate to consider only the local effects of vehicle emissions but rather to consider New Zealand's atmospheric pollution as part of a global atmospheric problem. Motor vehicles are responsible for 40% of New Zealand's greenhouse gas emissions. With approximately 615 vehicles/1000 population New Zealand is likely to make a proportionately greater contribution from traffic to atmospheric pollution than will Britain with 433 vehicles/1000 population.

A car oriented transport system is also detrimental to health in more subtle ways. For example, it has been demonstrated that traffic levels in residential streets are inversely correlated with the amount of social interaction among residents. Conversely a lack of public transport adversely affects community development. In Britain a large increase in bus fares in the city of Sheffield was accompanied by a fall in attendances at youth clubs, unemployed people visited job centres less often and as people became less able to afford to visit elderly relatives there was an increase in demand for home help services.

The predominance of car travel in the current transport system is the result of policy decisions in a number of government sectors. Most important has been the high capital investment in roads compared to other transportation modes. The completion of a network of motorways and an increase in the availability and reduction in the cost of car parking have encouraged car
The development of a healthy transport system will require a greater degree of integration of transport policy with environment, land use, energy and health policies. The National Road Safety Plan represents a tentative step in this direction by recognising the need for a multi-sectoral approach and by establishing some of the structures through which a multi-sectoral action might be achieved. The main thrust of the plan is on improving safety on present transport modes and there is an emphasis on individual responsibility for safety at the expense of more collective approaches, such as public policy and environmental change. Who will provide leadership in this quest for a healthy transport system is, at present, unclear. Ideally, the Public Health Commission, as the guardian of the public health, would monitor the health impact of transport policies and bring these issues to public debate. The development of a healthy transport system will require a vision of an equitable, sustainable transport system where 760 road deaths a year are no longer considered an inevitable consequence of mobility.

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Book Review

Fetal and Infant Origins of Adult Disease

The editor of the British Medical Journal is to be congratulated on his initiative in suggesting the publication of this book. The contents are thirty-one papers published over the last six years by Dr D J P Barker and his colleagues. Dr Barker is director, health and education, MRC environmental epidemiology unit, and professor of clinical epidemiology at the University of Southampton. There is also an introduction by an associate editor of the British Medical Journal.

The book has a striking cover.

The unifying theme of the book is the investigation of the "maternal programming hypothesis" by which is meant that factors that budgeting at pregnancy and infancy might have specific importance for the development of specific diseases in adults. The early studies were ecological, the more recent studies have taken brilliant advantage of old records on individuals. Studies which in the new climate in New Zealand might not be possible in the future, either because records are not stored or, in the absence of informed consent, access is denied to researchers.

The data presented by Barker have been debated both in publications and in public meetings. It is a pity that one of the reviews critical of the interpretation by Barker et al. was not included in order to give the reader another view of the data. The main problem with the general hypothesis is the difficulty in separating out the effects of the environment early in life from its effects later in life. Teasing out the role of confounding will be difficult and new and imaginative solutions are required. In the meantime, the programming hypothesis is of great interest to vested interests, opposed to the current emphasis on the role of dietary fat as the underlying cause of coronary heart disease.

This book will be of interest to clinicians, from paediatricians to geriatricians, as well as to public health specialists. Whilst awaiting for the results of further research, we should continue to direct our preventive efforts to ensure the optimal conditions for pregnant women as well as continuing to encourage healthy living habits for the entire population.

Robert Beagulehole, Auckland
(93.4%), a car park in three cases, a playing field in two and a boat ramp in one. Of the 79 cases for which the direction of travel of the vehicle was recorded, in 66 (83.5%) the vehicle was reversing. Sixty (66%) children were run over; that is, the wheel of the vehicle passed over the child; 23 (25%) were struck but not run over; six were crushed between the car and another object and two were dragged by a moving vehicle. The driver of the vehicle involved was related to the injured child in 50% of cases and was a friend or neighbour in 11%. The identity of the driver was unknown for 39% of the cases.

Thirty-nine per cent of injuries occurred in the three months from January to March with the greatest number of injuries occurring in March. Sixty-nine per cent of injuries occurred between midday and 8.00 p.m., with the highest number occurring between 4.00 p.m. and 6.00 p.m. The median duration of hospital admission for all patients was three days with a range of 0–66 days.

**DISCUSSION**

The results of this study indicate that the typical non-traffic child pedestrian injury involves a 2-year-old child reversed over in the domestic driveway by a relative. The study also reveals that non-traffic injuries represent a much larger proportion of all child pedestrian injuries than has been reported previously. After correcting for misclassification, non-traffic injuries were found to represent 15.4% of all child pedestrian injury admissions, twice that reported based on ICD 9 E coded hospital morbidity data. The degree of misclassification in hospital morbidity data is therefore even greater (48% misclassified) than that reported with mortality data (36% misclassified).

The residential driveway is clearly identified as the main site of non-traffic child pedestrian injuries with 87% of deaths and 93% of injuries occurring in this location. Whereas an Australian study based on police and road authority data found that driveways were the site of only 4% of all child pedestrian injuries, they were the site of 14.4% of child pedestrian injuries resulting in hospital admission in Auckland. The difference, however, is more likely to reflect under-reporting in police data than a true difference in the incidence. Certainly in New Zealand, Ministry of Transport (MOT) data would grossly underestimate the number of these injuries since driveways do not come under MOT jurisdiction.

Non-traffic child pedestrian injuries represent a significant child health problem both in terms of death and serious injury and effective prevention strategies are urgently required. Potentially, interventions could be directed towards the driveway environment with barriers to prevent children gaining access. Interventions could also be directed towards the vehicles involved, with efforts made to improve rearward visibility, or at parents with education messages warning of the potential hazards of children in driveways. Further studies are required to determine which of these strategies has the greatest potential to reduce injury rates.

**REFERENCES**

Conclusion

The confused medical awareness of which contraceptive methods are appropriate may partly explain why advice to women with sickle cell disease is often lacking. We cannot exclude a possible risk of crises and thrombotic episodes with the use of the combined contraceptive pill. Despite this, we do not consider it to be contraindicated in this group of women as any complications should be balanced against the substantial risks of pregnancy. We feel that all methods of contraception may be considered in women with sickle haemoglobinopathies, though with appropriate caution.

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References


(Revised 8 April 1993)

Why have child pedestrian death rates fallen?

Ian Roberts

Pedestrian injuries are a leading cause of childhood mortality and disability. Over the past two decades in Britain child pedestrian death rates have fallen despite large increases in traffic volume. In this paper Roberts examines the likely reasons for this decline. He argues that neither prevention programmes nor improvements in medical care are a plausible explanation and that the decline is most likely the result of a substantial reduction in children's traffic exposure. He believes, however, that restricting children's traffic exposure exacerbates socioeconomic differentials in childhood mortality and denies children their right to mobility. Roberts is convinced that one answer is for British transport policy to be aimed at providing mobility equitably rather than struggling to meet the ever increasing demands of car travel.

Between 1980 and 1990 in England and Wales an average of 239 children were killed each year on the roads as pedestrians. For every death around 10 children required hospital admission for injuries.1 Pedestrian injuries were among the leading causes of childhood admission to intensive care facilities.2 Between 60% and 80% of these children have severe head injuries and are likely to experience long term disability.3 With the more widespread recognition of the public health importance of child pedestrian injuries in recent years several epidemiological studies have been mounted aimed at identifying modifiable risk factors. These studies have used case-control or cohort methods in an attempt to identify the factors which place some children at high risk of pedestrian injury.4 However, an effective public health response to the problem of child pedestrian injury demands that a second aetiological issue should be addressed. This concerns the identification of determinants of the incidence, attempting to understand why child pedestrian death rates change over time. Answering this question is likely to be as important as identifying risk factors, because if the determinants of the incidence could be identified it might be possible to control them, with gains for the whole child population.5

Over the past two decades child pedestrian death rates have fallen in many developed countries. In England and Wales between 1968 and 1987 the pedestrian mortality among children aged 0-4 years fell by 67%, and among children aged 5-14 years it fell by 39%.6 To gain an insight into why child pedestrian death rates have fallen changes in the potential determinants of the child pedestrian death rate must be considered.

Potential determinants of child pedestrian deaths

The determinants of incidence are most readily identified when their prevalence changes abruptly. For this reason the effect of traffic volume on child pedestrian mortality was most evident during the energy crisis, when an increase in the price of petrol had a measurable effect on the growth in traffic volume. In New Zealand government restrictions on car use in the aftermath of the energy crisis effectively arrested the growth in traffic volume for seven years, during which there was a 46-4% reduction in child pedestrian mortality.7 Before this the death rate had been increasing in parallel with increasing traffic volumes. That the rate fell, as opposed to levelling off in line with traffic volume, suggests that there were other processes operating, tending to reduce the mortality, but which became evident only when traffic

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volume was unchanging. In Britain since 1968 the child pedestrian death rate has fallen despite an almost exponential increase in traffic volume (fig 1). This implies even more substantial changes in other, more powerful determinants of incidence. These changes have been particularly important for children aged 0-4, for whom reductions in mortality have been most dramatic.

PEDESTRIAN SKILLS TRAINING

It would be comforting if there were evidence to show that at least some of the reduction in child pedestrian mortality could be attributed to pedestrian injury prevention programmes, but this evidence is lacking. In Britain the main thrust of preventive strategy has comprised efforts to improve child pedestrian behaviour through pedestrian skills training programmes—for example, the Green Cross Code. However, data from evaluation studies suggest that these programmes are of limited value. Some North American studies have claimed reductions in injury rates following pedestrian education programmes but evaluation in these studies was based on before and after comparisons, so that the apparent reductions may have been confounded by changes in the background rate. Studies which have employed more rigorous methods have concluded that even large efforts to improve pedestrian behaviour are rewarded by only small gains. Furthermore, as programmes have been aimed predominantly at schoolchildren they cannot explain the large reduction in pedestrian mortality among preschool children. It therefore seems implausible that pedestrian education programmes have had a substantial effect on child pedestrian mortality.

In Britain between 1968 and 1987 the number of police reported child pedestrian casualties fell by 49% but the number of deaths fell by 61% (J Broughton, Transport Research Laboratory, personal communication, 1992), suggesting that some of the decline in child pedestrian mortality may be due to a reduction in case fatality. These data must be viewed with caution, however. Child pedestrian injuries are significantly underreported in police accident databases, and changes over time in casualty numbers might simply reflect changes in the extent of underreporting. Furthermore, as children under 5 have a higher case fatality rate possibly the apparent overall reduction in case fatality is due to a change in the age distribution of injured children, young children now making up a smaller proportion of the total casualties. If there has been a reduction in case fatality this may have resulted from a decrease in injury severity or from improvements in medical care. Regardless, the 49% decrease in casualty numbers implies that most of the reduction in child pedestrian mortality is due to a reduction in collisions between child pedestrians and motor vehicles.

TRAFFIC EXPOSURE

The most plausible explanation for the downward trend in child pedestrian mortality is that it reflects a decline in children's traffic exposure. As the volume of road traffic has increased streets have become more dangerous and increasingly children have been kept away from them. Until recently the only testimony was old photographs or paintings depicting towns and cities as they were before the heyday of the motorcar, in which children would often be seen playing in the street. The urban landscapes of L S Lowry starkly portray the grime and pollution of industrial England, in which the street scenes convey a vivacity and a sense of both safety and community which is absent today (fig 2).

A recent British study which examined changes in children's independent mobility over the past two decades has provided compelling evidence for a decline in children's traffic exposure. For example, it was found that whereas in 1971, 80% of 7 and 8 year old English children were allowed to travel to school unaccompanied, in 1990 the figure was 9%. The principal reason parents gave for their reluctance to allow their children to travel unaccompanied was traffic danger. Similarly, the age at which children receive parental "licence" to cross roads has increased considerably, and there was a pronounced decline in the proportion of children who were allowed to cross roads alone in 1990 compared with 1971. These findings might explain why the decline in pedestrian mortality has been least in the 5-14 year age group, as it would be more difficult for parents to limit the traffic exposure of older children. Moreover, a study in Manchester found that the pedestrian injury rate among children aged 11-14 had increased by 15% between 1969 and 1987.

The importance of traffic exposure is also apparent in case centred epidemiological studies. A North American case-control study found that the absence of a play area adjacent to the home was associated with a fivefold increased risk of pedestrian injury (odds ratio 5·3; 95% confidence interval 2·6 to 11·0). The effect of this factor is likely to be mediated through the greater traffic exposure of children who have fewer alternatives to playing in the street.

INDICES OF SAFETY

A consideration of children's traffic exposure has been the missing element in virtually all of the political deliberations on road safety for children over the past two decades. As a result the effect on child pedestrian safety of the massive increase in traffic volume which has taken place over this period has been completely obscured. In the absence of an exposure measure the pedestrian injury rate has been used as an index of safety. The fallacy inherent in this reasoning is apparent from a consideration of age specific child pedestrian injury rates.

In the absence of information on traffic exposure, using pedestrian injury hospitalisation rates as a measure of safety would lead us to conclude that a 3 year old child (68-9/100 000 admissions/year) is safer in a traffic setting than a 6 year old (68-9/100 000/year) (unpublished observations, New Zealand data). In contrast, for motor vehicle occupants the established safety measure is deaths per vehicle mile travelled, the rationale for which was given in the motor vehicle safety position paper of a recent American injury control conference—"highway transportation has been..."
created to facilitate mobility and mobility is of value. Strategies that... reduce the need for car travel or substitute car travel with safer forms of transport would sub... will... reduce population death rates. Thus deaths per vehicle mile travelled clearly signals that improving safety in safety must not limit car use. Because children’s mobility is not valued the decline in child pedestrian mortality has taken place at its expense.

Implications of limiting child mobility

As a means of preventing child pedestrian injuries limiting children’s traffic exposure has powerful disadvantages. In particular, it will exacerbate the striking socioeconomic inequalities in child pedestrian injury morbidity and mortality that already exist. Both British and overseas studies have shown that poor children have a risk of pedestrian injury some three times greater than the least poor, and census area unemployment has been shown to be strongly correlated with census area child pedestrian injury rates. Indeed, pedestrian injuries are a major contributor to socioeconomic differentials in childhood mortality. As one third of British households do not have access to a car escorting children is likely to be far more difficult for some families. Poor children are likely to have fewer alternatives to playing in the street, and supervising children will be far more demanding in single parent families.

The British epidemiologist Geoffrey Rose has argued that in disease prevention two broad types of strategy can be distinguished: those that restore biological normality and those that take us further from the conditions for which we were genetically adapted. Restoration of biological normality is generally safe whereas the consequences of moving away from our biological condition are often unknown and the potential for harm may easily be overlooked. In this context limiting children’s independent mobility is a clear departure from biological normality. Changes in childhood exercise patterns may impact on children’s cardiovascular health, and with children increasingly confined to the home because of traffic danger heightened family tensions may erupt as family violence. Historically, public health investigators have been slow to recognise the importance of such social processes and as a result have witnessed the waxing and waning of mortality from many diseases, although often ignorant of the reasons and powerless to intervene.

The future

Traffic volume is expected to increase by 142% by the year 2025, and no doubt the rampant individualism of free market economic policies will ensure that this prophecy is realised. The increase in traffic volume will inevitably result in a more hostile urban living environment for children. More fortunate children will reap the benefits of increased car travel while being largely immune from the accompanying dangers. But for the increasing number of British children living in poverty paramount among threats to health are vehicles that most will only ever have the opportunity to steal. Further reductions in children’s independent mobility may offset the increase in danger but already child pedestrian death rates seem to be levelling off and in some countries—for example, the United States—may be rising.

It must be recognised that unfettered market forces will inevitably disregard the rights of the more vulner-

able members in society and that a more collective social responsibility is appropriate. British transport policy should aim to provide mobility equitably and for all people rather than continually struggle to meet the ever increasing needs of car users. Of course, challenging the dominant position of the private passenger car in the transport system will inevitably confront powerful vested interests. The car lobby is strong and well organised. The lessons learnt from previous public health struggles with pecuniary power will be invaluable. Mobility is of value but so is equity. The transport system of the future should be concerned with both these of these.


(Accepted 25 March 1993)

Correction


A type-setting error occurred in table 1V of this paper by John S Yudkin (15 May, pp 1313-8). In the bottom line of the table (lowering systolic blood pressure > 140 mm Hg) the entry in the second column of figures is wrong: it should read 0.38 (0.07 to 1.79), not 0.83 (0.07 to 1.79).
BLAMING CHILDREN FOR CHILD PEDESTRIAN INJURIES

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Abstract—Pedestrian injuries are a leading cause of childhood mortality. In this paper a case study of a child pedestrian death is presented in order to examine the apportionment of responsibility for child pedestrian injuries. The case presented illustrates how responsibility is located with the child, whilst structural contributors, in particular aspects of the transport system, are ignored. The strength and pervasiveness of the ideology of victim blaming in child pedestrian injuries is explained by the special position that the road transport system holds in relation to dominant economic interests. Victim blaming ideology is a strategy that serves to maintain these interests at the expense and suffering of children. Increased recognition of the political roots of the ideology of victim blaming in child pedestrian injuries, by the sectors of the community who suffer its consequences, will be an important step towards effective preventive action.

Key words—pedestrian injury, injury prevention, ideology

In her book *Hidden Arguments*, Tesh [1] examined the political ideology that underlies the apportionment of responsibility for health to individuals but which ignores structural determinants of health. The prevailing prevention policies for cardiovascular disease and cancer, are traced back to their origins in the political ideology of individualism, the ideology most compatible with the current economic order.

Whilst cardiovascular disease and cancer are the major causes of death in adults, in childhood, vehicular injuries, particularly pedestrian injuries, are the leading cause of death [2]. For every death approximately ten children are seriously injured and many of these children will suffer long term disability [2]. Once again, individualism constitutes the ideological base of preventive policies. For example, strategies for the prevention of child pedestrian injuries are almost entirely aimed at improving child pedestrian behaviour, despite a wealth of evidence that this is unlikely to be effective [3, 4].

In this paper, a case study of a child pedestrian death is presented, in order to examine the apportionment of responsibility for child pedestrian injuries. An attempt is made to examine the more ideologically unacceptable structural contributors. Structural in this context referring to nonbiological extrinsic factors in the physical and social environment [5]. The case study is based on an examination of the official documentation relating to a child pedestrian death, including a transcript of the coroner's inquest. In addition, data collected during a detailed site investigation by a civil engineer are examined. This data collection was instigated by the authors.

THE CASE

A ten-year-old girl was walking home from school with a friend at 3.30 on a Wednesday afternoon. Whilst crossing a two lane road she was struck by a van. She was thrown into the air and landed on the verge. An ambulance was called, when it arrived cardiopulmonary resuscitation was started. This was unsuccessful and she died.

The first person with the role of providing an interpretation of the event and consequently able to place it within an ideological context was the attending police officer. The officer is required to complete a 'Traffic Accident Report', a 3 page pre-printed questionnaire. The report is divided into 19 sections with boxes for the entry of data on the time, date, location and location of the accident, information relating to the vehicle, the driver and the road conditions. The speed limit in force at the injury site was 50 kph.

Sections 12 and 14 of the questionnaire provides several lines for the officers analysis of what happened and why. The following is an extract from the report:

What happened: Driver travelling east along named road. Child stepped out onto roadway into the path of driver without looking. Driver collided with child who was knocked into the air and landed on grass verge.

Why the accident happened:
- Driver factors: Driver unable to stop in time due to sudden movements by child.
- Road factors: (nothing recorded)
- Vehicle factors: (nothing recorded)
- Other factors: Appears as though child has walked out onto road without looking to her right.

A copy of the Traffic Accident Report is later forwarded to the police crash enquiry section where an
accident summary is compiled. The following are extracts from the accident summary:

Child was standing on the footpath, without any warning she ran diagonally across the road into the path of an approaching van. The driver of the van was travelling towards named road, and had no chance of stopping before she hit the child.

Traffic Safety Branch have interviewed the driver and other witnesses, and there is no indication of excess speed. Driver states that she was travelling about 40 kph. A scene examination by Traffic seems to confirm this. Child was not on any medication at the time of the incident.

In the summary the impulsiveness of the child’s actions are emphasized, “without any warning she ran”. It is noted that medication could not be held responsible for this behaviour. A second copy of the Traffic Accident Report, including the accident summary, is later sent to the Road Traffic Standards Section of the Ministry of Transport. At this section the report is coded for statistical purposes, remediable factors are identified and the appropriate preventive action is initiated. The crash was coded as “Pedestrian: crossing road heedless of traffic, unattended child”. No preventive action was initiated.

CIVIL ENGINEERS ASSESSMENT

One week following the injury, on the same weekday as the injury and at the same time of day, a civil engineer visited the injury site and measured a profile of vehicle speeds and traffic volume. Previous work has demonstrated that these measurements are likely to accurately reflect conditions at the time of injury.

The engineer’s assessment of the injury site found that vehicle speeds were approximately normally distributed with a mean of 58 kph and a standard deviation of 7.4 kph. Based on this data it can be calculated that the probability that any vehicle at that site would be travelling at 40 kph or less is 0.8%. The probability that a vehicle would be travelling at a speed less than or equal to the speed limit of 50 kph is 14%. There was a mean traffic flow at the injury site of 377 vehicles per hour, approximately 15 vehicles every minute. Thus the mean time available for crossing, assuming a steady flow, would have been only four seconds. It is quite likely therefore, that running was a necessary prerequisite for road crossing rather than an indication of impulsiveness.

THE CORONER’S INQUEST

The office and duties of the coroner in New Zealand are similar to those of British coroners and they are constrained by similar legislative structures [6]. In New Zealand all accidental deaths must be referred to the coroner and in the majority of cases a coroners inquest is held. Unlike the ‘accusatorial’ civil and criminal courts, the coroner’s court is purportedly not competent to address the issue of culpability. The stated aims of a coroner’s inquest are to determine the ‘facts’ surrounding the death, primarily for the purpose of reliable record keeping for the State. The coroner’s inquest also serves a number of public interests. These were identified in the Brodrick report in 1971 [7]. Specifically these are:

1. To determine the medical cause of death;
2. To allay rumours or suspicion;
3. To draw attention to the existence of circumstances which, if unremedied, might lead to further deaths;
4. To advance medical knowledge;
5. To preserve the legal interests of the deceased person’s family, heirs or other interested parties.

Although ostensibly an objective fact finding process, as Green [8] observes facts and opinions are rarely distinct and the language of the court is steeped in morality. Green comments:

It is not that the Coroner does not accept facts what we would hold to be constructed from various interests; but, rather, that such ‘facts’ are deliberately employed to provide a truth which suffices both for the statistical gaze of the State and also for the participants.

The inquest for the deceased child was held two months after her death. The following material is based on notes taken during the inquest. The coroner began by introducing the court, in particular pointing out that “the coroner’s court is not preoccupied with culpability and indeed is not competent to decide on such matters”. It was stated that the court aims “to establish the facts” but this was qualified as “not always easy”. It was explained that the court should “establish the identity of the deceased, the date and place of death, the cause of death, and look at circumstances surrounding the death to discover anything that may have been avoidable”. The case was presented by the police and during the course of the presentation, the coroner was provided with various pieces of evidence, such as a diagram of the scene and statements from the driver and other witnesses. The child’s parents were not present at the inquest.

Following the case presentation the coroner made a brief reference to the autopsy findings. He then asked:

Did she have to cross the road to get home, I am interested to know why the road had to be crossed at that particular point?

The police officer responded: “I don’t know the reason why she crossed at that point”.

The coroner then enquired whether the child had any hearing defect. No defect was reported. In the preamble to the verdict, the coroner observed that because of the widespread provision of traffic education in schools the type of erratic traffic behaviour displayed, would be unusual for a 10-year-old. He observed that children are repeatedly told “don’t jaywalk, but (name) may have been doing a little bit of jaywalking”.

The verdict returned by the coroner stated: “I find
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that (name) died at (place) accidentally, sustained when she ran out into the path of an approaching vehicle without checking that the road was clear of traffic."

DISCUSSION

This case study illustrates how the circumstances surrounding a child pedestrian death came to be interpreted in an ideological context. The process began when the attending police officer made a judgment on causality based on a consideration of factors relating to the vehicle, the driver and the drivers account of the child's behaviour. Essentially a choice was made between the two main contenders for individual responsibility, the driver and the child victim. Since the driver's claim of travelling at 40 kph (within the 50 kph speed limit) was accepted, no negligence was attributed to the driver so that responsibility was located with the victim. Although walking out into the road clearly did result in this child's death and might appropriately be considered a cause, it was nevertheless only one of a number of causes. Other causes of pedestrian injury which have been identified in epidemiologic studies which could equally have been chosen for consideration would include poverty [9–11], high traffic volumes and high vehicle speeds [12]. However a drawback of the multicausal approach to aetiology is that it allows some causes to be singled out for attention above others. A choice motivated by ideology[1].

Although the coroner's court was supposedly not competent to address the issue of culpability, it is clear that for the "statistical gaze of the State", blame is unambiguously apportioned to the child. The reference to jaywalking albeit only "a little bit of jaywalking" clearly signals negligence on the part of the child. Structural contributors, in particular the causal factors pertaining to the transport system, emerge from this process of moral arbitration unscathed. Poverty, the volume of traffic, the lack of provision of safe places to cross and particularly in this case, the state's inability to enforce its own speed limits are ignored. In as much as the coroner failed to draw attention to these factors it could be argued that the inquest failed to serve the public interest functions as identified by the Brodrick Committee. Although it is not possible to generalise from a single case report to all child pedestrian deaths or to suggest that the approach of the coroner in this case study is typical of coroners in other countries, nevertheless the outcome of this case is representative. As Hillman et al. [13] observed, the police find children responsible in over 90% of pedestrian injuries. Indeed the strength and persuasiveness of the ideology of victim blaming is reflected in the observation that even children hold themselves to be responsible in over half (51%) of cases [13].

The reason why locus of responsibility is a public health concern is that assignment of responsibility to children, leads to child orientated prevention strategies which are, in general, likely to be much less effective than those guided by a structural approach. For example, the belief that unsatisfactory child pedestrian behaviour is the cause of child pedestrian injuries, results in the choice of pedestrian skills education programmes as the primary strategy for prevention. However, although some pedestrian skills education programmes have been shown to lead to observed behaviour change, few programmes internationally have ever been shown to lead to reduced injury rates [14]. For those that have, the findings have been either internally inconsistent or unduplicated [2]. Even with the most rigorous evaluative efforts it has been concluded that even large efforts to improve child pedestrian behaviour are rewarded with only small gains [4]. Nevertheless despite this lack of proven efficacy, strenuous efforts are made to justify their use, reflecting the power of the ideological meaning they embody.

In 1975 a Special Research Group on Pedestrian Safety was convened by the Organisation for Economic Co-operation and Development (OECD) and the European Conference of Ministers of Transport (ECMT). The stated aim of this group was "to strengthen and improve relations between research and policy in the field of pedestrian safety" [15]. Road safety education for children was designated a priority area and an attempt was made to define training objectives. The report began however by questioning the need for training "given the paucity of empirical evidence to support educational measures". The justification that was found was admittedly "for reasons which owe more to ideology than to empirical fact".

The rationale given was that:

society has a basic responsibility to provide children with the best possible information and instruction to enable them to cope with the road environment of today, whether or not it helps to reduce accidents, or—more optimistically—even if its results do not become fully apparent for another generation [15].

In contrast, as a guide to preventive action a structural perspective offers some powerful advantages. In particular:

it does not mistake political and economic systems for natural objects. They become amenable to redress. Thus policy makers adopting the structuralist perspective need not limit themselves to disease prevention proposals that preserve the current distribution of power. They need not compromise prevention possibilities at the outset by omitting those that do not fit into the status quo [1].

Once liberated from these constraints, the prospects for prevention take on new possibilities. One might begin by addressing poverty. The rate of pedestrian injury for poor children is between three and four times that for the least poor. This strong relationship with poverty is consistent across many studies and has been observed in several countries [2]. Indeed, pedestrian injuries are a major contributor to socioeconomic inequalities in childhood mortality [16].
Poverty unambiguously is a cause of child pedestrian injuries and efforts to reduce socioeconomic inequalities would be an appropriate public health approach to prevention [17].

Similarly, the characteristics of the transport system are also seen as amenable to change. Again the prospects for prevention are dramatic. In New Zealand, government policies to discourage car use in the aftermath of the energy crisis, albeit motivated by economic rather than health concerns, were associated with a 46.4% reduction in the child pedestrian mortality rate [18]. These observations suggest that public policy changes which strengthen the public transport system and discourage the use of private transport have the potential to significantly reduce child pedestrian mortality rates. But by investing so heavily in educational strategies, governmental bodies responsible for childhood safety are relieved of their responsibility for taking such steps which would involve challenging the dominant position of the private passenger car in the transport system.

Although the relative merits of these contrasting approaches to prevention policy are widely recognised, the trend towards greater individual responsibility has nevertheless continued to acquire momentum. Whereas Ryan in his book Blaming the Victim [19] characterised victim blaming as a subtle process, “cloaked in kindness and concern”, contemporary victim blaming, particularly in the field of road safety, has acquired a more venomous nature [20]. Whilst victim blaming in chronic diseases is implicit in the lifestyle paradigm, few would advocate the criminalisation of smoking or obesity. Yet calls for criminalisation are not unusual in road safety, even for children as pedestrians [20]. The trend towards a more malignant form of victim blaming is also apparent in the content of childhood road safety messages. For example in Britain, the “Mind that child” safety campaign slogan was superseded by “One False Move and You’re Dead”, with the obvious implications for personal responsibility [21].

To understand the nature of the forces which sustain the ideology and process of victim blaming, the sociopolitical context in which they operate has to be considered. Indeed, the same political objectives spawned the lifestyle paradigm for the prevention of chronic diseases. In that case, as Crawford recognised [22], the victim blaming ideology provided a justification for limiting access to medical services, at a time when upwardly spiralling health sector costs constituted a serious threat to corporate interests. The lifestyle paradigm also conveniently took the heat of medicine for its failure to improve the health of populations, at the same time providing a diversion from a social causation of disease. Victim blaming ideology resolves these issues but without presenting a threat to economic interests.

In the case of road safety, because the road transport system is such an essential part of the infrastructure on which economic expansion is predicated, any

analysis of the road safety problem which does not take the road transport infrastructure as sacrosanct immediately poses a threat to economic interests. Compared with rail or sea transportation, road transport due to its high degree of atomization, occupies a special position in relation to these interest, in that it provides a high degree of flexibility with the minimum of opportunities for workers organisation. Moreover not only does the road transport system permit economic expansion, it is in itself an important source of consumption, notably of steel, rubber, oil, and concrete [23]. Because of these considerations victim blaming in the case of road safety fulfils an even more urgent political function.

Victim blaming in child pedestrian injuries is a strategy which serves to maintain the economic interests of the dominant groups in society at the expense and suffering of children, particularly those from low income families. Increased recognition of the political roots of this ideology, by the sectors of the community who suffer its consequences, will be an important step forward towards effective preventive action [24].

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