CHILDHOOD INJURY MORTALITY 1991–1994: MODELLING THE IMPACT OF ELIMINATING CHILD POVERTY

The New Zealand Census-Mortality Study

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A dissertation submitted in partial requirement for the degree of
Master of Public Health,
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December 2003

Abstract

Objective

To quantify the independent effect of household income on childhood injury mortality in New Zealand during 1991 to 1994, and then model the impact of changing the income distribution on child injury mortality.

Methods

A census-mortality record linkage study of 603,219 children (75% of the total child population) aged 0 to 14 years on census night 1991 followed up for unintentional injury mortality for 3 years. The household income-injury mortality association was determined using weighted logistic regression, where the weights adjusted for possible linkage bias in the record linkage. Proportional changes in injury mortality were calculated using counterfactual scenarios of alternate income distributions.

Results

33% of study participants were in households earning less than 60% of the median household income. There was a gradient of increasing injury risk with decreasing income, with evidence of a superimposed threshold effect. Children from the lowest income groups compared to the highest experienced a two to three-fold greater risk of injury mortality. There remained an independent effect of income after controlling for age, ethnicity, education, family type, and labour force status (Odds ratio 1.83 for the lowest income category compared to the highest). 30% of total injury mortality was attributable to (low to moderate) income using the highest income group as the reference group. Altering the income distribution to eliminate poverty, defined as an equivalised household income of either less than 50% or 60% of the national median equivalised household income, may reduce injury mortality by 3 to 7%. As a greater proportion of Māori and Pacific Island children live in households earning less than 60% of the median income, eliminating poverty for these groups may reduce injury mortality by 6 to 9%.

Conclusion

Income is a major cause of the social gradient in child injury mortality, independent of other socioeconomic factors. A large number of children live in low-income households, disproportionately Māori and Pacific Island children. Most deaths attributable to low income occur amongst households that are not defined as "in poverty". Increasing income for children from the lowest income groups may reduce injury mortality. However population-based injury prevention strategies will also be required to reduce the burden of injury mortality, and should be designed and implemented so as not to increase inequalities.

Statistics New Zealand Security Statement

The New Zealand Census-Mortality Study (NZCMS) was initiated by Dr Tony Blakely and his co-researchers from the Wellington School of Medicine, University of Otago. It was approved by the Government Statistician as a Data Laboratory project under the Microdata Access Protocols. The NZCMS fully complies with the 1975 Statistics Act.

Requirements of the Statistics Act
Under the Statistics Act 1975 the Government Statistician has legal authority to collect and hold information about people, households and businesses, as well as the responsibility of protecting individual information and limits to the use to which such information can be put. The obligations of the Statistics Act 1975 on data collected under the Act are summarised below.

1. Information collected under the Statistics Act 1975 can be used only for statistical purposes.

2. No information contained in any individual schedule is to be separately published or disclosed to any person who is not an employee of Statistics New Zealand, except as permitted by sections 21(3B), 37A, 37B and 37C of the Act.

3. This project was carried out under section 21(3B). Under Section 21(3B) the Government Statistician requires an independent contractor under contract to Statistics New Zealand, and any employee of the contractor, to make a statutory declaration of secrecy similar to that required of Statistics New Zealand employees where they will have access to information collected under the Act. For the purposes of implementing the confidentiality provisions of the Act, such contractors are deemed to be employees of Statistics New Zealand.

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Census data
Traditionally, data from the Population Census is published by Statistics New Zealand in aggregated tables and graphs for use throughout schools, business and homes. Recently Statistics New Zealand has sought to increase the benefits that can be obtained from its data by providing access to approved researchers to carry out research projects. Microdata access is provided, at the discretion of the Government Statistician, to allow authoritative statistical research of benefit to the public of New Zealand.

The NZCMS uses anonymous census data and mortality data that are integrated (using a probabilistic linking methodology) as a single dataset for each census year. The NZCMS is the first project for which the census has been linked to an administrative dataset for purposes apart from improving the quality of Statistics New Zealand surveys. The project has been closely monitored to ensure it complies with Statistics New Zealand's strict confidentiality requirements.

Further information
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Acknowledgements

This dissertation would not have been possible without the guidance and support of a number of people. I am especially grateful to my supervisor, Dr Tony Blakely, who has constantly supported my interest in the social determinants of child health, postulating that it would be interesting for a dissertation to explore the effect of eliminating poverty on child injury mortality by using the NZCMS. I am most appreciative of the tireless support and guidance that Tony has provided during the course of this dissertation. I am also most appreciative for the invaluable advice provided to me by my co-supervisor, Professor Alistair Woodward.

For support in managing the data, the use of SAS, and the biostatistics required for this dissertation, I am most grateful to June Atkinson, the NZCMS Data Manager. The other members of the NZCMS team have also provided me with valuable assistance over the period of my dissertation: Jackie Fawcett, Shilpi Ajwani, Sarah Hill, and Darren Hunt.

For assisting in my understanding of the complex policy issues surrounding child poverty in New Zealand, I am grateful to a number of individuals and organisations. I am particularly grateful to members of the New Zealand Child Poverty Action Group (in Auckland and Wellington), the Ministry of Social Development, UNICEF, ACYA, and the Public Health Association.

Finally, I must also thank those people in my personal life who have also had an important role to play during the development of this dissertation, namely, Alwyn and Gabriella.

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Abbreviations

ACYA	Action for Children and Youth Aotearoa
CI	Confidence interval
CPAG	Child Poverty Action Group
CRA	Comparative Risk Assessment
DMCDS	Dunedin Multidisciplinary Child Development Study
DPMC	Department of Prime Minister and Cabinet
ELSI	Economic Living Standard Index
GBD	Global Burden of Disease Study
GDP	Gross Domestic Product
LIS	Luxembourg Income Study
MED	Ministry of Economic Development
MSD	Ministry of Social Development
NGO	Non-governmental Organisation
NHI	National Hospital Index
NLMS	National Longitudinal Mortality Study (United States)
NMDS	National Minimum Dataset
NZCMS	New Zealand Census-Mortality Study
NZPMP	New Zealand Poverty Measurement Project
OECD	Organisation for Economic Co-operation and Development
OR	Odds ratio
PIF	Potential Impact Fraction
PSID	Panel Study of Income Dynamics (United States)
RR	Relative risk or rate ratio
SIDS	Sudden Infant Death Syndrome
SNZ	Statistics New Zealand
UNCROC	United Nations Convention on the Rights of the Child
WHO	World Health Organization

Chapter 1: Introduction

Injury is the commonest cause of death for New Zealand children over one year of age, as it is in all developed nations. Internationally, New Zealand ranks poorly compared to 26 other OECD countries, having the fifth highest rate of child injury mortality (including intentional and unintentional injuries) and the third highest rate of traffic deaths (UNICEF 2001). Whilst the absolute risk of injury death is relatively small, when considering the larger extent of morbidity and disability from injury it is clear that injury is one of the most important health issues facing children (UNICEF 2001). It has also been observed that injury mortality may have the steepest social gradient of child deaths, and may be the leading cause of the social gradient for total child mortality (Roberts and Power 1996; Roberts 1997). New Zealand also has a relatively high proportion of children living in low-income households. This dissertation explores the association between these observations, namely the impact that household income and poverty have on child injury mortality.

In New Zealand unintentional injuries make up the majority of injury deaths for children aged 0 to 14 years. For 1990 to 1998, 86% of 1118 child injury deaths were unintentional (i.e. not from assault, self-inflicted or of undetermined intent) (IPRU). This dissertation will concentrate on unintentional deaths.

This chapter will begin by briefly reviewing our current understanding of the role of social and economic determinants of health. A framework for understanding the social origins of injury, which is important for this dissertation, will be presented. This will be followed by a brief discussion on why we should be interested in social inequalities in health (and injury). To set the scene for this dissertation, there will be a background on child poverty in New Zealand. To conclude this chapter the objectives of this dissertation will be stated.

1 Theory of social causation of health

The way we conceptualise health is important in that it determines our approach to health research and the research question that we ask, and it determines how we go about developing interventions to improve health.

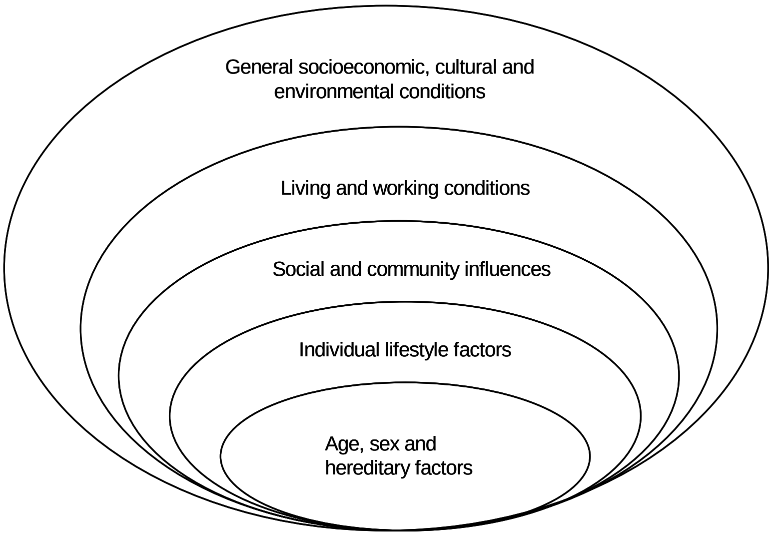
There exists a large literature on the history of the theories of health and prevailing paradigms for a particular period (Susser 1998). Widely known are the ‘miasma’ theory of the nineteenth century; the ‘germ’ theory from the late nineteenth century; and the growing theorising around chronic disease that has dominated the twentieth century. There has been substantial overlap and coexistence of these concepts. Each is associated with particular types of interventions: the sanitary movement in response to miasma; hygiene, antibiotics and immunisation for the germ theory; and attention to risk-factors and life-style factors for chronic disease (Pearce 1996; Susser 1998).

In fact, discussions surrounding our conceptualising of health and the roles of epidemiology have been decidedly spirited over the latter decades of the twentieth century (Susser 1998). There has been resurgence in interest of social origins of health and disease, and at the same time interest and expertise in the area of genetics has grown. Epidemiology has developed into numerous different branches, including social epidemiology. Social epidemiology has been defined as the study of ‘*the social distribution and social determinants of states of health*’ (Berkman and Kawachi 2000).

Within epidemiology there are ongoing challenges on how we conceptualise health and the ability of epidemiological methods to respond to an increasingly complex understanding of health. Some commentators argue that we are at the cusp of a new era in epidemiology, an era of understanding that should involve a more dynamic, multilevel interactive systems-based model (Susser 1998). Terms that have recently been suggested to describe this include ‘eco-epidemiology’ or ‘ecosocial epidemiologic theory’(Susser 1998; Krieger 2001). This is an ongoing discussion in the epidemiological literature, which is by no means resolved. In part, this is because of the limitations of available methods in characterising multilevel dynamic forces. This will be discussed in further detail on page 143.

Accepting that our theorising on health and our health research methodologies are continuing to develop, there are several models that have formed the basis for our current understanding on health determinants. The well-known work of Dahlgren and Whitehead (see Figure 1) diagrammatically presents the different influences on individual health as a number of concentric circles.

Figure 1: Dahlgren and Whitehead's (1991) model of the determinants of health (cited in Whitehead 1995)



One New Zealand-specific model has been developed by Howden-Chapman and Cram (Howden-Chapman 1999) to represent the socioeconomic and cultural determinants of health and is presented in Figure 2. A further model, based on work by Machenbach, has also been used in New Zealand to develop an intervention framework for reducing socioeconomic inequalities in health (see Figure 3).

Figure 2: A New Zealand model of socioeconomic determinants of health (source: Howden-Chapman 1999)

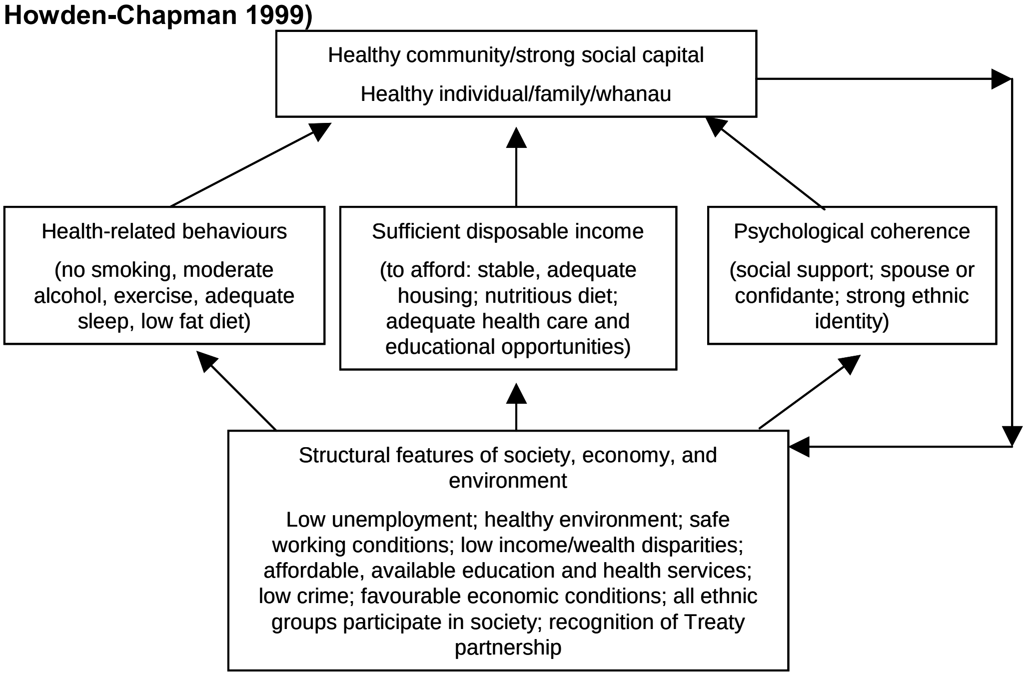
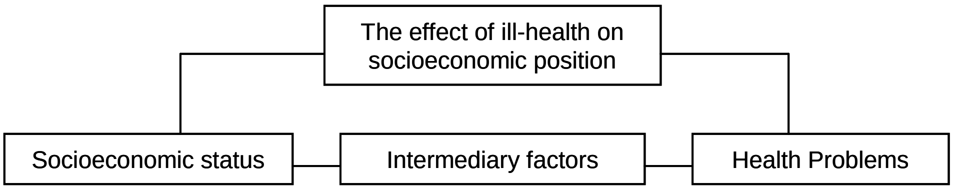


Figure 3: Mackenbach's framework for interventions to reduce socioeconomic inequalities in health (Source: National Health Committee 1999)



This constellation of conceptual frameworks for health forms the underlying theory of this dissertation. No one model perfectly captures the likely dynamic nature of the variables. The next section will present a more detailed model specifically for the social determinants of injury.

This dissertation uses the term "socioeconomic position" to refer to 'the social and economic factors that influence what position(s) individuals and groups hold within the structure of society, i.e., what social and economic factors are the best indicators of location in the social structure that may have influences on health' (page 14 Lynch and Kaplan 2000). Socioeconomic position is a complex, dynamic multi-dimensional construct, which by its nature is difficult to measure (Liberatos, Link et al. 1988). Many different dimensions of socioeconomic position that have been examined are associated with health, but each dimension may effect health in different (yet overlapping) ways as well as being a marker for social rank, and are not necessarily interchangeable with each other (Benzeval, Judge et al. 2001; Daly, Duncan et al. 2002). An individuals socioeconomic position is due to a number of different influences, such as an accumulation of prior circumstances and behaviours, that also act to determine future opportunities in complex ways (Sorlie, Backlund et al. 1995).

For health, particular periods of the life course may be more vulnerable to socioeconomic influences. For instance, there is research, albeit inconsistent, suggesting that there are social gradients in child health (using parental social position as a marker of the child's social position), but during the transition period of adolescence, this social gradient may disappear or is attenuated, before returning to influence adult health outcomes (measured using adult socioeconomic position) (Wise, Kotelchuck et al. 1985; West 1988; Blane, Bartley et al. 1994; West 1997; Pensola and Valkonen 2000). However, other studies have found the continuation of a gradient throughout adolescence (Mare 1982; Judge and Benzeval 1993; Singh and Yu 1996; Singh and Yu 1996).

This dissertation is interested in one aspect of social position, the economic dimension of income. Income is related more directly to access to material resources, goods and services than are other dimensions of socioeconomic position. The role of income and other dimensions of social position in influencing health will be considered in more detail in chapter 2.

2 Theory for social determinants of injury

It seems that for children, more than any other cause of death (with the possible exception of SIDS (Blakely et al 2003)), injury may display the steepest social gradient (Roberts and Power 1996; Singh and Yu 1996; Roberts 1997). Despite increasing knowledge on the social gradient in injury mortality, the mechanisms linking the individual, socioeconomic position, the socioeconomic characteristics of an area, and injury mortality remain poorly understood. Injury prevention research has tended to concentrate on the downstream (proximal) factors that may influence injury. For example, in developing injury prevention interventions, the Haddon matrix (Haddon 1980) is widely used, and focuses on host behaviour, modification of the agent, and modification of the environment. There has been little research on the upstream factors that may determine injury mortality (Laflamme 2001). More recently there has been a call for modifying the socioeconomic determinants of health as an injury prevention strategy, particularly in traffic injury prevention (Roberts, Norton et al. 1996; Roberts 1997; Laflamme and Diderichsen 2000). The UNICEF report on injury provides a reminder of the importance of considering 'who' as opposed to 'what' in our efforts at injury prevention (UNICEF 2001). This international review of injury deaths comments:

> '*the breakdown of injury deaths by immediate cause can distract and mislead. Too exclusive an emphasis on compartmentalising injuries can lead to a blizzard of statistics that blinds policy-making to the common underlying risk factors associated with child injuries from all causes. Whether the proximate cause be traffic accident, assault, drowning, fire or poisoning, the likelihood of a child being injured or killed appears to be strongly associated with such factors as poverty, single parenthood, low maternal education, low maternal age at birth, poor housing, large family size, and parental drug or alcohol abuse*'.
>
> UNICEF 2001

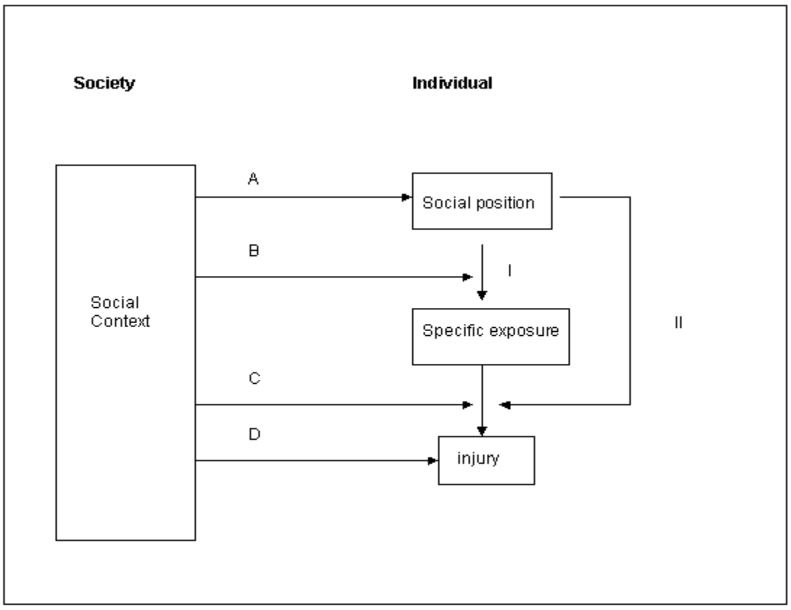
2.1 Conceptualising the social determinants of injury

A good example how concepts of disease causation may vary over time was the move by the British Medical Journal editors to ban the word ‘accident’ from 2001 (Davis and Pless 2001). The reason for this is the acknowledgement that ‘*most injuries and their precipitating events are predictable and preventable*’. The editors of the BMJ argue that the term ‘accident’ incorrectly implies that there is no known cause of the event.

The framework by Swedish researchers, Diderichsen and Hallqvist[1] (see Figure 4) presents a theoretical model for understanding the social aetiology of injury. This model combines the effect of the broader social context, which is defined as ‘*encompassing interwoven elements in the physical, cultural, social, and economic environments that characterise a neighbourhood or society*’, interacting together with individual socioeconomic qualities to determine injury.

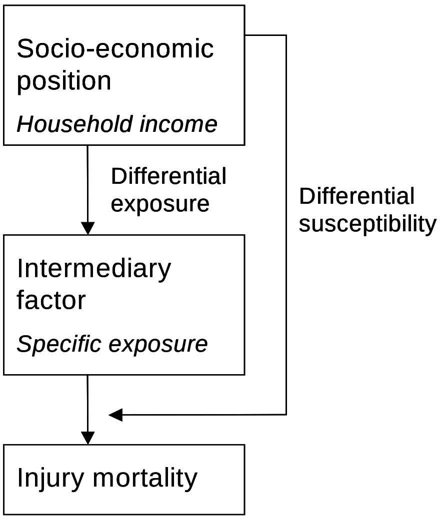
Figure 4: Framework by Diderichsen and Hallqvist for the social determinants of injury

Individual level	***Contextual effect***	
I Differential exposure	**A Social stratification**	**C Differential susceptibility**
II Differential susceptibility	**B Differential exposure**	**D Directly on injury**



A simplified way of conceptualising the social determinants of injury appropriate for this dissertation, based upon Diderichsen and Hallqvist’s framework is presented in Figure 5. Laflamme and Diderichsen argue that it is differential exposure of hazards that best explains the variation in injury risk by social class (Laflamme and Diderichsen 2000).

Figure 5: Simplified model of the social determinants of injury (modified from Diderichsen and Hallqvist's framework)



2.2 Mediating factors in the income-injury association

Examining the model presented in Figure 5, there are plausible intermediary mechanisms on how income may act as a distal cause of injury mortality. The majority of these factors influence exposure to risk (i.e. there is differential exposure to risk according to household income). Differential susceptibility to injury may also have a role to play. For example, whilst driving in a safe late model vehicle may reduce the risk of a crash (for example, from improved braking systems), the presence of air bags and side intrusion bars may make occupants less susceptible to injury. There are four types of mechanisms that can be postulated to act as an intermediary in the income-injury relationship:

1. Access to safety-promoting material resources, including the ability to afford:

- A late model car with safety features (Roberts and Power 1996; Roberts, Norton et al. 1996).
- To appropriately maintain a car (for example, ensuring a current warrant of fitness).
- To consistently provide a safe car seat.
- To provide transport (a child from a low-income family may be more likely to walk to school, and experience greater exposure to pedestrian risk (Roberts and Norton 1994)).
- Safe household appliances, nursery furniture that comply with safety standards, and functioning smoke detectors (Duncanson, Woodward et al. 2002).
- To maintain fencing of property.

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[1] Cited in (Laflamme and Diderichsen 2000), original reference not available.

- The maintenance of constant electrical supply.

2. Neighbourhood characteristics – for example, low-income neighbourhoods may be more likely to have (Roberts, Norton et al. 1994; Roberts, Norton et al. 1995; Roberts, Norton et al. 1996):

- Busier roads and highways.
- Less traffic calming.
- Fewer options for safe road crossing.
- Fewer options for safe play areas.

3. Access to health services – such as well-child injury prevention health education.
4. Psychosocial mechanisms – the stressors associated with low-income may influence a household's

- Ability to implement known injury prevention health education messages.
- Ability to ensure an appropriate level of child supervision.

Another possible intermediary factor may be through access to health services once an injury has occurred. It is possible that having sustained an injury, children from low socioeconomic households may be more at risk of death than other children. There is little literature on this. Whilst this mechanism may have some part in determining the social gradient in injury, it is not likely to be a major factor. Serious injury events in New Zealand are universally attended by emergency services. It is possible that children living in rural areas (who may be more likely to have low-incomes) may have less rapid access to emergency services.

3 Why reduce inequalities in child injury?

There are good reasons why we should be reducing health inequalities, including inequalities in child injury. Woodward and Kawachi have summarised four arguments why reducing inequalities is important over and above improving the average health status of the population (Woodward and Kawachi 2000):

- Inequalities are unfair and unjust when poor health is due to an unjust distribution of the underlying social determinants of health (for example, income).
- Inequalities affect everyone – conditions associated with health inequalities can affect all members of society (referred to as 'spill-over effects').
- Inequalities are avoidable and can be changed by appropriate policy intervention.

- Interventions to reduce health inequalities can be cost effective.

The authors conclude that the strongest argument for reducing health inequalities is because of equity and fairness. A child injury death is a particularly compelling outcome for arguing that there should be a strong focus on reducing inequalities as well as improving average health. Death from injury childhood conjures an immense sense of unnecessary and tragic loss and suffering, not only because of the loss of a young life, but also the distress experienced by the family and community. Two important reasons why we should be interested in the inequalities in injury mortality include fairness or equity (social justice), and because inequalities are not inevitable. In other words, social inequalities in the risk of injury mortality for children are unjust, and do not need to be accepted. Inequalities in the risk of injury also provide an indication of the reduction in injury that may be possible (Laflamme and Diderichsen 2000; Laflamme 2001).

Children are arguably the most vulnerable members of our society, and it is the responsibility of society to safeguard their rights and (together with their caregivers) to ensure their safety. In New Zealand in 1991 (the start of the study period for this dissertation) children were much more likely to live in poor households compared to other members of society, and this remains true today (Ministry of Social Development 2003). The inequality in the distribution of economic resources to this segment of the population is not only unfair and may be in breach of international legislation (New Zealand ratified the 1989 United Nations Convention on the Rights of the Child (UNCROC) in 1993), but it may also carry with it a greater risk of injury death for poor children. These are perhaps the most convincing arguments for promoting interventions to reduce injury inequalities.

Understanding inequalities in injury can also help in explaining the aetiology of injury and in developing intervention strategies, be they population based or targeted to high-risk groups. One can also not ignore the fiscal arguments for reducing injury deaths; each child death from injury is associated with a high number of person years lost and the loss of potentially economically active members of society. The costs sustained by the health system are also substantial, particularly so when considering that death is the tip of the injury iceberg (UNICEF 2001).

4 Child poverty and social policy

'By the middle of the century that has just ended, the world's richest nations were confident that poverty would be overcome by a combination of economic growth and welfare spending. A prediction that poverty would still afflict significant numbers of their children in the 21st century would not have been believed. Today, despite a doubling and redoubling of national incomes in most nations since 1950, a significant percentage of their children are still living in families so materially poor that normal health and growth are at risk. And … a far larger proportion remain in the twilight world of relative poverty; their physical needs may be minimally catered for, but they are painfully excluded from the activities and advantages that are considered normal by their peers' (page 3 UNICEF 2000).

This powerful statement forms part of the introduction of an UNICEF report into child poverty, that ranks rich countries according to the percentage of children living in poverty (defined as households earning incomes less than 50% of the national median; with results for 23 countries ranging from 2.6% to 26%). The UNICEF report highlights that childhood poverty is very much a problem in many developed countries. Sweden has the lowest child poverty rate (2.6%), and Mexico the highest (26.2%). The United Kingdom ranked twentieth at 19.8%, and Australia ranked 15th at 12.6%. New Zealand was not included in this study. The six countries with the lowest levels of child poverty were the same irrespective of whether the poverty was measured using relative or absolute scales, and it was found that these countries combine a 'high degree of economic development with a reasonable degree of equity' and have the highest proportions of Gross National Product on social expenditures (UNICEF 2000).

Child poverty is a complex issue, and has become the focus of intense academic and social debate in New Zealand. This section will begin with a discussion on the conceptualisation and definition of poverty, and will then review social policy surrounding child poverty in New Zealand and internationally.

4.1 Defining poverty

For this dissertation, poverty is defined as an equivalised household income that is beneath an income threshold (a 'poverty line'). This is due to the availability of income data from the census (there is no direct measurement of living standards in the census), and because the policy intervention that is being explored in this dissertation is that of increasing income. Not all households defined as living in poverty may be experiencing economic deprivation. Additionally, any prevalence measure of poverty does not give an insight into the depth of poverty, the time dimension, or the meaning of poverty for those who are experiencing it.

The concise Oxford dictionary (Pearsall 2001) defines poverty as '*the state of being extremely poor*'. This denotes the inexactitude that exists when poverty is defined. It is implies, however, that poverty is due to a lack of economic resources i.e. resources are insufficient to meet needs. Any definition of poverty is generally associated with a sense that it is an 'unacceptable' state. In considering the definition of poverty, the concept of 'minimum needs' is also used (Perry 2002).

Any definition of minimum need or of poverty is arbitrary no matter how it is measured. One ongoing debate is whether to conceptualise poverty in absolute, or in relative terms (Marmot 2002). An absolute measure requires the identification of a set monetary value, beneath which, there is considered to be insufficient income to afford basic essential necessities (such as food and shelter). A relative measure is more commonly used in developed countries, and refers to '*a lack of access to sufficient economic and social resources that would allow a minimum adequate standard of living and participation in that society*' (the definition used by the New Zealand Poverty Measurement Project) (UNICEF 2000; Perry 2002; Waldegrave, Stephens et al. 2003). In both instances, it can be seen that constructing a poverty line is complex. The UNICEF report concludes that both absolute and relative measures of poverty are important and capture different aspects of poverty – and that both need to be monitored and reduced (UNICEF 2000).

There is much discussion on the benefits of using an 'input' measure or an 'output' measure to identify those households living in material hardship; each has conceptual and methodological problems. Essentially, the link between current income (a component of 'permanent' income that determines patterns of consumption) and the standard of living or material well-being is very complex. An input measure, usually income, is linked to the minimum acceptable standard of living. It measures the resources available to purchase goods and services that determine the standard of living possible. Expenditure is another form of an 'input' to living standards, and may better represent the economic resources available to a household than income, however, it is difficult to accurately measure (and is not measured in the census) (Perry 2002; Ministry of Social Development 2002).

An output measure directly measures the standard of living (for instance, as can be measured by asset ownership and consumption of goods and services), and does not relate this back to a lack of financial resources. Research suggests that there is a substantial 'mismatch' between poverty measured using income, and that measured using living standards. Perry has suggested that the extent of this mismatch may be up to 50-60% i.e. half of those people with unacceptable living standards have incomes above the poverty line, and half of those with incomes below the poverty line have acceptable living standards (Perry 2002). The Ministry of Social Development has developed a tool to measure living standards (i.e. an output measure), the Economic Living Standard Index (ELSI). The ELSI scale covers a range of items that include personal possessions, household amenities, social and recreation activities, ability to have preferred foods, access to services, and general self-ratings (Ministry of Social Development 2002).

New Zealand does not have an official poverty line, although it is acknowledged that it is important to have 'some idea of the extent of economic deprivation' (page 90 Statistics New Zealand 1999). The Government Statistician has recommended against the adoption of a poverty line because it may oversimplify the issue of poverty, and that it doesn't measure changes in the degree of deprivation for those people living under the poverty threshold (Statistics New Zealand 1999). The Government's ELSI scale does not define the equivalent to a poverty threshold i.e. there is no defined minimum acceptable standard of living (Ministry of Social Development 2002).

The problems in constructing an official poverty line have been summarised by Statistics New Zealand (Statistics New Zealand 1999):

- What a poverty threshold actually means (for instance, living conditions in households just above the defined poverty line may be similar to a household just below the threshold).

- Determining the most appropriate income level to use as a poverty threshold. This is complicated by different costs of living (particularly housing costs) in different regions.
- Determining the equivalence scale to be used – this will effect the income threshold and the type of households that will be below the poverty threshold.
- How to adjust the poverty threshold over time – adjusting for inflation ('real' purchasing power). This may be complicated if 'real' incomes are changing over time, for instance, if incomes are increasing when the economy is growing. Measuring changes in the number of people in economic deprivation over time is complicated when the measures of central tendency (the median and the average) have diverged over time. For example, from 1981, real average incomes fell (therefore increasing the numbers living in poverty if there was a set real income threshold). Average incomes then increased, however the median did not (Statistics New Zealand 1999).
- How to handle households experiencing short-term periods of low income.

In developing countries, an absolute poverty threshold is commonly used. For instance, the World Bank sets absolute poverty lines of US$1 and US$2 per day (Chen and Ravallion 2000). In developed countries, relative poverty is generally considered to play the more important role, however, there may be aspects of both relative and absolute poverty occurring together (UNICEF 2000).

The USA has a poverty line that is based on an 'absolute' measurement of poverty, developed in the 1960s (President Johnson's era, during the 'War on Poverty'). The poverty line was based on the cost of an adequate diet multiplied by three (i.e. food accounted for one third of average household expenditure). Over time, this has been adjusted for changing prices, but not a minimum acceptable standard of living (and note also that food now accounts for less than one third of expenditure) (UNICEF 2000).

The European Union adopted a relative measure of poverty in 1984, and this is generally the most commonly used definition in the developed world. Poverty is defined as those incomes that fall below 50% of the median national income. For instance, The international Luxembourg Income Study (LIS) that compares the income distribution of different countries uses this relative measure of poverty, but two other poverty thresholds are also investigated: 40% and 60% of median equivalent household disposable income (Stephens and Waldegrave 1997; UNICEF 2000).

Many countries are measuring poverty using a range of methods, including absolute and relative, and also direct or output measures of deprivation. The UK measures poverty using income on an absolute and a relative scale, as well as measuring outputs such as housing conditions (UNICEF 2000).

The New Zealand Poverty Measurement Project (NZPMP) has conducted much research into poverty, particularly on the meaning and measurement of poverty in a New Zealand context. The researchers, concerned of the arbitrary nature of an income based poverty measure (particularly a relative measure that may capture income inequality more than income adequacy and the associated standard of living) were interested in exploring a poverty measure that captured the reality of living on a low income. Their poverty measure was developed using data on income, living standards, and a subjective measure of poverty. The researchers determined from a series of focus groups the minimum adequate household expenditure, and using national data from the Household Economic Survey, and related the findings to the current social, economic and political context. The poverty threshold was based on focus groups determining a minimum adequate expenditure, and not one that enables adequate participation in the community (i.e. it is essentially an absolute measure). The determined poverty threshold was then compared to the income distribution for the total population to develop a relative measure. They found that an appropriate poverty line for New Zealand is 60% of median equivalent disposable household income. The NZPMP are updating their poverty measurement over time (with changes in socioeconomic conditions and changing policy) to ensure that it remains relevant (Stephens and Waldegrave 1997; Waldegrave, Stephens et al. 2003).

In summary, this dissertation will use a relative measure of poverty on the basis that this is '*the most revealing single indicator of child poverty in industrialised nations*' (UNICEF 2000) and because there is no equivalent accepted absolute measure of poverty. Due to the variations in the cut-off for relative income poverty, for modelling the elimination of poverty, this dissertation will use the two most common poverty thresholds: 50% and 60% of the median equivalised household income.

4.2 Child poverty and social policy

Children who happen to be born into poverty do not have the same opportunities as those who are not poor. Child poverty has been associated with a number of adverse outcomes across a range of domains (including health, education, criminal justice, and the labour market) and may have life long consequences. The increase in attention to child poverty by policy-makers and others is due in part to sentiments of social justice, but also because of concerns of the long-term financial costs of not addressing child poverty (UNICEF 2000). The UNICEF report sets a challenge: '*For the sake of both today's children and tomorrow's world, therefore, the beginning of a new century demands a new commitment to ending child poverty in the world's riches nations*' (UNICEF 2000).

4.2.1 New Zealand

Childhood poverty has been a prominent feature in New Zealand for the last 15 to 20 years. There is relatively little information on the extent of the problem prior to this. What is well known, is that child poverty dramatically increased from the late 1980s to the early 1990s, coinciding with a turbulent period of major socioeconomic reform and widening income inequalities. Māori and Pacific children, children from one-parent families, large families, children living in rental accommodation, and children in families reliant on a benefit, appear to have been disproportionately affected (Ministry of Social Development 2001). Many would argue that the reforms had a major adverse effect on children, an effect that was not adequately considered when developing and implementing these reforms (Blaiklock, Kiro et al. 2002). There is evidence that in times of economic turmoil escalating child poverty is not inevitable – governments can introduce measures to hold child poverty rates in check (for example, such measures were taken in the Czech Republic and in Hungary in the early 1990s) (UNICEF 2000).

Despite the now well officially documented increase in child poverty over the late 1980s and early 1990s, at the time, poverty in New Zealand was not officially recognised. For example, in the early 1990s, the Prime Minister (Jim Bolger) implied that there was no poverty in New Zealand with the comment that there was no starvation in New Zealand (Stephens and Waldegrave 1997). Child poverty research increased over the 1990s and early 2000s. The non-governmental organisation (NGO) Child Poverty Action Group

(CPAG) was formed in 1994 in response to concerns on child poverty (CPAG 2003; Stephens and Waldegrave 1997).

Government statistics show that in 1987-88, 14.6% of children lived in households earning incomes less than 60% of the median (after housing costs); by 1992-93 this figure was 34.7%; and 29.1% in 2000-01 (Ministry of Social Development 2003). Recent Government statistics have found that 29% of children experience at least some restriction in the standard of living (compared to a figure of 17% for non-child families), for 7% of children it is classified as severe (Ministry of Social Development 2002). The reality for many New Zealand families is that their income level is not sufficient to provide for an adequate quality of life. Many families do not have income to provide for a healthy diet (Russell, Parnell et al. 1999). Research on living standards has found that a substantial proportion of children go without visits to the doctor or dentist or go without glasses because of the costs involved. Many children do not own wet weather gear or appropriate shoes; many children have to share a bed because of cost (Ministry of Social Development 2002).

There are many reasons that the elimination of child poverty should be considered an important social policy objective, including:

- Upholding the rights of children to an adequate standard of living, in line with New Zealand's international obligations (UNCROC).
- Equity - children experience a high proportion of poverty compared to other vulnerable groups in New Zealand (for instance, the elderly (Ministry of Social Development 2003)).
- The higher risk of adverse outcomes in childhood and adulthood. There is increasing evidence showing the importance of considering a 'life-course approach'. This includes considering the effects of cumulative disadvantage, and the importance of critical development periods in determining future potential.
- Social investment for future generations and for supporting an increasingly aging population.
- To reduce costs from the current and future burden of poverty-related outcomes.

The importance of child poverty is now generally well recognised, and there are several government documents investigating the extent of child poverty. Further to this, there have increasingly been government documents highlighting the elimination of child poverty as a priority government policy commitment (see Table 1). The Associate Māori Affairs Minister Tariana Turia recently called for 'zero tolerance' of child poverty, '*we must not rest until child poverty is eradicated*' (Turia 2003).

Table 1: Government reports or policy documents with a section on child poverty

Document and Agency	Year	Relevant section or policy commitment
The Social Report 2001 (MSD)	2001	Presented figures for the % of children in households earning < 60% disposable income. 'This government …will tackle hard issues like child poverty' (page 5).
Living Standards 2000 (MSD)	2002	Presented data on living standards. 'The elimination of child poverty is regarded as a fundamental social policy goal all over the world' (page 118).
Briefing to the incoming Minister: Improving wellbeing for all Nzers (MSD)	2002	Social Investment Priority: Reduce early childhood poverty Goal 'Promote economic security for children and young people and reduce the negative impact effects of poverty… (page 7 chpt 4)
Agenda For Children (MSD)	2002	'Vision: economic security – no children live in poverty' 'Action Area 3: An end to child poverty'
Growing an innovative New Zealand (MED)	2002	'Strengthening the Fundamentals': priority to 'a modern cohesive society' by 'ensuring adequacy of income for people in need'.
Sustainable Development for NZ: Programme of Action (DPMC)	2003	'Investing in Child and Youth Development' one of 4 action areas. Desired outcomes include: 'adequate material living standards', 'good health'. Focus on targeted interventions
The Social Report 2003 (MSD)	2003	'Desired outcome': 'New Zealand is a prosperous society where all people have access to adequate incomes and enjoy standards of living that mean they can fully participate in society and have choice about how to live their lives'. Updated data on % of children in households earning < 60% disposable income. Specific reference to tackling 'hard issues like child poverty' seen in the Social Report 2001 is absent in the 2003 report and is replaced by 'further work is being undertaken to review family income assistance'.

The non-governmental sector, expressing their frustration at the slow progress made on reducing child poverty, has produced several publications calling for child poverty eradication to be prioritized[2]. The advocacy group Child Poverty Action Group (CPAG) has published two documents that go further, and detail the steps that they consider are necessary to reduce child poverty[3].

The current political discourse appears to indicate that there is an acceptance of the extent of the problem of child poverty. There have been some small steps taken to

[2] For example, '*Making it Happen*' the NGO report on how the Agenda for Children should be implemented (see www.makingithappen.info); and '*Children and Youth in Aotearoa 2003*' the NGO report to the United Nations Committee on the Rights of the Child (ACYA 2003).
[3] See '*Our Children: The Priority for Children';* 1st edition 2001, 2nd edition 2003 (CPAG 2003).

improve the financial well-being of low-income families, such as reintroducing income-related rents for state housing. However, a working programme to effectively reduce child poverty has not yet been developed. The current debate appears to centre on the costs involved in reducing child poverty, and what interventions should occur to reduce the prevalence of and adverse effects of child poverty.

4.2.2 Internationally

The eradication of child poverty has been on the agenda in many rich countries, including the European Union (EU), France, Ireland, and the United States. Ireland committed to a 10 year National Anti-poverty Strategy in 1997. The target of this strategy (revised in 1999) is to reduce the percentage of the population earning less than 60% of the median income (and experiencing deprivation) from 15% to less than 5% by 2004. A Cabinet committee was established to monitor progress (UNICEF 2000).

In March 1999, the Prime Minister of the United Kingdom (Tony Blair) committed to eradicating child poverty within a generation. The declared target was to halve child poverty within ten years, and to eradicate it within twenty years (UNICEF 2000). A number of policy initiatives have been introduced, including methods of monitoring progress towards the declared targets. It has been estimated by government and by independent research, that from the measures currently being implemented, the prevalence of child poverty is expected to reduce from 26% to 17% (UNICEF 2000).

In 2000, the European Council called for '*decisive steps to eradicate poverty*' as a part of a strategy for making the EU the '*most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth, more and better jobs and greater social cohesion*' (Swedish Govt 2001), and have called for member states to develop targets to assist in monitoring progress (UNICEF 2000). In response, Sweden has developed an 'Action Plan Against Poverty and Social Exclusion' and details an implementation plan and targets (Swedish Govt 2001).

5 The New Zealand Census-Mortality Study

The New Zealand Census-Mortality Study (NZCMS) commenced in 1998 and has for the first time enabled the investigation of the association between an array of socioeconomic factors and mortality outcomes using routinely collected government statistics for the total New Zealand population (Blakely 2002). The study design is a retrospective cohort study using the entire New Zealand population as the study population to investigate the association between socioeconomic factors (derived from the census record) to mortality (obtained from the New Zealand Health Information Service). This large study anonymously and probabilistically links mortality records to census records. For each population census from 1981 (conducted every 5 years) the NZCMS is able to link mortality records for the following three-year period. These four cohorts traverse a period of unprecedented major socioeconomic change in New Zealand.

Initial work on the NZCMS has been to describe the associations between various socioeconomic factors and various mortality outcomes for adults aged 25 to 64 years (Blakely 2002; Blakely, Woodward et al. 2002) and more recently, for children aged 0 to 14 years for the 1991 to 1994 time period (Blakely, Atkinson et al. 2003). The NZCMS has also allowed improved analyses of mortality trends over time by ethnic group (by using the census self-identified ethnicity to correct for the systematic 'undercounting' of Māori and Pacific ethnicity on mortality records) (Ajwani, Blakely T et al. 2003).

At the time of commencing this dissertation the linkage procedure for the 1991 census had become well established, both for children and adults up to the age of 74 years. The linkage of the 1981, 1986, and 1996 population censuses was still to be completed. This dissertation was therefore able to use the NZCMS for the 1991 census child cohort, followed for mortality for the time period from 1991 to 1994. The initial cohort analyses suggested a strong social gradient in injury mortality for children. This dissertation takes this finding further, by endeavouring to tease out the role that household income plays in the social gradient for injury deaths with view to informing policy (changing household income is an intervention available to social policy-makers). Using the information on the role of income in the injury social gradient, this dissertation will model the impact that changing the distribution of income (for example, eliminating poverty) may have on child injury mortality. Chapter 4 will discuss the NZCMS methodology in more detail.

6 Objectives of this dissertation

The purpose of this dissertation is not only to describe the social patterning of child injury mortality, but also to quantify the independent and causal association of income and child injury mortality and to use this information to explore the expected effect of potential interventions aimed at modifying levels of household income. This dissertation is not questioning whether or not we should be striving to eliminate child poverty, the author believes that there are good reasons why eliminating child poverty is important. The interest of this dissertation is the impact that income poverty, and conversely the effect of eliminating income poverty, may have on child injury mortality.

The objectives of this dissertation are:

- To review the literature on socioeconomic gradients in childhood injury mortality.
- To review the literature on the independent effect of income on mortality outcomes (i.e. the role that 'money' plays).
- To determine as best as possible the 'independent' (i.e. unconfounded) effect of income on child unintentional injury mortality.
- To model the impact of changing household income on child injury mortality.
- To discuss the implications for policy-makers and injury prevention on the influence of poverty in determining child injury mortality in New Zealand.

Chapter 2: Causal pathways from income to child injury mortality: Literature review

Chapter 2: Summary and Overview

It is well known that socioeconomic disadvantage is associated with mortality; however, it is difficult to disentangle the influence that different dimensions of socioeconomic position may play in this association. Our ability to accurately infer income as a cause of mortality is complicated by a number of important methodological and conceptual issues such as in the way that income is measured, the possibility of reverse causation, and of confounding by other socioeconomic variables. Improved understanding of the causal effect of income has important policy implications, and could be used to improve population health.

The available evidence suggests that the income-mortality association whilst attenuated, is still present after adjusting for confounding and reverse-causation. There is little robust evidence on the unconfounded effect of income on child injury mortality, with many studies relying upon an area-level proxy measure (as opposed to a direct measure) for household income, which because of random misclassification, may dilute any income association that may exist. The expanding literature on the social determinants of child injury mortality in general also suggests that there may be considerable variation in the social gradient across age group, time, place, type of injury death, and the socioeconomic factor of interest.

This chapter will summarise a large volume of literature on income as a determinant of mortality, particularly child injury mortality, and will summarise the key issues surrounding the use of income as a socioeconomic variable in health research. The first section reviews income as a health determinant, and discusses the major issues involved in researching income. The second section reviews the evidence that we have that supports or refutes the hypothesis that income has an independent effect on mortality. The third section reviews the potential confounding factors that may distort an income-injury mortality association, or those factors that may act as pathway variables, and is particularly relevant to the analyses to be performed in this dissertation so as to best determine the unconfounded association of income and child injury mortality.

There is abundant evidence from many countries, including North America, Britain, the Czech Republic, Sweden, Finland, Norway, and New Zealand, that socioeconomic disadvantage is associated with higher child mortality[4]. More recently, there has also been increasing interest in the social origins of child injury mortality.

Most of the available research on social inequalities in child health has interchanged concepts of poverty, low income, and social disadvantage. The fundamental premise of this dissertation is that insufficient income is a cause of injury mortality i.e. this dissertation is concerned with the impact that income alone (separate to other socioeconomic variables) has as a determinant of child injury mortality. Income is of particular interest because of all the socioeconomic health determinants, income may be the most modifiable. For example, adjusting the income of the most disadvantaged people in society can potentially occur relatively rapidly, such as from modifying benefit levels or taxation policy (Benzeval, Judge et al. 2001).

The role that income plays in determining health outcomes in general has been an area of much interest and debate in the social epidemiology literature (Marmot 2002). Income has been associated with many health outcomes, including mortality, as well as other measures of morbidity and self-reported well-being (O'Dea and Howden-Chapman 2000; Benzeval and Judge 2001). Income has been considered to be a powerful predictor of mortality, and it is suggested that this association has become stronger over recent decades (Duncan 1996; Singh and Yu 1995). One New Zealand publication has gone as far to say that income is the '*single most important determinant of health*' (National Health Committee 1998).

However, of the large volume of literature on socioeconomic disadvantage and mortality (both adult and child), relatively little has specifically investigated the role that income itself plays in determining health. In general, most individual-level studies of socioeconomic position use measures other than income, such as occupational class, education level, or the receipt of a benefit. Those studies that do measure income often do not address the issues of confounding by other associated socioeconomic factors. There has also been relatively little research on the causal mechanisms of how social

[4] Wise, Kotelchuck et al. 1985; Östeberg and Vagero 1991; Östeberg 1992; Singh and Yu 1995; Singh and Yu 1996; Östeberg 1997; Bobak, Pikhart et al. 2000; Pensola and Valkonen 2000; Blakely et al. 2003.

disadvantage may lead to poor health. Also, whilst it is important to improve the health of the most disadvantaged children, there has been little consideration of the continuous distribution of risk (as opposed to a poverty threshold effect) of poor health that might be found across the population. A greater understanding of the causal pathways from social disadvantage to poor health will be important if we are to improve the policy response to reducing health inequalities.

1.1 Income and health

Income may be found to be associated with health in one of three ways: 1, in relation to the gross domestic product of a country; 2, the effect of an individual's income; and 3, from how income is distributed within a society (income inequality) (Marmot 2002). This dissertation concentrates on the effect of household low income on child injury mortality i.e. Marmot's second mechanism. The independent effect of income inequality (over and above household income) will not be discussed in this dissertation.

There are three ways in which household income may exert a 'causal' effect on health: it may be mediated directly via access to material resources; via psychosocial pathways; or by the effect income may have on health-determining behaviours such as smoking (Marmot and Wilkinson 2001; Marmot 2002). These three mechanisms are not mutually exclusive; rather, they are likely to be mutually reinforcing and highly intertwined. Individual income may be more important in a context where there is relatively less public provision of goods and services, compared with a context of high public social investment (Marmot 2002).

There are many examples of material goods and resources that are dependent on income that may determine health: quality of housing, healthy diet, good sanitation, access to health care, and a safe living environment. There are also many ways in which income can affect health through psychosocial pathways. Experiencing low-income may cause stress (such as from struggling to provide the basic necessities for a family on an inadequate budget) or impact on one's sense of control of circumstances, and it may also restrict options available for participating in society (Marmot and Wilkinson 2001; Marmot 2002). There is increasing evidence, albeit somewhat inconsistent, that exposure to chronic psychosocial stressors may trigger a biological response (via neuro-endocrine processes) that are damaging to health (Judge 2001). Negative health-related behaviours may also mediate the income to health relationship. There is evidence that some health-damaging behaviours (such as smoking) are used as a method of reducing stress, and helping cope under very difficult circumstances (Benzeval and Webb 1995). Some speculate that once there are adequate material conditions, income may predominantly exert its effect through psychosocial pathways (Marmot 2002).

It is also worth considering the shape of the relationship between income and health. In general, for any measure of socioeconomic position, the association with health is a 'gradient' rather than a threshold effect i.e. there are progressive improvements in health with increasing socioeconomic position, and there is no cut-off point at which there are no further gains. There is evidence suggesting that for income, this relationship is non-linear i.e. there is a different effect of income on health at different income levels. The gradient is steeper at lower income levels (McDonough, Duncan et al. 1997; Backlund, Sorlie et al. 1999; Benzeval, Judge et al. 2001). This non-linear association between income and health has persisted after adjustment for confounding and health selection (Benzeval, Judge et al. 2001).

The non-linear association between income and health means that for each unit increase of income, there is greater health gain at low-income levels compared to the higher income levels. This is an important consideration if income redistribution is to be used as a strategy to improve population health. There potentially will be relatively little change in the health of the highest income earners, but greater health gains for those at the bottom of the income distribution (O'Dea and Howden-Chapman 2000).

Research on the effect of income on health is complicated by a number of different issues (Benzeval and Judge 2001), each of which will be discussed in turn:

- How income is measured.
- Consideration of the time-dimension and the life-course perspective.
- The possibility of reverse causation whereby poor health causes income to be lower, causing a spurious association of low income causing poor health.
- Confounding by other variables that are correlated with income and health. To quote Marmot, '*the distinction between really mattering and appearing to matter is important*' (Marmot 2002). This will be discussed in detail in section 1.3.

There has been some discussion in the literature that the only way to confidently confirm the causal effect of income on health is through a randomised controlled experiment (Duncan 1996; Rodgers 2001). A review of randomised studies of income supplementation (usually undertaken to access workforce participation or to assess re-offending rates) found that by and large, opportunities to access the impact on health have been missed (Connor, Rodgers et al. 1999).

1.1.1 The measurement of income

Income can be measured in a number of different ways. For instance, there are variations in what may be included as income (for example, wages, benefits, interest); whether to use household or individual income; and whether it should be net of taxes and housing costs. Additionally, because income is usually measured by self-report, often in response to a single question, respondents may have different interpretations on the definition of income (Benzeval, Judge et al. 2001). This inconsistency in income measurement can present problems in enabling comparability between studies.

In social science research, equivalised household disposable income (from all income sources) is considered the best measure of income to ensure comparability between studies (Benzeval, Judge et al. 2001). Some studies have shown a stronger relationship to health using this measure, and note that the use of individual, unequivalised or gross incomes may underestimate the income-health effect (Benzeval, Judge et al. 2001; Judge 2001). As opposed to an individual measure of income, household income better reflects the access to resources that is possible for household members (Benzeval, Judge et al. 2001). Net income (after tax has been deducted) is also considered to better represent the resources available to a household, rather than gross income. Equivalisation ensures that family size and composition and economies of scale are taken into account, i.e. the living standard possible from a particular household income will depend on the number of people that are required to be supported from that income.

Sometimes it is possible to adjust for housing costs, but it is difficult to adjust for other factors that will influence the possible living standard possible on a given income. For instance, there may be different health, transport, debt repayment or childcare costs or different commitments to support others outside the household (Perry 2002). New Zealand research has found that the incidence of poverty increases once housing costs are taken into account (Stephens and Waldegrave 1997). Adjusting for housing costs may be desirable, but there are also some potential limitations. Firstly, the equivalence procedure for total household income may not be valid for an income minus housing costs. St John (St John 1997) also describes a scenario comparing two households on the same low-income. One household chooses to live in an old caravan that is inexpensive; the other spends a much larger sum on rent to obtain more reasonable housing conditions. The former household may look better off, but when compared to a debt-free owner-occupier household on the same low-income, the two households of this example are both equally much worse off (St John 1997).

1.1.2 The time dimension

The majority of studies on income and health have used cross-sectional measures of income, as this dissertation has used. Income levels can fluctuate over time, unlike some other measures of socioeconomic position such as education. Household income fluctuation depends on household circumstances but may also be related to the performance of the economy and the influence of other socio-political factors (Duncan 1996). For instance, income inequality increased in many countries during the last 20 years with New Zealand experiencing one of the most rapid increases (Statistics New Zealand 1999).

The influence of the dynamic process of moving into and out of poverty over time is also likely to be important when considering the impact of income on health. Bradbury et al (Bradbury, Jenkins et al. 2001) make the point that a 10% prevalence of poverty in a population may mean that 10% of the population live in poverty over a sustained period of time; or it may mean that the entire population spend 10% of the time in poverty. A prevalence measure of poverty will not distinguish between those who experience chronic poverty, with those that may cycle in or out of poverty (therefore having less exposure, and potentially time to 'recover' from the period spent in poverty) (Benzeval and Judge 2001; Bradbury, Jenkins et al. 2001).

There is evidence that average income over time (long-term or 'permanent' income) is a better representation of lifetime asset wealth and access to resources (and consumption) than a single measurement of income at one point in time (McDonough, Duncan et al. 1997; Benzeval and Judge 2001). Current consumption (which determines material well-being) relies not only on current income, but other factors such as the ability to borrow or draw on savings, on past acquisition of assets and their state of repair/disrepair (both are also related to permanent income) or financial support from family (Perry 2002). There is evidence that relying on cross-sectional data may underestimate the effect of income on health, i.e. long-term income is more important for health than short-term income (Benzeval and Judge 2001; McDonough, Duncan et al. 1997). There is also evidence that persistent exposure to poverty is more harmful to health than intermittent episodes (Benzeval and Judge 2001; McDonough, Duncan et al. 1997). Despite these issues, short-term income may be important for injury (with a shorter time-lag from exposure to outcome) and be more relevant for policy.

There has also been increasing awareness of the importance of taking a life-course perspective, i.e. the conditions of early life may exert an influence on outcomes later in life (Ben-Shlomo and Kuh 2002). This may be mediated through numerous complex pathways, such as exposure to health damaging factors (e.g infections, environmental tobacco smoke, poor diet) or by 'health capital' (accumulated resources, physical and psychosocial, that determine current health and health potential). The life course effects may occur at a 'critical period' of development, and/or may represent accumulated risk (Judge 2001; Ben-Shlomo and Kuh 2002). Being restricted to a one-off measurement of income, this dissertation cannot explore this in more detail. With regards to a life-course perspective, it is difficult to conceptualise a 'critical period' model having a major role to play in determining child injury mortality. It is possible to conceptualise accumulation of risk over time as being associated with injury mortality, especially for adolescents.

1.1.3 Reverse causation

Reverse causation may occur, although studies of income and health that have adjusted for initial health status have indicated that although attenuated, an association between health and income persists (Duncan 1996; McDonough, Duncan et al. 1997; Benzeval and Judge 2001). Furthermore, in a study of child injury mortality, reverse causation is extremely unlikely to play a significant part in the income-injury mortality association. The duration from the time of injury to the time of death is usually relatively short and it would be unlikely to significantly reduce the household income. If this effect were present, the reduction in income would have to be captured at the time of the census.

This dissertation is therefore less prone to the problems associated with reverse causation.

1.2 Income and mortality: the evidence

Despite the described difficulties inherent in studying income and health, it is widely accepted that income is an important determinant of health. This dissertation will now concentrate on the effect of income on mortality. As there is relatively little literature that specifically investigates the causal effect of income on mortality, this section will first briefly review the findings for adult populations. The literature on income and child mortality (all-cause and injury mortality) will then be presented.

1.2.1 Adult mortality and income

The following studies have investigated the association between income and adult mortality. The studies have all found that increasing income is associated with a reduced risk of mortality. Many of the studies have not been able to sufficiently address the issues of confounding or health selection.

In New Zealand, the NZCMS is the only study to have specifically analysed the impact that income has on mortality. Findings for adults aged 25 to 64 years for the period 1991 to 1994 have found that income has an effect on adult mortality, after controlling for confounding by age and ethnicity. The relative risk of mortality for males in the poorest income category (equivalised income less than $20,000) was 2.16 times (95% confidence interval 1.99 to 2.34) that of the highest income category (equivalised income greater than $50,000); for females the relative risk was 1.68 (95% confidence interval 1.52 to 1.86). This was present for most causes of mortality. Of all the socioeconomic variables analysed, income displayed the strongest effect (Blakely, Woodward et al. 2002).

In the international literature, several North American studies and two Finnish studies have also found an association of income and mortality. A census linkage study in the USA in the 1980s by Pappas et al (Pappas, Queen et al. 1993) also found an inverse relationship between income and adult mortality (adjusted for age and stratified by sex and ethnicity). Compared to a similar study from the 1960s the researchers found evidence that the income mortality gradient had actually increased over time.

Using the US Panel Study of Income Dynamics (PSID) from 1972 to 1989, McDonough et al found a strong inverse non-linear relationship between total household income and adult mortality (adjusting for age, ethnicity, period and household size), with the strongest effects found for those aged less than 65 years (McDonough, Duncan et al. 1997). Persistent low income was especially important in determining mortality, with an odds ratio of 3.03 for the poorest income group (<1993$15,000; 95% confidence interval 2.20 to 4.11) compared to the highest (>1993$70,000). There was no effect modification by sex or ethnicity. A smaller study of adults >45 years, but also using the PSID, for the period 1984-1994, found that wealth and recent household income had the strongest association with mortality compared to other socioeconomic variables such as education and occupation, after adjustment for age, sex and ethnicity (Daly, Duncan et al. 2002).

The US National Longitudinal Mortality Study of 530,000 adults followed from 1979-89 found a persistent association of income and mortality following adjustment for race, employment status, education, occupation, marital status and household size. The strongest associations were for adults aged 25 to 64 years (with a 45-60% excess risk of mortality for the poorest income category compared to the highest). There was no effect modification by sex (Sorlie, Backlund et al. 1995; Backlund, Sorlie et al. 1999). A record linkage study (1986-88) of 5% of residents of Manitoba, Canada, found an inverse association between income and mortality for adults aged 30-64 yrs, after adjusting for education. Individuals amongst the lowest income quartile had 1.43 the risk of mortality (95% confidence interval 1.10-1.86) compared to the highest quartile (Mustard, Derksen et al. 1997).

Two Finnish studies have also found an association of income and mortality. The first, a study of three million adults has found a mainly linear income-mortality relationship, RR 2.37 for men (95% confidence interval 2.30 to 2.44) and 1.73 for women (95% confidence interval 1.67 to 1.80) in the lowest income decile compared to the highest (Martikainen, Makela et al. 2001). The reduction of the association by adjusting for household structure, social class, education and labour force status was 61% for men and 52% for women. The second Finnish study investigated cardiovascular mortality and found a strong association with income even after adjusting for age, period, marital status, professional status, education, working conditions and occupation. The relative risk of mortality for the bottom income quartile compared to the top quartile was 1.80 (Virtanen and Notkola 2002).

1.2.2 Child mortality and income

There are even fewer studies that concentrate on the effect of income on child mortality other than the NZCMS, most of which are from the USA. As with the studies of adult mortality, studies of child mortality and income are also limited in the way that confounding has been addressed.

The NZCMS research on child mortality for the period 1991 to 1994 found a strong association between low-income and all-cause mortality (Blakely, Atkinson et al. 2003). There was a greater than two-fold increase in risk (RR 2.1 95% confidence interval 1.4 to 3.3) of death for children in the poorest households (<$10,000) compared to those from the wealthiest (>=$50,000), reducing to a relative risk of 1.4 (95% confidence interval 0.9 to 2.3) following controlling for age, ethnicity, education, car access, labour force, small area deprivation, crowding and family type. The effect for income was seen for all-cause mortality, unintentional injury, congenital, and SIDS (sudden infant death syndrome) deaths, and was across all ages up to age 14 years.

In the United States, Singh and Yu have reported on income differentials for child mortality for different age groups, with all age groups displaying an inverse income-mortality association (Singh and Yu 1995; Singh and Yu 1996; Singh and Yu 1996). Infant mortality was studied using National Linked Birth and Infant Death Datasets, and income data was determined using the National Maternal and Infant Health Survey. The income gradient was more pronounced for the 1980s than the 1960s, and was stronger for white infants, with an almost two-fold higher mortality rate for infants in the poorest households compared to the wealthiest. Note that black infants had a dramatically higher infant mortality rate for every income category, which had increased over time. Other than stratification by ethnicity, there was no adjustment for confounding (Singh and Yu 1995).

Singh and Yu then used the United States National Longitudinal Mortality Study (NLMS), a cohort study linking data from population surveys (Bureau of Census) to mortality files, to determine the income gradient for older children aged 1 year to 24 years (Singh and Yu 1996; Singh and Yu 1996). These models all adjusted for sex, ethnicity, and rurality. For children aged 1 to 4 years, there was an income gradient with the poorest income groups (<$10,000) experiencing over three times the risk of mortality (RR 3.0 95% confidence interval 1.39 to 8.05) compared to the wealthiest income category (>$15,000). The was no clear gradient for 5 to 14 years olds, but children in households earning less than $20,000 had a 1.62 times higher mortality rate than those in other households (95% confidence interval 1.08 to 2.41) (Singh and Yu 1996). An income-mortality gradient was present for 15 to 24 year olds[5], with a 60% greater risk of death for the poorest income category (70% for those with missing income) compared to the richest income category, after adjusting for the aforementioned variables (Singh and Yu 1996).

The US 1988 National Maternal and Infant Health Survey found a 60% greater risk of death for infants of mothers living below the US poverty level, and a two-fold greater risk of post-neonatal death, compared to mothers not in poverty. The effect of poverty on infant mortality was stratified according to various demographic variables; there was a stronger effect of poverty for women who were otherwise of low risk (i.e. educated, aged >18 years, white, non-smokers, and received early antenatal care) (Infant and Child Health Studies 1995).

Susan Mayer from the United States has been particularly interested in the impact of income on a wide variety of children's outcomes, including mortality (Mayer 1997; Mayer 2002). Mayer's conclusions are particularly worthy of interest, due in part to the influence that her work has had in the New Zealand policy context. The Ministry of Social Development commissioned Mayer to conduct a literature review on the influence of parental income on child outcomes (including cognitive development, educational attainment, mental health, teenage childbearing, infant health, nutritional status, illness and disability, and economic outcomes in adulthood). Mayer's conclusions on the effect of income on infant health outcomes (including mortality) were:

> '*The effect of parental income on children's birth outcomes, nutritional status and other measures of health is very small in all available studies. However, there is very little high-quality research on the effect of parental income on children's health, so one cannot put too much weight on this conclusion*' (Mayer 2002).

[5] Note that in this dissertation the age at death could be up to and including 17 years.

Her overall conclusions pertaining to all outcomes were that increases in income once basic needs have been met, provide some benefit to children, although not of a large magnitude as one may expect. This is because of confounding i.e. income is associated with other factors that also determine outcomes (such as parental characteristics). Mayer also acknowledges that much of the research on income uses a linear model – and this may underestimate the effect of income for low-income families. Mayer also states that the accumulation of small effect sizes may result in a '*substantial overall effect of parental income on children's well-being*' (Mayer 2002).

1.2.3 Child injury mortality and income

Whilst it is widely accepted that poverty is associated with a higher risk of injury, little is actually known on the unconfounded effect of income as a determinant of child injury. There have been a large number of ecological studies (studies where the unit of observation is a group of people, not the individual) that have investigated the influence of average area-level income or the area prevalence of poverty on injury mortality rates[6]. The majority of these studies have found a strong inverse association between average neighbourhood income level and child injury mortality. However, associations between exposure and outcome at an ecological level may not represent the association at a different level, that of the individual (and is known as the 'ecological fallacy') (Diez-Roux 1998). A further problem with ecological studies is in the limited ability to effectively adjust for confounding. For these reasons, findings from ecological studies may lead to incorrect causal inferences. The effect of an area or neighbourhood on injury (i.e. an area's injury-promoting or injury-protecting qualities), over and above the socioeconomic characteristics of individuals or household may well be very important, but is outside the scope of this dissertation where the interest is of the effect of household income on injury mortality. This dissertation will concentrate on study designs at an individual-level.

Most research at an individual-level has relied on routinely collected data that has not been designed specifically to help distinguish which socioeconomic factors are causally associated with injury. This is especially true for household income. There has been

[6] See Pomerantz, Dowd et al. 2001; Durkin, Davidson et al. 1994; Anderson, Agran et al. 1998; Dougherty, Pless et al. 1990; Pless, Verreault et al. 1987; Rivara and Barber 1985; Braddock, Lapidus et al. 1991; Roberts, Marshall et al. 1992; Carey 1993; and Duncanson, Woodward et al. 2002.

varying methodology between studies, and many have significant limitations that need to be considered before confidently accepting the findings. This section will now consider the literature (concentrating on individual-level studies) on income as a determinant of child injury mortality. It will be presented according to the type of income measure used. Many of the studies have significant limitations, and it is difficult to draw robust conclusions from these studies.

Household income measure

There are few papers that investigate the social gradients child injury mortality using an individual household income measure, and other than the NZCMS, most are from the United States. There are three papers reporting results from a large cohort study which used a household income measure. Two other studies used a cross-sectional study design to explore injury differentials using eligibility for aid or the receipt of a benefit as a measure of poverty. There are substantial limitations in our ability to infer causation from these last two papers due to the income measure used, and the lack of adjustment for confounding.

The initial NZCMS findings that prompted the research contained in this dissertation found that children from households earning less than \$10,000 (equivalised income) experienced 3.3 times the risk (95% confidence interval 1.5 to 7.4) of unintentional injury compared to children from households earning greater than \$50,000; and there was a gradient throughout the middle-income categories. The excess risk for the poorest children reduced by almost one-half once adjusted for confounding by education, car access, labour force, area deprivation, crowding, and family type (RR 2.3 95% confidence interval 0.9 to 5.8) (Blakely, Atkinson et al. 2003).

Most of the evidence from the USA has come from the National Longitudinal Mortality Study (NLMS). An analysis of the social differentials in injury mortality for 141,444 children aged one to 14 years for the period 1979 to 1985 by Singh and Yu (Singh and Yu 1996) found a significant inverse relationship between family income and mortality. It is unclear whether family income was equivalised. Intentional and unintentional injuries were included. After adjusting for sex, ethnicity, and rurality, children with family incomes less than \$10,000 had a relative risk of 1.87 (95% confidence interval 1.2 to 3.13); and those with incomes between \$10,000 and \$19,999 a relative risk of 1.62

(95% confidence interval 1.01 to 2.60), when compared with children with family incomes greater than $20,000 (Singh and Yu 1996). Results for the 15 to 24 year old age group (n=114,706) found that compared to children from the highest family income group (>$25,000), those with incomes less than US$10,000, the relative risk for injury mortality was 1.56 (95% confidence interval 1.17 to 2.09). When adjusted for sex, ethnicity, residence (inner city or other), US born or not, and for 20 to 24 year olds own education and marital status, the relative risk was 1.52 (95% confidence interval 1.13 to 2.06). The authors found a stronger income association for females (Singh and Yu 1996).

Of interest, Hussey (Hussey 1997) also used data from the NLMS to attempt to disentangle the effect of household socioeconomic factors on child injury mortality. Hussey's study included children ages 0 to 17 years, and used mortality data for the period 1979 to 1989. Family income was not equivalised, but the number of household members was included in the regression analysis. The natural log of income was used in the regression analyses. Detailed results by income category were not presented. For unintentional injuries, education had the strongest effect, with an 88% higher risk of injuries for children in the lowest education group compared to the highest education group, reducing to a 65% excess risk when adjusted for race, income, household size and structure, residence, sex, and age. Household education and household size were found to be important risk factors in multivariate models. The author found no independent effect of income or household structure on injury mortality (Hussey 1997). It is difficult to draw robust conclusions on the effect of income from this study.

Earlier studies in the United States have also been interested in the effect of low income on injury mortality, but methodologically have been limited, particularly in their ability to control for confounding. A study in North Carolina linked mortality records for children aged 28 days old to 17 years to Medicaid registries. Children from families eligible to receive 'Aid to Families with Dependent Children' were found to have higher mortality rates for these children than those not eligible. For injury deaths, children eligible for aid experienced 3.1 times the risk of non-traffic unintentional injury, 1.4 the risk of motor vehicle injuries, 6.9 times the risk of fire-related death, and 6.1 times the risk of poisoning. Whilst the results were stratified according to age and ethnicity, control for confounding by other variables was not possible (Nelson 1992). A study of child (aged 8 days to 17yrs) mortality in Maine from 1976-1980 found children in households in receipt of social welfare programmes experienced a 2.6 times greater unintentional injury mortality rate (Nersesian, Petit et al. 1985).

Neighbourhood income as a proxy for household income

The following individual-level studies were not able to measure household income, but used neighbourhood or census tract income as a proxy measure for household income. Whilst this is a more limited methodology that is prone to misclassification (by using aggregated income data to represent individual-level income), these studies are briefly reveiwed because of the small pool of individual-level studies on injury mortality. The likely random misclassification means that these studies may be more prone to underestimate the size of an association if present.

Scholer et al (Scholer, Mitchel et al. 1997) conducted a large cohort study on unintentional and intentional injury mortality in Tennessee from 1985-1994. Birth certificates and census records for 0 to 4 year olds were linked to form a cohort of 3,414,436 child years. Children were followed up until the age 5 years. The mean annual per capita income derived from the 1990 census file was used as a proxy for individual income (for 71% of the study population the mean annual 'block group' per capita income was used with a mean of 1104 residents per group; if this was not available, the census tract or county average income was used). Univariate analysis showed a 3.1 times greater risk of injury if neighbourhood income was <$10 000 compared to the reference group of income >$20,000. This effect was not present in multivariate analysis, when controlling for education, number of children, maternal age, race, marital status, delayed antenatal care, rurality, sex, or gestational age: RR 1.07 (95% CI 0.65-1.76). In the multivariate model, only maternal education, number of children and maternal age were found to have an independent effect. Multivariate analysis stratified by age found an association with income for children aged 1 to 4 years although the 95% confidence intervals included one (RR 1.45 95% CI 0.76 – 2.81 for the lowest income group compared to the reference group). For <1 year olds there was also no statistically significant effect of low income (RR 0.61 95% CI 0.29 – 1.32) (Scholer, Mitchel et al. 1997). As well as misclassification of income by using an area-level proxy, the use of mean income as opposed to median income means that the income profile of an area may be less representative due to distortions caused by outlying very high incomes, also potentially biasing the effect size towards the null.

Using similar methodology of assigning block group mean per capita income to represent individual income, in their study of fire-related mortality in <5 year old children, Scholer et al (Scholer, Hickson et al. 1998) found that low income was strongly associated with increased fire mortality in univariate analysis (RR 4.69 for the lowest income quintile compared to the highest), but this lessened in the multivariate analysis (variables as above) (RR 1.44 95% CI 0.82 to 2.51) and all 95th confidence intervals included one.

Other more limited studies include that by Wise et al (Wise, Kotelchuck et al. 1985) of child (0 to 18 years) mortality in Boston where census tract median income level was used as a proxy for individual income. For the period 1972 to 1979, after adjusting only for age and sex, there was an inverse relationship between income and death from fire, but a positive relationship between income and motor vehicle occupancy. This may be due to reduced vehicle ownership in low-income families. A case control study in Washington State (1981-1990) of 207 infant injury deaths also used census tract median income as a proxy for individual income (Cummings, Theis et al. 1994). A high proportion of death records (94.7%) were linked to a birth certificate but only 34% of records had data available on census tract median income. The estimated relative risk for unintentional injury death for those children living in a census tract with median income <$15,000 (reference group >$15,000) was 1.3 (95% CI 0.5-3.6), adjusted for parity, maternal age and rurality.

1.2.4 Child injury mortality and other measures of socioeconomic position

As data on income as a determinant of injury is relatively sparse or of limited quality, this section will briefly review the evidence on other individual-level social determinants of child injury mortality. This section will include evidence from the United States and the United Kingdom that the child injury socioeconomic gradient may be increasing over time (Scholer, Hickson et al. 1997; Roberts and Power 1996).

Research from the United Kingdom for the period 1985 to 1992 examined cause-specific injury gradients for 0-15 year old children based on paternal occupation (Roberts 1997). The lowest social class had 4.6 times the rate of injury death compared with those in the highest group. All injury types were associated with a social gradient. Steep gradients were found for fire-related deaths (16 times the risk) and pedestrian injury deaths (5 times). Motor vehicle occupants had the least social gradient (1.6 times). Children from families with no parent in employment were excluded from this study, therefore the results are likely to underestimate the social differential. Roberts and Power (Roberts and Power 1996) investigated the social trends in unintentional injury mortality over time for 0-15 year old children in England and Wales using paternal occupational class. They found children in the lowest social class experienced 3.5 times the death rate of the highest social class for 1979 to 1983; this differential increased to a 5-fold greater risk of injury mortality for the lowest social class for 1989-1992. There was a 33% decline in child injury in non-manual occupation families and a 17% decline for manual families, consequently increasing injury differentials. There was an increase in the rate of fire-related deaths for those children in the lowest social class (Roberts and Power 1996).

There have been several studies on the social gradient in injury mortality from Sweden. A linkage study of child (aged 1-19 yrs) mortality from 1981-86 briefly described a social gradient for injury death using an occupational and education based social class measure. This relationship was stronger for boys than girls (Östeberg 1992). A further linkage study by Östeberg (Östeberg 1997) of children ages 0-12 years reported higher injury mortality for children in families of manual workers, self-employed persons and farmers than non-manual workers. The highest mortality was for children of farmers and children from unemployed households (greater than two-fold higher risk of injury mortality). There was no effect modification by sex.

Another Swedish record linkage cohort study of children less than 15 years at the 1985 census were followed up for injury mortality (unintentional and intentional) from 1991 to 1995 (Hjern and Bremberg 2002). The age at death ranged from 5 years to 25 years; 13.6% of deaths were under 15 years of age. The occupation of the head of the household was used as measure of social class: the odds ratio for the lowest social class compared to the highest was 1.3 (95% CI 1.1 – 1.6, adjusted for sex, rurality and year of birth), and remained unchanged when additionally adjusting for maternal country of birth, family situation, and parental risk factors (imprisonment, alcohol and drug admissions, psychiatric admissions). The attributable risk percent for parental socioeconomic status less than the highest category was calculated to be 13.4% (42.5% for motor traffic injuries) (Hjern and Bremberg 2002).

A large (n=2,661,664) Swedish cross-sectional study (linking data from 15 national registers) on fatal and non-fatal cause-specific child injury mortality (aged 0 to 19 years) was conducted from 1990-94 (Engstrom, Diderichsen et al. 2002). Social class was measured using parental occupation status. Social class differentials tended to increase with increasing age group, with minimal social differential for children aged 0-4 years. There were significant social differentials in traffic injury for all children over 5 years. The greatest absolute and relative social differentials were for traffic injury, particularly for males aged 15-19 years (with greater than 50% excess risk for children of unskilled workers compared to the highest occupational class). Adjusting for parental country of birth, single parent, or receipt of a benefit only slightly reduced the relative risk estimates for traffic injury, the adjusted relative risks by age group: 5-9 years RR 1.36 (95% CI 1.23 – 1.51); 10-14 years RR 1.23 (95% CI 1.14 – 1.34); 15-19 years RR 1.52 (95% CI 1.43 – 1.62). Fall injury did not demonstrate a social differential. No effect modification by sex was detected.

In the Czech Republic, a national record linkage study of unintentional and intentional injury mortality in infants was conducted from 1989 to 1991 (Bobak, Pikhart et al. 2000). Young maternal age, high parity and low maternal education were all associated with injury mortality. The effect of maternal education was strong: OR 3.53 (95% CI 1.45 – 8.56, adjusted for sex, marital status, maternal age, multiplicity, and birth order) for the lowest education group compared to the highest education group.

A series of record linkage studies from the United States have also found education to be inversely related to infant mortality. Research by Scholer et al (Scholer, Hickson et al. 1999) for the period 1985-91 on national infant injury mortality (unintentional and intentional) found strong multivariate associations for maternal age and education (RR 2.22 for <12 years education compared to >=16 years, 95% CI 1.95-2.53, adjusting for maternal age, number of children, ethnicity, marital status, residence, sex, and birth weight). Using a socioeconomic score based on maternal age and education, and number of children, Scholer et al found that from 1978 to 1995 there was no reduction of the socioeconomic differential in 0 to 4 year old injury mortality. For the period 1992-1995, injury differentials actually increased (Scholer, Hickson et al. 1997).

In North Carolina and Washington State from 1968 to 1980, maternal age and education were also inversely related to infant injury mortality (Wicklund, Moss et al. 1984). Brenner et al (Brenner, Overpeck et al. 1999) investigated intentional and unintentional injury mortality for infants from 1983 to 1991. Multivariate analysis showed that infants had at least twice the risk for injury deaths with the following risk factors: low maternal education (odds ratio for <=11 years education compared to 16+ years education, 2.31, 95% CI 2.01-2.66), absent prenatal care, parity >= 2, indigenous ethnicity, and young maternal age. Infants of unmarried mothers experienced 1.55 times the risk of infant death compared to infants of married mothers.

Traffic-related injury

There have also been a number of studies investigating the social gradient in traffic-related injury, particularly from New Zealand and Sweden. Much of our understanding of the social origins of child pedestrian injury comes from the Auckland Child Pedestrian Study (Roberts 1994; Roberts, Norton et al. 1995). This case-control study of child (less than 15 years) pedestrians killed or injured due to a motor vehicle collision for the period January 1992- March 1994 measured socioeconomic position using the Elley Irving occupational class scale. There were 265 eligible cases in total, with a response rate of 97%. The odds ratios of child pedestrian injury for those in social class 6 (lowest) to those in the highest 3 classes was 2.82 (95% CI 1.77-4.51), with a social gradient present. This effect varied by ethnic group, although the confidence interval was wider and included one. For Maori, the odds ratio for social class 6 compared with the highest 3 social classes was 2.05 (95% CI 0.70-6.02); for European, 1.52 (95% CI 0.74-3.15); and for Pacific Island people, 0.81 (95% CI 0.17-3.80) (Roberts 1994). That these odds ratios are all less than the odds ratio of 2.82 found for all ethnic groups suggests that there was substantial confounding by ethnicity. Other univariate analysis showed a strong association with low maternal age (< 25 years compared to reference group >26 years, odds ratio 3.8); car access (odds ratio 2.35 for nil car access compared to car access); sole parent families had an odds ratio of 1.57 compared to other families; and those families with greater than 5 children compared to 2 children or less had odds ratios of 2.90.

When analysed for pedestrian injury on a public road, the investigators found an odds ratio of 2.32 (95% CI 1.40-3.84) for those children in the lowest social class (class 6), 1.32 (95% CI 0.81-2.15) for those in social class 4 and 5, compared to the highest three social classes (Roberts, Norton et al. 1995). When adjusted for confounding variables (ethnicity, car access, traffic volume, speed and curb parking) the odds ratios were 1.56 (95% CI 0.68-3.56) for social class 6 and 1.81 (95% CI 0.87-3.74) for social classes 4 and 5. This implies that there was confounding of the univariate associations, however some of the variables controlled for may also act as pathway variables.

Looking only at driveway-related child pedestrian injuries, the Auckland case control study found a dramatic increase in the risk of death or injury for those children in social class 6 (OR 5.07, 95% CI 1.67-18.36) or social class 4 and 5 (OR 2.26, 95% CI 0.75-8.16) when compared to the highest social classes (Roberts, Norton et al. 1995). When adjusted for age, sex, ethnicity, family type and number of children the odds ratios were 1.60 (95% CI 0.42-6.12) and 1.65 (95% CI 0.50-5.42) respectively, indicating the presence of major confounding. A key finding from this study was an increased risk of 3.50 of injury or death for those children where the play area was not physically separated from the driveway.

Laflamme et al investigated fatal and non-fatal road traffic injury and socioeconomic status (measured using parental occupation and education) in a cross sectional study of 2.2 million Swedish children. For children aged 5 to 19 years there was a significantly increased risk of traffic injury for children of unskilled workers. Little socioeconomic differences were found for 0 to 4 year olds. Socioeconomic differences were most pronounced for 10 to 14 year old bicycle injuries, and 15 to 19 year old vehicle occupants. There was no effect modification by sex (Laflamme and Engstrom 2002).

1.2.5 Other relevant New Zealand evidence

Most of the New Zealand literature on the socioeconomic determinants of childhood injury has come from the NZCMS, or been focused on traffic and pedestrian injury as discussed above. There has also been research into possible causal pathways from social inequalities to injury, particularly focusing on differential exposure to pedestrian risk according to social class (Roberts, Marshall et al. 1992). There is less in the New Zealand literature on the social origins of other types of childhood injury, or injury as a whole. This section will briefly review the other relevant New Zealand literature on the social gradient in child injury, namely, results from the Dunedin Multidisciplinary Child

Development Study (DMCDS), and will conclude with the findings of studies into the differential exposure to pedestrian risk according to social class.

Some of the first New Zealand papers that specifically investigated social gradients in childhood injury (note, morbidity only) were published from the Dunedin Multidisciplinary Child Development Study (Langley, Silva et al. 1980; Langley, Silva et al. 1983). This is a longitudinal study following up a cohort of 1037 children born during a one-year period from April 1972. At age 5 years the children were grouped according to the number of medically attended accidents (nil, one, or more than one). There was no difference by socioeconomic status (measured by the Elley Irving scale, based on paternal occupation), family mobility, or parental education level between the three groups (Langley, Silva et al. 1980).

At age 7 years, the number of medically attended injuries was further analysed by socioeconomic status (Langley, Silva et al. 1983). Using parental education, a housing index and the Elley and Irving socioeconomic index based on paternal occupational to measure socioeconomic position, the authors still found no relationship with injury morbidity. Given the strong associations found between social class and injury found in other studies, these findings are most interesting. There may be good reasons why the DMCDS did not reveal an association between social class and injury: there may be non-differential misclassification bias of socio-economic position (biasing the result towards the null); differential misclassification bias of outcome may occur if the seeking of or ability to pay for medical treatment for injuries varies by social class; or the study may not have been powerful enough to detect an association. The study group is relatively socioeconomically advantaged and under-representative of Māori and Pacific children when compared with the general New Zealand population also potentially limiting generalisability.

Exposure to risk

In an attempt to explain the variation of child pedestrian injury morbidity and mortality by social class, there have been several New Zealand papers investigating the social differentials of exposure to risk for child pedestrian injury. The lack of car access, walking home from school and the greater number of roads crossed that has been found to be associated with low socioeconomic position from the following studies may well be acting as pathway variables in the income-injury association.

One national study using information from a national household travel survey found that children aged 5 to 9 years in the lowest income group crossed 50% more roads than children in middle or high income groups (Roberts, Keall et al. 1994). There was little income effect on children aged 10 to 14 years. Roberts et al (Roberts, Keall et al. 1994) conclude that this increased exposure to risk may explain part of the higher risk of pedestrian injury for children from low socioeconomic households. Of interest, females crossed more roads than males thereby implying that this increased exposure to risk is not mediating the higher risk of pedestrian injury for males (Roberts, Keall et al. 1994).

A survey of 3388 6 and 9 year olds based in Auckland found car ownership to be a key determinant of child pedestrian exposure to risk (Roberts, Norton et al. 1996). The study used car and home ownership as a marker of material deprivation. The findings indicated a higher mean number of streets crossed for those children that live in households that do not own their home or a car. The number of streets crossed varied also by ethnicity, with Māori and Pacific Island children crossing significant more streets than other ethnic groups. Roberts concludes that this differential exposure to risk may be enough to explain the observed socioeconomic differentials in child pedestrian injury.

An earlier survey of 442 Auckland families also showed that children from social class 6 were more likely to walk home from school than the highest three social classes (63.5% and 25.2% respectively). Māori and Pacific Island children were also more likely to walk home (61.2% and 74.6% respectively) compared with European children (29.4%). 78% of children without access to a car walked home from school compared with 36.7% of children with car access. This study reported no variation in parental perception of risk by ethnicity or socioeconomic position. Indeed, for some classes of road, Māori and Pacific Island parents perceived greater hazard than European parents (Roberts and Norton 1994).

1.3 Could an income-injury association be due to confounding?

In understanding the role that income plays in determining injury death, it is important to separately consider the characteristics of other related socioeconomic variables, and to consider how they too may influence child injury mortality. This section will consider those factors (confounding factors) that potentially could lead to a spurious association of income and injury i.e. injury is not associated with a lack of money, but because of other factors that are associated with (and not caused by) low-income. This section will review whether or not the relationships of different socioeconomic variables with the exposure (income) and the outcome (child injury mortality) fulfil criteria for being potential confounders, potential pathway variables, or both. This is an important component of this dissertation as the relationships between these variables are complex, and this dissertation relies upon the accurate characterisation of the 'independent' (or unconfounded) effect of income.

Confounding is simply defined as a 'mixing of effects' (Rothman and Greenland 1998). '*The apparent effect of the exposure of interest is distorted because the effect of an extraneous factor is mistaken for or mixed with the actual exposure effect (which may be null)'* (Rothman and Greenland 1998). Confounding can cause the effect size to be over- or under-estimated and may alter the direction of an effect. There are three characteristics that a factor must display to be a confounder (although the presence of all three characteristics does not necessarily mean that confounding is occurring) (Rothman and Greenland 1998):

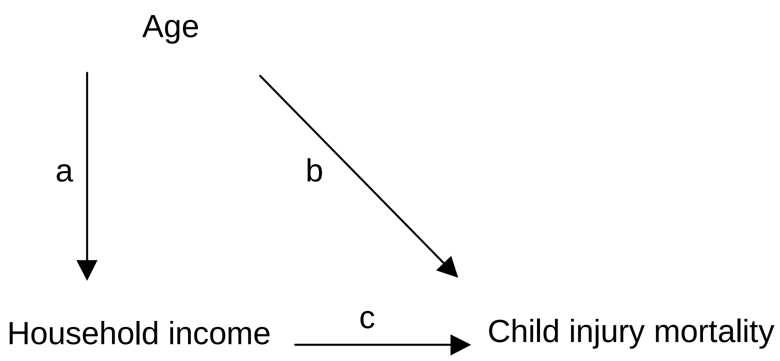
1. A confounding factor must be a risk factor for the outcome
2. A confounding factor must be associated with the exposure under study in the source population
3. A confounding factor must not be affected by the exposure or the disease. It cannot be an intermediary in the causal path between the exposure and the disease.

Effect measure modification means that there is variation in the size an effect of an exposure, if the study population is divided into different categories of another variable, the 'effect modifier'. This is known as heterogeneity (i.e. modification or statistical interaction) of the chosen effect measure (Rothman and Greenland 1998). Effect measure modification is different to confounding (although both may occur) as it is not a bias but a property of the effect that the study aims to characterise (Rothman and Greenland 1998).

1.3.1 Age

The age of the child has an influence on the risk of injury mortality (represented by arrow (b) in Figure 6). Unintentional injury mortality is high over the course of the preschool years up to 4 years (14.0 per 100,000), and reduces in magnitude from the age of 5 years (5.2 per 100,000 for 5 to 9 years; 10.5 per 100,000 for 10 to 14 years), then dramatically increases during adolescence (27.7 per 100,000) (IPRU 2003). Whether or not age is in someway associated with household income will determine if age can be a potential confounder in the income-injury mortality relationship (arrow (a) in Figure 6).

Figure 6: Causal diagram for the effect of age on the income-child injury mortality relationship



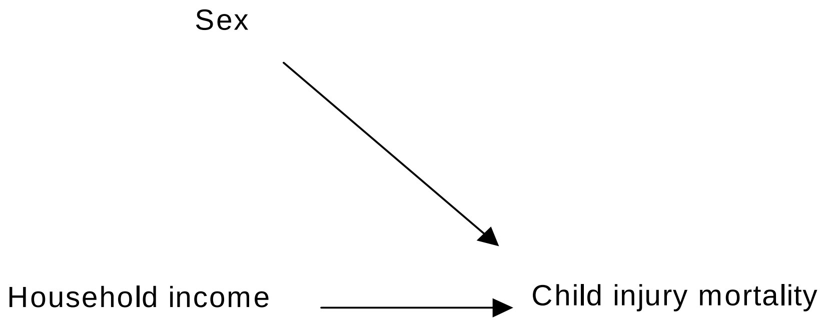
The age of the child will influence the household income level if for instance the age determines parental labour force participation, a key determinant of income. A child of preschool age may exert greater influence as to whether one or two parents reduce hours or cease paid employment for childcare purposes. The age of the child cannot act as an intermediary from income to mortality. A further possible scenario is that a young child may be more likely to have younger parents, who may be earlier on in their career progression therefore commanding lower income.

In summary, without controlling for possible confounding by age, there may be a spurious association between low income and injury mortality. There is also a possibility that age may act as an effect modifier in the income-injury mortality relationship.

1.3.2 Sex

Whilst sex is associated with child injury mortality, with males experiencing a higher risk of injury death (IPRU 2003), the sex of the child is unlikely to have an association with household income. Therefore, in the absence of an association between sex and household income, there should not be confounding by sex. It may be postulated that sex could potentially acts as an effect modifier.

Figure 7: Causal diagram for the effect of sex on the income-child injury mortality relationship

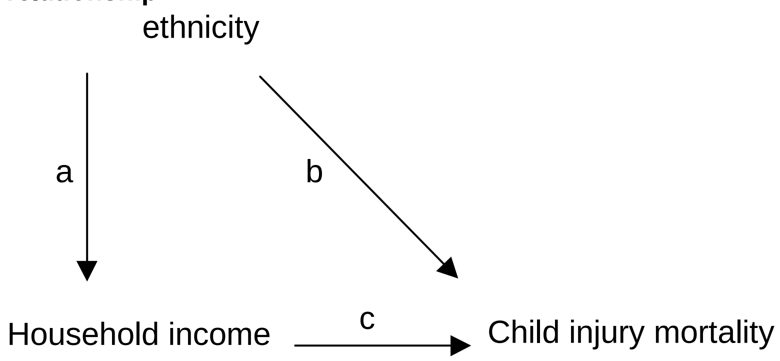


1.3.3 Ethnicity

Whether or not ethnicity is a variable that should or is able to be 'controlled for' is a complex area. Māori children experience a much heavier burden of poverty and of injury mortality (IPRU 2003; Ministry of Social Development 2003). These are serious and complex issues that urgently need to be addressed. The focus of this dissertation is the effect that income has on injury; all analyses will be performed separately by ethnic group to test for effect measure modification. The major part of the modelling exercise of this dissertation is to estimate the effect of eliminating poverty for the total population; this requires the accurate characterisation of the income-injury relationship. It is necessary to consider whether ethnicity could act as a potential confounder. Figure 8 represents this relationship. This dissertation will endeavour to model the impact of eliminating poverty by ethnic groups. This is an intervention that has the potential to reduce ethnic inequalities in injury mortality.

In New Zealand, ethnicity is associated with injury mortality (arrow (b)). Māori children have higher rates of injury mortality (Ajwani, Blakely T et al. 2003). The underlying reasons for this are complex and not yet well characterised; much of the difference may be due to socioeconomic factors. There is an association between ethnicity and income (arrow (a)) (Ministry of Social Development 2003). Māori and Pacific families have lower incomes than non-Māori non-Pacific families, probably due to a number of different factors such as education, labour force status, institutional racism, or differential access to welfare entitlements. Ethnicity will not be an intermediary factor on the pathway from income to mortality. Therefore, ethnicity has the potential to confound the association between income and injury mortality. Ethnicity may also potentially act as an effect modifier.

Figure 8: Causal diagram for the effect of ethnicity on the income-child injury mortality relationship



1.3.4 Labour Force Status

Labour force status is an important variable to consider when studying the effects of income on health. Firstly, there is an association between labour force status and health (Wilson 2000). Secondly, from the 1970s, unemployment has been prevalent in New Zealand, rapidly increasing from 1987 and peaking at 1992, during the time of this study (National Health Committee 1998; Wilson 2000). The burden of unemployment fell heavily on the socioeconomically disadvantaged, young people, and on Māori and Pacific communities (Wilson 2000). Thirdly, labour force status is a determinant of income (National Health Committee 1998).

The association of unemployment with health has been the subject of intense debate for many decades, and there is yet to be a complete characterisation of this relationship. This debate is concerned with the direction of the causal effect, the mechanisms involved, and the effects of confounding. The impact of unemployment on other family members and children has received less attention, but there is evidence suggestive of adverse social and health effects impacting on the wider family (Moser, Fox et al. 1984; Moser, Fox et al. 1986; Olafsson and Svensson 1986). Changes in the increasingly ‘flexible’ labour force market other than unemployment may also influence health, such as the increasing part-time and casual work and job insecurity that has occurred over the 1980-90s.

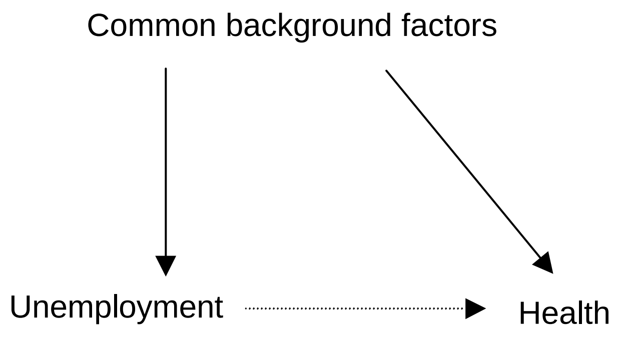
This section will present the evidence surrounding the health effect of unemployment as it applies to adults, as this has been the predominant focus of the literature on unemployment, before concentrating on the health effect of unemployment on children. This will enable a causal diagram to be developed to best represent the relationship between income, labour force status and child injury.

Unemployment and adult health

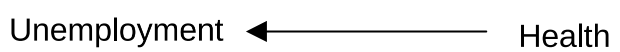
It is now generally accepted that unemployment causes ill-health, with consistent results coming from a number of longitudinal studies (Jin, Shah et al. 1995; Wilson 2000). Widely considered to be a less prominent phenomenon, '**direct health selection'** acts in the reverse direction, whereby ill-health leads to unemployment (Bartley 1994; Bartley 1996). Some authors also argue that an '**indirect selection**' based on prior psychosocial factors (e.g. personality) has been understated (see Figure 9) (Martikainen and Valkonen 1998). If direct health selection were to have a significant effect, one may expect higher mortality rates of the unemployed initially and which then taper. This pattern has not been observed (Montgomery, Bartley et al. 1996; Bartley, Ferrie et al. 1999).

Figure 9: Possible relationships between unemployment and health

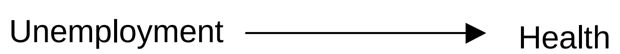
a, Indirect selection (a confounding effect)



b, Direct selection (reverse causation)



c, Causative effect



Returning to the concept of 'indirect selection', prior background factors (e.g. earlier life experience, personality) that may increase the risk of both unemployment and ill-health, independently of each other, may create the appearance of a causal association between unemployment and poor health because of a confounding effect (see Figure 9) (Martikainen 1990; Martikainen and Valkonen 1998; Bartley, Ferrie et al. 1999). Research by Montgomery et al (Montgomery, Cook et al. 1999) using a longitudinal study design, found that the negative effect on mental health from unemployment persisted after adjusting for prior psychological vulnerability (i.e. suggesting that indirect selection does not fully explain the observed association).

There is compelling evidence that unemployment is causally associated with total mortality, poor self-rated health, mental health disorders (anxiety, depression, substance abuse, and suicide), cardio-vascular disease, cancer, and injury (Bartley 1994; Morris, Cook et al. 1994; Blakely, Collings et al. 2003; Jin, Shah et al. 1995; Montgomery, Cook et al. 1999; Martikainen 1990; Moser, Fox et al. 1984). Four potential mechanisms for a causative effect can be postulated (Bartley 1994; Montgomery, Bartley et al. 1996; Bartley, Ferrie et al. 1999; Wilson 2000).

Firstly, the health effect of unemployment is mediated through lower incomes and poverty. Secondly, the social exclusion and psychosocial stress that may result from unemployment can negatively impact on health. Further evidence supporting this mechanism has come from Ferrie et al (Ferrie, Shipley et al. 1995) who present robust evidence indicating the negative self reported health effects of the anticipation of job loss. Thirdly, the health effect is mediated through accumulated disadvantage over the life course, including the experience of unemployment. This includes an effect on the development of human capital (reduced access to continuing education, work experience, and career progression) as a consequence of unemployment. Finally, the health effect may be mediated by an increased risk of negative health-related behaviour due to unemployment. New Zealand data indicates higher rates of smoking and binge drinking amongst unemployed people (Wilson 2000). This mechanism is by no means indisputable as there is conflicting evidence related to the timing of unemployment following the onset health-related behaviour indicating that this effect that may be due to confounding rather than lying on the causal pathway (Bartley 1994; Jin, Shah et al. 1995; Bartley, Ferrie et al. 1999). The negative health effect attributed to the anticipation of job loss described by Ferrie et al, was not related to a change in health-related behaviours (Ferrie, Shipley et al. 1995). It is unlikely that the pathway mediated by health related behaviour plays a principal role (Mathers and Schofield 1998).

Labour force status is also highly correlated with socioeconomic position. Labour force status is therefore a potential candidate for a confounder in the relationship between socioeconomic position and health, and is complicated by the possibility of reverse causation (poor health contributing to unemployment). Further to this, labour force status is also a key determinant of income, potentially complicating the 'control' of confounding by labour force status if the association is very strong.

Unemployment and child health

Whilst there is compelling evidence for a causative effect of unemployment on adult health, there are few studies confirming a causative effect on child health (Olafsson and Svensson 1986). This has been much less researched partly due to the limited quality and amount of data available and the fact that children experience lower mortality rates. In reviewing the family effects of unemployment, Mathers et al (Mathers and Schofield 1998) reports higher levels of: separation and divorce; domestic violence; unwanted pregnancy; perinatal and infant mortality; increased health service utilisation; and poor infant growth.

For 1971, Brennan et al (Brennan and Lancashire 1978) obtained aggregate census data and child mortality rates from each county and borough (excluding London) and found a strong correlation between unemployment and child mortality after controlling for social class. This effect was mainly in children under 2 years of age, and was predominantly due to mortality from respiratory infection. The authors postulate that low income, leading to poor diet and heating, was the likely mediating factor in causing death. Being an ecological level study, conclusions of causality at an individual level should be taken with caution (Piantadosi, Byar et al. 1988).

Olafsson et al (Olafsson and Svensson 1986) reviewed the evidence for unemployment affecting child health. They found that there were a limited number of studies, however there were some reports indicating that children of unemployed fathers were more at risk of hospital admission (all-cause); child abuse; delinquency; and para-suicide. They also found evidence suggesting that as adults, children of unemployed fathers were more likely to experience unemployment themselves (Olafsson and Svensson 1986).

In contrast, the results of the NZCMS analysis of child mortality for 1991-1994 (Blakely, Atkinson et al. 2003), the same dataset used for this study, indicate that following control for socioeconomic position, there is no independent effect of labour force status on all-cause child mortality.

It could be postulated that an increased risk of child injury could be mediated through life-style risk factors (e.g. smoking, binge drinking) that may be associated with unemployment, via mechanisms such as access to matches, reduced supervision and so on. Health and social effects of unemployment (such as mental health disorders, increased stress, family breakdown) are also possible plausible explanations of an independent effect on child injury mortality.

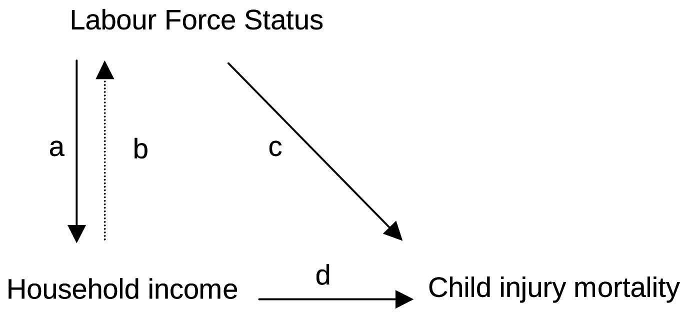
Labour Force Status and the income-child injury mortality relationship

Despite the limited number of studies confirming a causal link, labour force status potentially may have a direct effect on child health (see arrow (c) in Figure 10). There is a relationship between income and labour force status (represented by arrow (a) in Figure 10). If this relationship is predominantly a causal effect of labour force status leading to income, and if these two variables are very closely correlated, then controlling for labour force status may lead to an unreliable statistical analysis. Mathers et al (Mathers and Schofield 1998) report that in Australia, unemployment has been the key driving force in increasing the rate of poverty.

With regards to labour force status as a possible intermediary (arrow (b)) in the relationship between income and mortality, low socioeconomic position (and low income as a component of this) is associated with unemployment. If there is a significant effect of low income causing unemployment (arrow (b)), then controlling for labour force status may underestimate the income-mortality relationship.

Reverse causation is unlikely to be significant for a health outcome such as child injury mortality. It is difficult to postulate how child injury mortality may influence either unemployment or household income.

Figure 10: Causal diagram for the effect of labour force status on the income-child injury mortality relationship



In summary, labour force status fulfils the criteria for being a confounder but is complicated by its possible intermediary role, and by its possible close correlation with income. These issues, particularly how separable the two variables are, will be explored further in the results section.

1.3.5 Small Area Deprivation

The term 'small area deprivation' in this study is used to describe relative disadvantage at an area or group level (Salmond, Crampton et al. 1998). An area level measure of deprivation can enable the assessment of the contextual effects of a neighbourhood on health, or be used as an easily obtained measure of socioeconomic position when there is limited individual-level data available (Salmond and Crampton 2000). Relative disadvantage may vary in its depth, and be material or social in nature. Internationally there has been development of composite indices using census-derived variables, to best represent this disadvantage at a group level. The NZCMS uses the New Zealand specific tool NZDep91 (or NZDep96) to assess small area deprivation.

The NZDep91 index calculates the deprivation level of a small aggregation of approximately 100 people (based on Statistics New Zealand's smallest geographical unit, the meshbolck) (Salmond, Crampton et al. 1998). Seven dimensions of deprivation are represented by ten weighted variables, standardized for age and sex: one-parent family; receipt of a means-tested benefit; low household income; nil car access; nil qualifications; unemployed; separated or divorced aged 18 to 59 years; separated or divorced aged over 60; not in owned home; and household crowding. Household crowding and household income were equivalised according to household size (Salmond, Crampton et al. 1998). The NZDep91 index has values from 1(least deprived) to 10(most deprived), and has been validated (Salmond, Crampton et al. 1998).

It is important to consider the extent that a composite index such as NZDep91 represents a true contextual area level effect, or a summation of individual level effects (Salmond, Crampton et al. 1998). To what extent does the NZDep91 index measure the sum effect of individual socioeconomic position? The NZCMS suggests that at least half, and probably greater than this (due to our limited ability to fully capture individual socioeconomic position), the effect of small area deprivation is due to individual socioeconomic position (Blakely and Pearce 2002). Blakely et al (Blakely and Pearce 2002) suggest that area level effects are likely to be important, but less so compared with socioeconomic effects at an individual level. Supporting this position, in their analysis of the higher mortality in deprived areas the United Kingdom Office of Population Censuses and Surveys' longitudinal study found that personal socioeconomic position fully accounted for mortality differentials between electoral wards (Sloggett and Joshi 1994). It may be that census derived area based measures do not fully capture the deprivation of an area.

In their New Zealand analysis of deprivation and health, Salmond et al (Salmond and Crampton 2000) argue that the strength and consistency of the associations of high deprivation score with poor health indicate causality at both individual and contextual level. In reviewing models of smoking behaviour, Salmond et al (Salmond and Crampton 2001) concluded that for smoking there was a definite contextual effect at a neighbourhood level. The authors extrapolated that this is likely to be true for other health outcomes. Research in Britain and the USA using area level deprivation measures also suggests that there is evidence supporting the existence of a contextual effect (Krieger 1992).

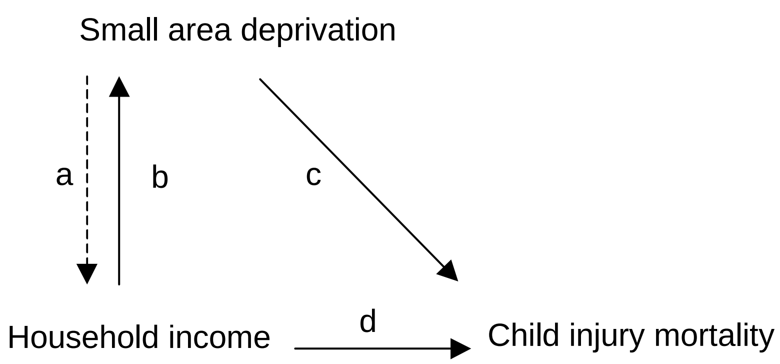
It is also important to note that an individual's neighbourhood deprivation level indicated by NZDep has a weak correlation with that individual's socioeconomic position (Salmond and Crampton 2001). Not all people who experience socioeconomic disadvantage live in deprived neighbourhoods (Blakely and Pearce 2002). When used as a proxy for individual socioeconomic position there is therefore a significant risk of measurement error. There are also limitations in inferring causal relations at an individual level on the basis of aggregated data (Piantadosi, Byar et al. 1988; Krieger 1992).

A further critique of the use of census-derived area measures has been the time lag between the particular census used to develop the area measure of deprivation, and when the study data is collected (Geronimus and Bound 1998). The NZDep91 measure used in this analysis was derived from the same census as used for our study population, and the follow-up period being limited to three years minimises the possible effect of changing small area characteristics over time. It has also been debated in the literature that the way in which areas are aggregated may or may not influence the observed effects (Krieger 1992; Geronimus and Bound 1998). Aggregations of smaller size (such as NZDep91) may be more homogenous than larger groups, however decreasing size may be accompanied by greater statistical limitations.

Small area deprivation and the income-child injury mortality relationship

Figure 11 represents the possible relationships between NZDep91, household income and child injury mortality. The preceding discussion contends that there may be an area level effect on health, although it is difficult to disentangle the individual socioeconomic effects from those genuine contextual effects. In considering child injury mortality, neighbourhood effects over and above individual level socioeconomic effects may well play a role.

Figure 11: Causal diagram for the effect of NZDep91 on the income-child injury mortality relationship



Characteristics of a neighbourhood may influence the likelihood of injury in a number of possible ways. Roberts et al (Roberts, Norton et al. 1995) have presented compelling evidence of the local environment increasing the risk of child pedestrian injury, through factors such as increased exposure to high volume traffic, high density curb parking, and increased traffic speed (see also Chapter 2, section 1.2.5). Neighbourhoods experiencing deprivation may have less exposure to traffic calming mechanisms or pedestrian crossings. Other possible mechanisms for arrow (c) may also be increased exposure to environmental water hazards, and a lack of safe playing areas (both in the availability and quality of playgrounds). These postulated mechanisms are material in nature, however it is possible that a small area effect may be socially mediated. Examples may include the characteristics of local schools and early childhood education centres, for example, whether there is a culture promoting safety; it is also possible to speculate that the level of social capital of a neighbourhood may also influence child injury mortality, although the relationship between small area deprivation and social capital is complex and requires further characterisation.

To fulfil the criteria to be a potential confounder in this relationship, NZDep91 should also be associated with household income (arrow (a)). NZDep91 is correlated with individual socioeconomic position (and therefore income), however, this relationship is complicated by a possible intermediary pathway represented by arrow (b). The level of household income almost certainly has an effect in determining one's area of residence. Controlling for confounding by NZDep91 may then underestimate the causal effect of income on child injury mortality by excluding the effect mediated via small area deprivation. The net effect of arrows (a) and (b) may well be negligible, or even dominated by arrow (b). There is unlikely to be reverse causation from child injury mortality to household income, or for NZDep91.

In summary, whether NZDep91 may be a potential confounder is complicated by its possibly substantial intermediary role between income and child injury mortality. Further to this, is the nature of the measure of NZDep91. I have pointed out that it may predominantly reflect individual level socioeconomic position rather than a contextual effect. That the measure is derived from two variables reflecting income (receipt of a means tested benefit, and household income) may also contribute to an underestimate of the true effect of income on child injury mortality if NZDep91 is included in the same model as income.

1.3.6 Education

It has been well established that educational attainment is inversely related to mortality, risk factors, and poor self-reported health measures (Wilson 2000). Education is an important and commonly used marker of socioeconomic position because it is reasonably easily measured; it is generally fixed by early adulthood (limiting concerns of reverse-causation) and can be assigned to most people (Liberatos, Link et al. 1988; Lynch and Kaplan 2000). It is also important to note that educational achievement may have different 'social meanings and consequences at different time periods and in different cultures' (Lynch and Kaplan 2000), for example, the economic benefits from education may be less for women and for some ethnic groups (Lynch and Kaplan 2000).

Education may be associated with health via three different pathways, all of which are likely to be important (Liberatos, Link et al. 1988; Lynch and Kaplan 2000). Firstly, education may directly influence health through its effect on individual behaviour. This may be mediated directly via health-related behaviours, but also potentially through more subtle means, such as behaviours related to the way in which the future is perceived, attitudes and beliefs that may influence health, or the degree of perceived control one has over life circumstances that education may bring. Education may 'provide a set of cognitive resources that have broad potential to influence health' (page 22 Lynch and Kaplan 2000). Secondly, education may influence health by being a precursor to future success, for example, higher educational attainment is associated with higher income earning potential and occupational status, and better living and working conditions, although this may vary over time (page 22 Lynch and Kaplan 2000; Liberatos, Link et al. 1988). Thirdly, education may also act as a marker of socioeconomic position or ranking, and may particularly capture life-course effects of advantage or disadvantage from childhood.

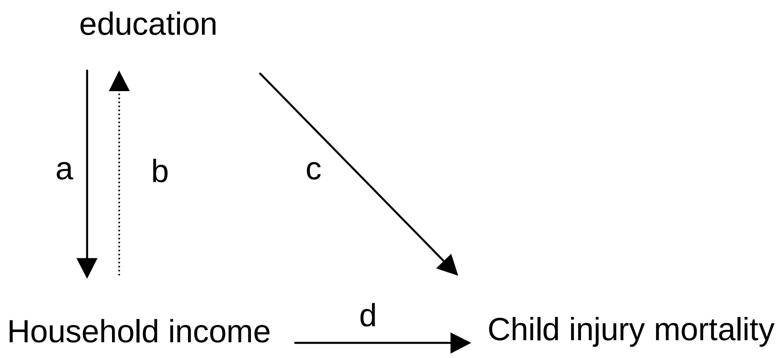
Education and the income-child injury mortality relationship

The variable of highest household education level is a strong contender as a potential confounder in the income-injury mortality relationship as Figure 12 illustrates. Education is likely to have an independent effect on child injury mortality (arrow (c)). Reverse causation from child injury mortality to household education (arrow (d)) is unlikely.

The association represented by arrow (a) is likely to reflect a causal relationship between education and income, but also it may represent an association of the two variables due to common prior background factors that influence both educational achievement and income level. In the reverse direction (arrow (b)), education is unlikely to have a strong effect as an intermediary between household income and injury mortality. It is likely that the household education level would be predominantly established prior to that of the household income variable.

In summary, household education fulfils the criteria for the characteristics of a potential confounder.

Figure 12: Causal diagram for the effect of education on the income-child injury mortality relationship

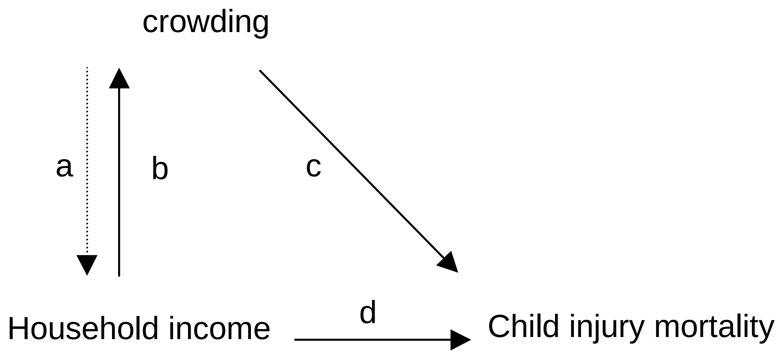


1.3.7 Crowding

There is little research on crowding and injury mortality separate to the effects of socioeconomic disadvantage (Gray 2001). It is plausible that overcrowded living conditions may be associated with injury mortality (see Figure 13 arrow (c)). For example, overcrowding may exert an effect by the increased demands and stress placed on caregivers when providing supervision. Another example may be by reducing the availability of safe equipment or other resources, such as in providing safe sleeping arrangements.

Figure 13 illustrates the relationships between crowding, household income, and child injury mortality. The predominant relationship in Figure 13 is likely to be a causal relationship between household income and crowding (arrow (b)). Household income is a determinant of the affordability of appropriate housing (Howden-Chapman and Wilson 2000). Crowding is therefore likely to be a significant intermediary in the household income and child injury mortality relationship. If crowding is controlled for, the total impact of income on child injury mortality is likely to be underestimated.

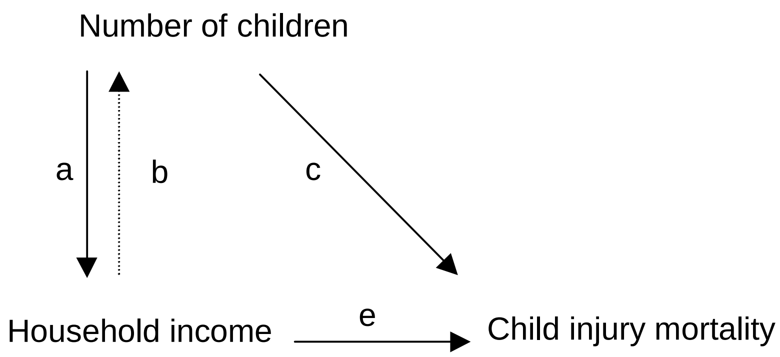
Figure 13: Causal diagram for the effect of crowding on the income-child injury mortality relationship



1.3.8 Number of children

The variable 'number of children' may meet the requirements necessary to be a confounder. Firstly, household income and the number of children are associated - the higher the number of children the lower the household income (arrow (a) in Figure 14) (Mowbray 2001; Ministry of Social Development 2003). There is unlikely to be a significant effect of arrow (b), where the number of children acts as an intermediary from household income to injury. Secondly, the number of children in a household may influence their risk of child injury mortality. One mechanism may be the greater demands placed on caregivers with greater numbers of children to supervise.

Figure 14: Causal diagram for the effect of the number of children on the income-child injury mortality relationship



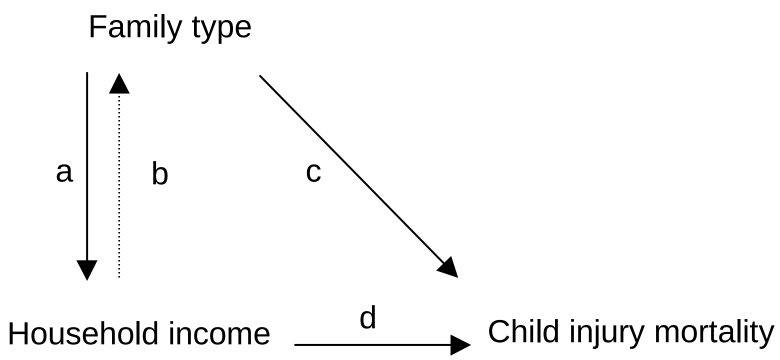
However controlling for the number of children may be problematic in this analysis because calculating the equivalised household income to ensure comparability of purchasing power necessitates an adjustment for the number of children (as well as adults) in the household.

In summary, whilst the number of children may fulfil the requirements for being a potential confounder, this is partly controlled for in the household income equivalisation procedure. For this dissertation, the number of children will not be included in multivariate analysis.

1.3.9 Family Type

Figure 15 represents the relationship between family type, household income and child injury mortality. There is a strong association between family type and household income (see arrow (a)). The proportion of one-parent families earning less than 60% of the median income (net of housing costs) was 60% compared to 17.5% for two-parent families (Ministry of Social Development 2003). One-parent families are over-represented in low-income groups and are more likely to be reliant on a welfare benefit. There is potentially a relationship between family type and child injury mortality (arrow (c)), although this relationship is not well-defined. Earlier results from the NZCMS on all-cause child mortality suggest that the modest effect of one-parent families is mediated by socioeconomic position, and not from an independent effect of one-parent families. Multivariate analyses for unintentional injury found a small increase in risk for children from one-parent families, but this was not statistically significant (RR 1.2, 95% confidence interval 0.7 to 2.2) (Blakely, Atkinson et al. 2003).

Figure 15: Causal diagram for the effect of family type on the income-child injury mortality relationship

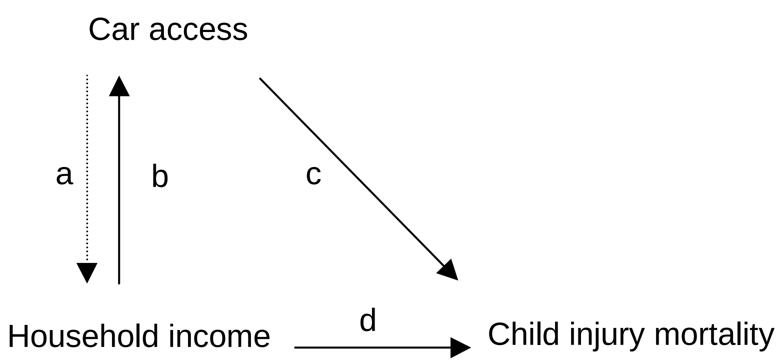


It may be postulated that arrow (b) exists if low-income families are more likely to experience family breakdown as a consequence of financial hardship. This intermediary pathway between household income and injury mortality is likely to be very small, the predominant direction of the relationship between family type and household income is most likely to be represented by arrow (a). Therefore, family type may fulfil the requirements necessary to be a potential confounder.

1.3.10 Car access

The variable car access is both a measure of asset wealth, and a measure of access to community resources. Figure 16 illustrates how this variable may relate to the income-injury mortality relationship.

Figure 16: Causal diagram for the effect of car access on the income-child injury mortality relationship



In Figure 16, the direction from income to car access indicated by arrow (b) is likely to be the prevailing force in the relationship. Income is an important determinant of car ownership. Therefore, car access is likely to play a significant intermediary role in this relationship. Car access may be on the pathway from income to injury mortality, and as such, to control for car access may lead to an underestimate of the effect of income on injury. It may be useful to investigate what proportion of the effect of income is mediated by access to a car, however, this is not the main purpose of this dissertation. There may also be an association between car access and income (arrow (a)), but this is unlikely to be substantial. There may be a causal relationship mediated via labour force status, whereby employment is dependent on the ability to access a private motor vehicle. There may be other reasons for such an association that are not causal, such as a common background factor that influences both car access and income.

With regards to arrow (c), access to a car is likely to affect injury mortality although this relationship may be rather complicated. An important postulated causal mechanism is that a lack of car access may influence injury mortality through increased exposure to pedestrian injury. Conversely, the lack of access to a car may reduce exposure to occupant motor vehicle injury. Car access also reflects access to health services, for example, well-child services (which includes injury-related health promotion services), in addition to being a general marker of socioeconomic position. The direct use of a car in accessing health services related to an acute and life-threatening injury is unlikely to have a significant impact on mortality, as most serious injuries would necessitate the use of emergency services.

In summary, whilst car access may have an independent effect on injury mortality, it is probably predominantly an intermediary variable in the income-injury mortality relationship.

1.3.11 Occupational Class

Occupational class is a commonly used indicator of socioeconomic position, and is consistently associated with health status. Occupational class may influence health through an economic dimension (income); the social prestige or social ranking associated with one's occupation; or from particular occupational exposures (Daly, Duncan et al. 2002). The major disadvantage of occupational class is that not all members of a population can be assigned an occupational class category, for instance, young mothers (Daly, Duncan et al. 2002).

The 1991 census collected only current occupational class, the ascertainment of female occupational class in this cohort has been particularly problematic. Many families with children, such as one-parent families, will not be able to be assigned an occupational class variable. Of the 1991 female cohort, 39.6% of 25-44 year olds, and 50.6% of 45-64 year olds were not assigned an occupational class variable (Blakely 2001).

Occupational class may act as a confounder in the income-injury association. It is clearly associated with income; it may have an independent effect on injury, and it is not a pathway variable. Therefore, the income-injury association potentially could be overestimated by not adjusting for the effect of occupational class.

Chapter 3: Methodology

This chapter is in two parts. Firstly, the characterisation of the income-injury association is possible using the NZCMS. Secondly, the modelling of the impact of eliminating child poverty is based on concepts of population attributable risk, using methodology developed for the WHO Global Burden of Disease Study (Comparative Risk Assessment).

1 The New Zealand Census-Mortality Study

The data for this dissertation is obtained from the NZCMS, which has been well described elsewhere (Blakely 2001; Fawcett, Blakely et al. 2002; Hill, Blakely et al. 2002). This section will present a synopsis of the methodology.

The primary objective of the NZCMS is to determine the relationship of socioeconomic variables with mortality for the entire New Zealand population, by linking census records to mortality records for the 3 years following the census. This dissertation is conducted as a retrospective cohort study, linking 1991 census data to 1991-1994 child injury mortality data.

A population census occurs five yearly as per Section 23 of the Statistics Act 1975. The census population is representative of the New Zealand population due to the high response rate. Although the exact response rate cannot be calculated, a Post Enumeration Survey for the 1996 census estimated that 1.2% of the population were not counted on that census night (Ewing 1997). It is reasonable to assume that the magnitude of undercounting should be similar for the 1991 census. The undercount varied according to demographic group: 1.4% of males and 1.0% of females were not counted; 2.9% of Maori, 3.1% of Pacific peoples, and 0.8% of New Zealand Europeans were undercounted; for the child population (age 0 to 14 years) it was estimated to be 1.4%; and there were regional variations (ranging from 0.8% to 1.3%). The magnitude of the undercount is small, and unlikely to impair the representative nature of the census population. It may lead to a small variation in record linkage success between different demographic groups if a decedent had not completed the census and therefore the mortality record could not be linked.

The exposures and co-variates able to be assessed from the 1991 census data are: age; sex; ethnicity; household income; education; labour force status; car access; housing tenure; small area deprivation; marital status; and receipt of a sickness benefit.

1.1 The exposure and other variables

1.1.1 The exposure: Income

The income measure used in this dissertation is the total equivalised gross household income (for further discussion see page 33). Each household member is accorded the same income measurement. The 1991 definition of a household is '*a group of persons, whether related or not, who live together and who normally consume at least one meal together daily or at least share cooking facilities*'. Approximately three-quarters of households consisted of one family, with the remainder made up of single person or non-family multi-person households (Blakely 2001).

Personal income was assessed in the 1991 census by the question: 'What will be your total income, including income support, before tax for the year ended 31 March 1991?'. Respondents were to include income from all sources, such as wages, salary and commission, business or farming income (less expenses), accident compensation payments, interest, dividends, rent, superannuation, and pension payments. It is important to note that this question relies on accurate recall, and does not necessarily measure *usual* income. The available options on the census form were:

- Nil income or loss
- $2,500 or less per year
- $2,501 to $5,000 per year
- $5,01 to $10,000 per year
- $10,001 to $15,000 per year
- $15,001 to $20,000 per year
- $20,001 to $25,000 per year
- $25,001 to $30,000 per year
- $30,001 to $40,000 per year
- $40,001 to $50,000 per year
- $50,001 to $70,000 per year
- $70,001 and over per year

Household income was calculated by the sum of personal incomes (using the midpoint income for each category, and the value of $99,300 for the top income category) within the household. The household income value derived from this process was then re-categorised according to the same income categories as for personal income.

The household income was then equivalised according to the Luxembourg Income Study (LIS) equivalence scale. The LIS equivalence procedure simply divides the household income by the square root of the number of household members (irrespective of the age of the household members) (Statistics New Zealand 1999). The LIS equivalence scale was chosen over a New Zealand specific model (for instance, the 1988 Revised Jensen Index, which also takes into account the ages of children), in part for simplicity, but also because it is used internationally to help enable consistent and comparable equivalisation methods. Relative to the revised Jensen Index, the LIS equivalence scale assigns a lower income to households with many children (as children and adults receive the same weight on the LIS equivalence scale) (Statistics New Zealand 1999). The equivalisation calculation used the midpoint of each household income category, based on the data from the 1991 Household Economic Survey (Blakely 2001).

Once each total household income had been equivalised, it was categorised according to its position on the income hierarchy compared to the *total* population median equivalised household income. This method of categorisation was used (as opposed to an income value) for the purpose of the modelling procedure of eliminating poverty, described in the next section. The median income is commonly used to describe the income distribution and to measure poverty as opposed to the mean income, as it corresponds to the income of the middle person in the income distribution and is not affected by outlier values. The mean income will always be a higher value than the median because of the effect of the skewed income distribution to the right (Saunders and Smeeding 2002).

There were two methods of categorising the income for the study participants. The seven-income categorisation, described below, was used for the analyses including the total study population, and for the modelling. This number of categories was chosen to minimise the effect of potential small numbers from too many categories, but to enable adequate characterisation of the income-mortality effect particularly for the lowest income groups where it is most important. Six income categories were used for analyses that were conducted separately by demographic strata.

Table 2: Income categorization (6-level and 7-level income categories)

6 Income Categories	7 Income Categories
• <40% median equivalised household income	• <40% median equivalised household income
• >=40% to <50%	• >=40% to <50%
• >=50% to <60%	• >=50% to <60%
• >=60% to <80%	• >=60% to <80%
• >=80% to <Median	• >=80% to <Median
• >= median	• >=median to <150%
	• >=150% median

In summary, it can be seen that the income measurement used in this dissertation may be prone to misclassification. The income value derived from the census questionnaire is based on the answer to one question, which is likely to be less accurate than multiple questions assessing different sources of income. It does not measure usual income and does not capture average income over time. The value is categorised and assigned the midpoint income value of that category. A further limitation is in the ability to accurately define higher income households, whereby the highest category able to be derived from the census is limited to >$70,000 for individuals. Lastly, whilst it is important to equivalise household incomes, it will not perfectly adjust for the variable living standards based upon the size of the household, and may potentially introduce some misclassification.

1.1.2 Eligibility criteria and covariates: age, sex, ethnicity, residence and dwelling type

Individuals could only be assigned appropriate household socioeconomic variables if they resided in a private dwelling (i.e a house, flat, or caravan), and were at their usual residence on census night. Absentee individuals could not be linked back to their usual residence and could not be included in the analyses. Individuals residing in non-private dwellings such as hospitals, motels, boarding houses and so on, were also excluded from the analyses. For the purpose of this dissertation, households must have had at least one adult greater than or equal to 18 years of age.

Households without a valid equivalised household income were excluded from the study. Income was the most common household variable to not have been responded to on the census form. Because of the importance of the multivariable analyses in determining the independent effect of income on mortality, households that were missing any of the covariates required for the multivariable analyses were also excluded.

All analyses were conducted on children aged 0 to 14 years on the night of the census. Within this age range, children were categorized into one of 4 age bands for the analyses to allow adjustment for potential confounding, and to test for effect modification:

- 0 to <1 year
- >= 1 to 4 years
- >= 5 to 9 years
- >= 10 to 14 years

Univariable analyses were conducted separately by sex to test for effect modification. As discussed earlier (see page 55) because sex cannot be a confounder, all further analyses pooled sexes.

Analyses were performed separately by ethnic group, and for the total population analyses, ethnicity was included in the analyses as a potential confounder. Ethnicity was determined in the 1991 census by the following question: 'Which ethnic group do you belong to? (*tick the box or boxes which apply to you)'.* The boxes were: New Zealand European, New Zealand Maori, Samoan, Cook Island Maori, Tongan, Niuean, Chinese, Indian, and Other (please state). The NZCMS uses the SNZ classification for ethnicity:

- New Zealand Māori ethnic group (the New Zealand Māori box ticked as one of the self-identified ethnic groups)
- Pacific Island ethnic group (any Pacific Island group self-identified; but not where also self-identified as New Zealand Māori box)
- Non-Māori non-Pacific ethnic group (all other ethnic groups other than New Zealand Māori and Pacific Island; respondents not specifying an ethnic group were classified in the Non-Māori non-Pacific category)

1.1.3 Education

The 1991 census personal questionnaire contained two questions on educational achievement:

1. 'What is your highest school qualification?'. The available answer options were mutually exclusive:
   - No school qualification
   - School Certificate in one or more subjects
   - Sixth Form Certificate or University Entrance in one or more subjects
   - Higher School Certificate or Higher Leaving Certificate
   - University Bursary or Scholarship
   - Overseas qualification
   - Other School qualification (please state).
2. 'What educational or job qualifications have you obtained since leaving school?'. One could select greater than one of the available answers:
   - No qualifications since leaving school
   - Still at school
   - Trade Certificate
   - Nursing Certificate or Diploma
   - Technicians Certificate
   - Teachers Certificate or Diploma
   - University Certificate or Diploma below Bachelor level
   - Bachelors degree
   - Postgraduate Degree, Certificate or Diploma
   - Other qualifications

Each child in the household was assigned an educational variable corresponding to the highest educational qualification of the adults in the household. This was ranked into the following hierarchical order:

- Tertiary (e.g university degree, nursing)
- Trade (e.g. technical certificates)
- School (any school-based qualification)
- Nil qualification

1.1.4 Family Type

Family type was assessed by one question from the personal questionnaire: 'Who are the persons that usually live in the same dwelling as you? (Include children and babies)'. Multiple answers were possible: my father/mother; my husband/wife; my partner; my sons/daughters; my brothers/sisters; other related persons; other persons; or 'I live alone'. Each child was assigned into one of two categories of family type:

- One-parent
- Other (including two-parent)

1.1.5 Labour Force Status

The 1991 census personal questionnaire included a series of questions to assess labour force status. If the answer to the first question, 'Do you work in a job, business, farm or profession?' was yes, the number of hours was assessed. If the answer was no, respondents were asked three further questions:

- 'Did you look for paid work in the last four weeks' – with answers being either no, yes (full-time work, >= 30 hours per week), or yes (part-time work, <30 hours per week).
- 'What methods did you use to look for paid work?' – with five possible answers available.
- 'If a job had been available, would you have started last week?' – yes or no.

Statistics New Zealand then assigned each individual into one of the following categories:

1. Employed full-time
2. Employed part-time
3. Unemployed and actively seeking full-time work
4. Unemployed and actively seeking part-time work
5. Not working, seeking work but not available for work
6. Not working, available for work but not seeking work
7. Not working, not seeking work nor available for work.

The household labour force variable assigned to each child in this dissertation used the following classification based on the above:

- Employed: if one or more adults in the household were employed (part- or full-time).
- Unemployed: if one or more adults in the household were unemployed and actively seeking work (full- or part-time) and no adult was employed.
- Non-active labour force: not working and not available for work or not seeking work (includes retirees, homemakers, students, and those permanently sick).

1.1.6 Car Access

This variable was ascertained from the dwelling questionnaire completed by the occupier, 'How many motor vehicles are available for private use by persons in this dwelling?'. Motorcycles and scooters were not included. A household car access variable was assigned to each child, and was determined using the following categories:

- Nil cars
- 1 car
- >= 2 cars

1.1.7 Crowding

Household crowding was measured in the 1991 census from the dwelling questionnaire. The number of people per bedroom was derived from the question 'How many rooms are there in this dwelling?', with a space to fill in the number of bedrooms, and the number of 'other rooms'. The number of people (including babies) present at the dwelling was also recorded. The categorization used in this dissertation is:

- < 1 person per bedroom
- >1<=1.5 person per bedroom
- >1.5<=2 people per bedroom
- >=2 people per bedroom

1.1.8 Neighbourhood Deprivation

This variable was discussed in detail on page 61. Briefly, this is an area measure (of approximately 100 people) according to the distribution of several socioeconomic factors, enabling each area to be ranked into one of ten deciles of ascending deprivation (NZDep 1 is the least deprived decile; NZDep 10 is the most deprived). From the address provided on the census form (using the meshblock code), each child was assigned into a decile of neighbourhood socioeconomic deprivation based on the New Zealand Index of Deprivation (NZDep91), and for the purposes of this dissertation, then classified into quintiles:

- NZDep deciles 1 & 2 (least deprived)
- NZDep deciles 3 & 4
- NZDep deciles 5 & 6
- NZDep deciles 7 & 8
- NZDep deciles 9 & 10 (most deprived)

1.2 The Outcome: Injury Mortality

Injury mortality records for the three years following the 1991 census (5 March 1991 to 5 March 1994) were obtained from New Zealand Health Information Services (NZHIS) National Minimum Data Set (NMDS), and were linked back to the census records. Only those mortality records for decedents that were alive on the night of the census were included (i.e. babies born after census night that died of injury during the three year follow-up period were excluded).

Unintentional injury is the outcome of interest for this dissertation, and was classified as a dichotomous occurrence. Death from intentional injuries and those of undetermined intent were not included. Adverse effects of medical care and medications are also not included. All analyses were conducted on unintentional injury as a single grouping, and not separately by different mechanisms of injury, because of small cell size. This dissertation used the classification of external cause of injury (E codes) from the International Classification of Diseases (ICD-9) system:

Unintentional injury	800-949
Road traffic crash	810-825
Other unintentional	800-809, 826-949

For descriptive purposes, the specific mechanisms of injury were grouped according to the framework developed by the Centres for Disease Control (National Center for Injury Prevention and Control) (see Appendix 1) (Centres for Disease Control 1997).

1.3 The Follow-up: Record Linkage

The linkage of mortality records and census records is a complex and crucial step in the NZCMS and has been discussed in much detail elsewhere (Blakely, Salmond et al. 2000;

Blakely 2001; Fawcett, Blakely et al. 2002; Hill, Blakely et al. 2002). A brief overview of the record linkage process, and the weighting procedure that was used for all analyses to mitigate the impact of linkage bias will follow. For greater detail of these complex processes, please refer to the publications referred to above.

The record linkage process was conducted by SNZ for the NZCMS using anonymous data (there were no names or text addresses), under the provisions of the 1975 Statistics Act. The linkage procedure was conducted probabilistically using a commercial software package, Automatch (Version 4.2, MatchWare Technologies, 1998). The aim of the linkage procedure is to link as many records as possible as accurately as possible.

The probabilistic record linkage involves comparing variables on both the mortality and census records to test for accordance. The matching variables used were: geocodes (meshblock and Census area unit based on the address of usual residence), sex, ethnic group, country of birth, and date of birth (disaggregated to day, month, and year of birth). The mortality records could provide multiple recordings of some of the matching variables, increasing the linkage success possible. This is because the National Health Index file and the death registration form were linked, increasing the yield of variables available (the NHI data is collected by hospital clerks prior to death, whereas the death registration is completed by funeral directors). This is particularly important for the ethnic group and geocode variables.

Because both the mortality and census datasets are large, a '*blocking'* procedure was utilised to increase efficiency. Comparisons between *matching variables* only occurred following a successful match of a specified variable, such as the geocode (in this case the initial blocking variable is the meshblock i.e. the smallest geographical area coded by SNZ, median of 90-100 individuals). Depending on the significance of a particular matching variable, a relative *weighting* is assigned (for example, a match for sex is assigned less significance than agreement on the NHI number). For each matching variable, the weighting requires the specification of the probability of agreement on a matching variable when the pair are a correct match (the *m probability,* related to the accuracy of the data*);* and the probability of disagreement on a matching variable when the pair are not a true match i.e. the probability of agreement purely by chance) (the *u probability*). For each pair of records (census and mortality) a total weight is assigned on the basis of the individual weights for each matching variable. This total weight indicates the relative probability of whether or not there is a true link between the census and mortality record.

At the completion of the linkage process, there were three files: a successfully linked census-mortality record file, a residual census file (unlinked), and a residual mortality file (unlinked). The majority of census records were not linked, as death is an uncommon event for children (the outcome in this case is classified as alive). Overall, for the total NZCMS 1991 census-mortality linkage process, there was a high degree of linkage accuracy i.e. the positive predictive value was over 98% (the percentage of census-mortality pairs that are a true match).

Overall, 67% of the 1991 child mortality records were successfully linked (Blakely, Salmond et al. 2000). The 33% of mortality records that were not linked would have the outcome classified as alive, when in fact, the individual had died. For the mortality records that were not linked, there were several variables present on the mortality file that could be used to assess whether successful linkage varied according to different demographic strata and regions i.e. linkage bias. Linkage bias is therefore 'differential misclassification bias of the mortality outcome' (Fawcett, Blakely et al. 2002).

Detailed work on the NZCMS for 0 to 75 year olds has quantified according to age, sex, ethnicity, NZDep, and region, the extent of linkage bias that is present. This was then used to develop a weighting procedure (not to be confused with the weighting allocated to matching variables in the Automatch linkage process) to appropriately adjust the number of linked mortality records to represent the true number of deaths, thus compensating for linkage bias. The weighting procedure has been validated (Fawcett, Blakely et al. 2002).

Mortality records were stratified according to sex, age, ethnicity, NZDep91, region and cause of death. For children, there was little linkage bias by age and sex, but there was some variation by ethnicity (57% of Maori, 71% of Pacific, and 71% of the remaining mortality records were linked) and small area deprivation. For the same strata on the census cohort dataset, the number of linked deaths was multiplied by the inverse of the proportion of deaths successfully linked. For example, if 20 out of 30 injury deaths for

Māori boys living in a NZDep 10 area were linked to a census record, the 20 linked deaths were assigned a weight of 1.5 (30/20) so that the number of deaths represented the actual number of deaths. Unlinked census records were weighted down to allow for the fact that some of these unlinked census records did belong to a decedent. This dissertation used the weight W_AgEthAdj. For more information on this procedure, please refer to the NZCMS technical report number 5 (Fawcett, Blakely et al. 2002; Blakely, Atkinson et al. 2003).

1.4 Cohort Study Data Analysis

All analyses were performed on the restricted study cohort (i.e. with complete data). To explore potential selection bias, the education and NZDep91 association with injury mortality was compared between the eligible cohort (i.e. at usual residence, private dwelling, and adult present in the household) and the study cohort. Analyses were conducted in SAS v8.0 using logistic regression. All analyses were conducted on the unweighted and weighted study cohort datasets (to determine the extent of linkage bias). The majority of results presented in this dissertation, and the modelling procedure use the weighted cohort dataset. The highest income category is used as the reference group.

Analyses were also conducted separately by strata of age, sex, ethnicity, and labour force status to test for effect modification of the income-injury association. Effect measure modification, i.e. heterogeneity of odds ratios across strata, was tested formally by two methods. First, the slopes of the income-injury association by strata were compared using linear regression (SAS v8.0). The median household income for each income category was the independent variable, and the outcome variable was either the odds ratio (testing for additive effect modification) or the natural logarithmic odds ratio (testing for multiplicative effect modification). Second, the general form of the Wald statistic (see page 275 of (Rothman and Greenland 1998)) was used to test for homogeneity of odds ratios across strata.

Univariable analyses included the crude and age-adjusted income-injury association. The multivariate analyses initially explored the effect of adjusting for age plus one other socioeconomic variable. The analyses then were based on three models derived from the theoretical discussion on confounding in Chapter 2. These three models are for the purpose of providing an indication of the effect that different relative risk estimates may have on the results of the modelling procedure:

- Age-adjusted - (which may over-estimate the income-injury association due to residual confounding).
- 'Preferred model' - age, ethnicity, education, family type, and labour force status (the best model on the basis of theoretical assumptions).
- 'Intermediaries model'- age, ethnicity, education, family type, and labour force status plus potential pathway variables: car access, crowding, and NZDep91 (which may under-estimate the effect of income, by eliminating the effect mediated through some pathway variables).

2 Modelling the impact of changing income

The aims of this dissertation are to determine the independent effect of household income on child injury mortality and to then seek the answer to the question 'how much reduction in child injury mortality would result had child poverty not existed'? This goal is provocative for policy-makers, and is challenging for researchers by the need to formulate models based on causal associations (rather than just crude associations).

The framework used in the modelling component of this dissertation is based on a methodology used for the second round of the World Health Organization Global Burden of Disease (GBD) Study, Comparative Risk Assessment (CRA) (WHO Comparative Risk Assessment Working Group 2000). This is a revised, systematic method of evaluating the global burden of disease and injury caused by a number of population exposures or risk factors with the aim to identify important intervention points for improving public health.

The concept of 'attributable fraction' refers to the proportion of disease that would be eliminated if the total population had been unexposed. This assumes that it is possible for the total population to be unexposed. The term 'attributable burden' extends this approach, and is defined as '*the reduction in the current burden that would have been observed if past exposure levels had changed to an alternative distribution of exposure'* (Murray and Lopez 1999). This alternative distribution is referred to as a counterfactual distribution. The term 'counterfactual' refers to the fact that the alternative circumstances are contrary to fact i.e. the cohort in this dissertation was exposed to a particular distribution of income; any other imagined income distribution is therefore counterfactual (Rothman and Greenland 1998). A counterfactual distribution of exposure is useful for continuous risk factor-disease relationships, as opposed to a dichotomous approach of being either exposed or unexposed (WHO Comparative Risk Assessment Working Group 2000).

Using CRA terminology, the attributable burden of injury due to a particular exposure is estimated using potential impact fractions (PIF), defined as: *the proportional reduction in the total number of new (incident) cases of a certain disease, resulting from a specific change in the distribution of a risk factor in the population at risk* (WHO Comparative Risk Assessment Working Group 2000). The major determinant of variation between populations in the attributable burden due to a particular exposure is the difference in the distribution of exposure levels, as opposed to different relative risk functions (Murray and Lopez 1999).

The three data inputs are required to determine the PIF (WHO Comparative Risk Assessment Working Group 2000):

1 Exposure level – current, as well as counterfactual distributions of exposure i.e. income.
2 Exposure-outcome relationships – i.e. the association of income and child injury mortality.
3 Outcome data - current and projected i.e. injury mortality.

2.1 Choosing counterfactual income distributions

To model what might be the reduction in child injury mortality if child poverty was eliminated this dissertation requires the observed (1991) distribution of income and the observed association of income and child injury mortality, to estimate what might have been the reduction in injury mortality had the income distribution been different. A *counterfactual* distribution of income is required.

There is a range of potential counterfactual scenarios that may be utilised, particularly so when analysing an alternative distribution for household income. Most international research demonstrates a gradient effect of income, i.e. each increase in income is associated with an increase in health. There is no clear threshold above which everyone has minimal risk that can be used as a counterfactual scenario. It is unrealistic to place the total population in the highest income band. Consequently, the choice of an alternative income distribution is somewhat arbitrary.

Murray and Lopez (Murray and Lopez 1999) have explored four options when choosing a counterfactual distribution of exposure:

1. Theoretical minimum risk – the distribution of exposure with the lowest associated population risk. This category assumes that the whole population has the same level of minimum possible exposure, for example, the entire population has the highest income, and in many cases such as in this dissertation, is an implausible scenario.
2. Plausible minimum risk – an imaginable or possible, but not necessarily a likely or feasible, distribution of minimum exposure. It is implied that this distribution could exist in some real population. In this dissertation, the elimination of child poverty is imaginable and possible. Zero child poverty is also one of the stated goals of government policy (Ministry of Social Development 2002).
3. Feasible minimum risk – an exposure distribution of minimum risk that has actually existed or exists in a particular population. An example of this option for this dissertation is to have child poverty levels equal to that in the country with the lowest child poverty (Sweden, 2.6% prevalence of poverty).
4. Cost-effective minimum risk – this is context dependent, and is the minimum risk distribution obtained through the implementation of all cost-effective interventions.

Murray and Lopez (WHO Comparative Risk Assessment Working Group 2000) have recommended that the counterfactual distribution of exposure be based on plausible minimum risk. This is based on the observation that a theoretical minimum risk counterfactual distribution may be unlikely to ever occur in reality, therefore potentially limiting its usefulness for policy-makers.

For income, the theoretical minimum risk distribution of exposure is clearly an implausible scenario. The aim of eliminating child poverty is a goal that is possible, particularly as it is clearly stated government policy. This will be the basis of the counterfactual modelling in this dissertation.

2.2 Elimination of childhood poverty – four counterfactual models

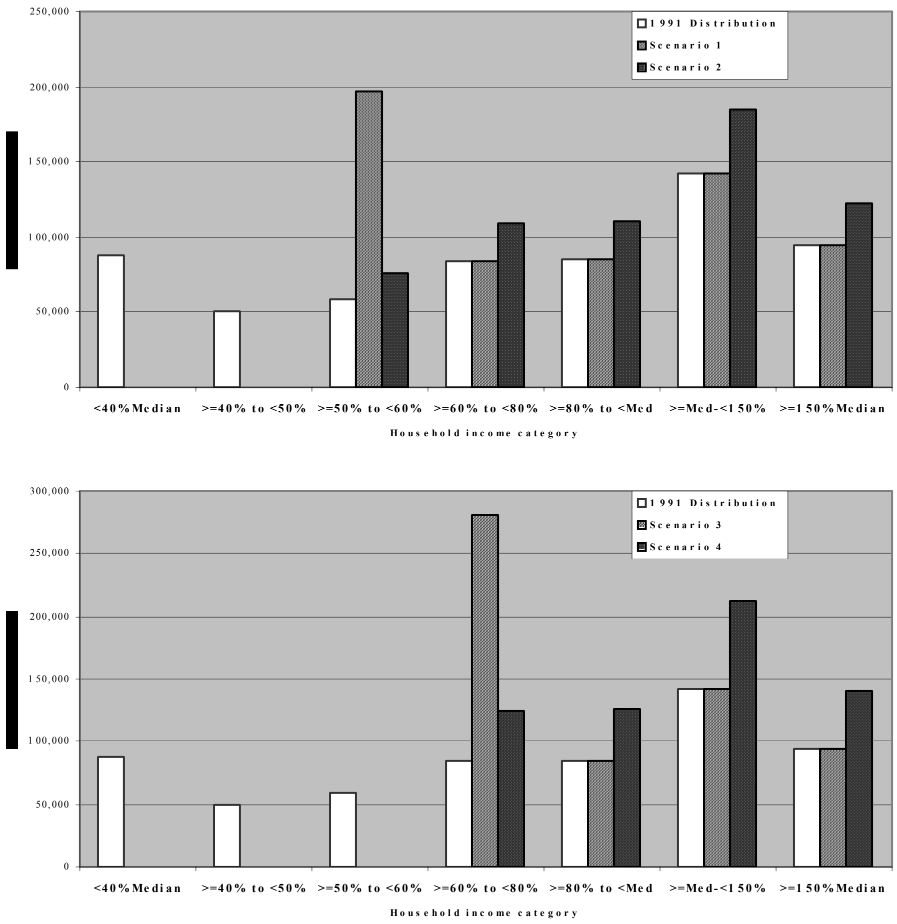
Using the observed 1991 income distribution for children, Figure 17 graphically illustrates potentially achievable alternative income distributions for children that will be used as counterfactual distributions in this modelling exercise.

Four scenarios are depictured depending on the chosen income threshold, and how the changed income is distributed. For this modelling exercise, two income thresholds are used: <50% and <60% of the median household income respectively. This is because there is no clearly defined threshold for poverty, but internationally, <50% of the median income is commonly used as the poverty threshold; and in New Zealand the use of <60% of median income is often used as a poverty threshold. This dissertation will explore the impact of using both poverty thresholds.

This dissertation does not specify how the increased income is to occur. It may be most likely that policies will increase incomes to the poorest households, thereby lifting these households to just above the determined poverty line. This will be one counterfactual scenario. However, increasing incomes is complex, and may also involve changing the incomes of households just above the poverty line or in other income categories. This dissertation will therefore also model increasing income by distributing it proportionately over the other income categories. It may be that the redistribution of income to eliminate child poverty falls somewhere between these scenarios.

One additional counterfactual scenario will be presented when modelling the counterfactual scenarios by ethnicity: that Māori and Pacific children experience the same income distribution as Non-Māori non-Pacific children.

Figure 17: 1991 household income distributions for children, and for 4 alternate counterfactual scenarios



COUNTERFACTUAL SCENARIOS OF HOUSEHOLD INCOME

Scenario 1

[<50% of median] income groups to increase income to [>=50% to 60%] category.

Scenario 2

[<50% of median] income groups to increase income, evenly distributed to other income groups.

Scenario 3

[<60% of median] income groups to increase income to [>=60% to <80%] category.

Scenario 4

[<60% of median] income groups to increase income, evenly distributed to other income groups.

2.3 Potential impact fractions

The measure of the impact that a counterfactual income distribution may have on injury mortality used in this dissertation is the 'Potential impact fraction' (or 'PIF'). The PIF estimates the proportional reduction of child injury resulting from the change in the distribution of income from the observed to the counterfactual income distribution, and is determined using the distribution of the exposure (household income in this case) and the relative risk of the outcome (injury mortality) per exposure category. The formula is (WHO Comparative Risk Assessment Working Group 2000):

$$\text{Potential Impact Fraction} = \frac{\Sigma P_x RR_x - \Sigma P_x' RR_x}{\Sigma P_x RR_x}$$

Where:

P_x = proportion of the population in exposure category x as observed

P_x'= proportion of the population in exposure category x as per counterfactual scenario

RR_x= relative risk for exposure level x compared to reference category

The observed distribution of household income for children in 1991 is as accurate as is possible given the quality of the available census-derived household income variable and the effect of the equivalisation procedure. There is potential for misclassification of household income, however this cannot be easily quantified. The effect from the choice of equivalisation procedure can be assessed, but was beyond the scope of this dissertation.

The second component of calculating the PIF is reliant on an accurate assessment of the relative risk of injury mortality for each income category. The complexities of estimating the effect of income independent of confounding have been discussed in Chapter 2. To respond to the uncertainty surrounding the estimates of relative risk, the modelling uses three sets of estimates as discussed on page 82:

- Age-adjusted, possibly overestimating the effect sizes due to uncontrolled confounding.
- The 'preferred' model (adjusting for age, ethnicity, education, family type and labour force status).

- The ‘intermediaries’ model, possibly underestimating the effect sizes (the preferred model plus car access, crowding and NZDep91).

The CRA Interim Guidelines also recommend that there should be a systematic assessment of the likelihood of causality in the risk factor-disease relationship. This dissertation has aimed to identify the causal effect of income on injury mortality. Considering how the income-injury relationship meets the Bradford-Hill criteria may also be useful in assessing causality, although there are few studies that investigate the causal effect of income on child injury mortality. The most useful standards for assessing causality are (WHO Comparative Risk Assessment Working Group 2000):

Temporality: In this dissertation income precedes injury.

Strength: Other studies, although small in number, support a reasonably strong relationship, even after adjusting for confounding.

Consistency: There have been repeated observations in different populations under different circumstances that show a relationship between income and injury.

Biologic gradient: There is evidence of a dose-response curve.

Plausibility: There is biologic plausibility of the income-injury relationship

Experimental evidence: There have been no experiments to investigate the income-injury association.

Chapter 4: Results

1 The demographics of the study population

There were 806 463 children aged 0 to 14 years enumerated in the 1991census count. This total child cohort contained 222 linked injury deaths and 330 weighted injury deaths. Table 3 presents each step in the restriction of the total cohort to create the study population used in this dissertation, and the corresponding number of linked and weighted injury deaths.

Table 3 : Number of census respondents and number of linked and weighted injury deaths for the total child population aged 0-14 years at time of census and for each level of restriction to study population

Cohort description	n	% Total cohort	Number (%) of linked injury deaths	Weighted number (%) of injury deaths
Total 0-14 yrs census cohort	806 463	100%	222 (100%)	330 (100%)
At usual residence and private dwelling	742 644	92.1%	213 (95.9%)	318 (96.4%)
With adult present in household (*eligible* cohort)	742 386	92.1%	213 (95.9%)	318 (96.4%)
Excluding those with missing data†	727 770	90.2%	210 (94.6%)	312 (94.6%)
With LIS household income variable present*	603 219	74.8%	165 (74.3%)	243 (73.6%)

† Valid household education, family type, labour force status, car access, NZDep91 level, and crowding variable present.
* Referred to as the ***study*** cohort (includes at usual residence and private dwelling, adult in household, and excluding those with missing data).
Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol

To ensure that the appropriate household variables were obtained for each child, only children living in their usual residence were included. Absentee children (i.e. children away from home on census night) could not be linked back to their usual household. Similarly, children that were living in non-private dwellings, such as hospitals were also excluded. This resulted in 742 644 children, or 92.1% of the total cohort that could be assigned valid household variables.

The additional restriction of including those households with an adult > 18 years old was required to ensure valid and comparable household income data were obtained for all study participants. The total household income calculation required a valid personal income variable for all adults aged 18 years and above. Therefore households that were headed by a young person aged less than 18 years were not able to be included. This restriction made little impact on the size of the cohort and the corresponding injury deaths.

At this point, our eligible cohort population contains 742 386 children (92.1% of the total census cohort). The study population was required to have a valid equivalised household income. Equivalised household income was the variable most often missing from the records of the eligible cohort. There was relatively little additional loss due to other missing variables; therefore, the study population (603 219 children; 81.3% of the eligible population) consisted of those children with a valid equivalised household income and the complete data required for the multivariable analyses (education, family type, car access, crowding, labour force status, and NZDep91 level). The study population corresponded to 165 linked injury deaths and 243 weighted injury deaths (73.6% of total weighted injury deaths).

Table 4 describes the demographic composition and the distribution of injury deaths (weighted) for the eligible cohort and the study cohort. The demographic distribution of injury deaths will be discussed in more detail in section 3 (page 102).

Table 4 : Distribution of children and weighted injury deaths by demographic strata for the eligible cohort (usual residence, private dwelling, and adults in household) and for the study cohort

Demographic Variable	Eligible Cohort			Study Cohort		
	n (Total=742 386)	% Total	Weighted deaths (n=318)	n (Total=603 219)	% Total	Weighted deaths (n=243)
Age at census						
<1 yr	54 852	7.4	36	42 888	7.1	24
1-4 yrs	208 527	28.1	81	165 375	27.4	66
5-9 yrs	242 853	32.7	60	198 243	32.9	39
10-14 yrs	236 154	31.8	138	196 710	32.6	117
Sex						
Female	363 870	49.0	117	295 374	49.0	87
Male	378 519	51.0	198	307 845	51.0	159
Ethnicity						
Maori	150 738	20.3	93	119 331	19.8	66
Pacific	51 504	6.9	27	35 457	5.9	12
Non-M Non-P	540 147	72.8	201	448 431	74.3	162
NZDep91 Quintile	n=741 777					
1 (least deprived)	141 732	19.1	39	117 246	19.4	24
2	138 945	18.7	48	114 864	19.0	39
3	136 719	18.4	48	112 818	18.7	42
4	142 971	19.3	75	116 373	19.3	66
5 (most deprived)	181 410	24.5	108	141 912	23.5	75
Education	n=737 925					
Tertiary	222 453	30.1	72	189 627	31.4	60
Trade	205 605	27.9	72	167 307	27.7	63
School	163 449	22.1	72	131 409	21.8	45
Nil	146 418	19.8	99	114 873	19.0	78
Labour Force Status	n=741 708					
Employed	576 819	77.8	216	474 483	78.7	165
Unemployed	54 876	7.4	39	45 069	7.5	30
Non-active Labour force	110 013	14.8	63	83 670	13.9	48

Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol

Infants less than one year of age were included as a separate category due to the unique characteristics of this group compared to other age groups. This age group is therefore substantially smaller than all other age groups.

One fifth of children were of prioritised Māori ethnicity, and 6% were of Pacific Island ethnicity. The population distribution by NZdep91 quintile shows that there were disproportionately more children (almost one quarter of the population) living in the most deprived two NZDep91 groups than the general population.

1.1 Selection Bias

For this study, it is difficult to predict the extent that selection bias will affect the observed effect of household income on injury mortality. This is because it is not possible to determine the association between income and injury mortality for the population of children that were excluded (excluded usually because of a missing household income variable). However, it is possible to gain some insight, although not definitive, into whether selection bias possibly may be present.

It is feasible to observe the difference in effect size seen for the study cohort when compared to the total eligible cohort when using an exposure that is usually available for children from both groups, such as the NZDep91 or household education variable (see Table 5). There appears to be some variation in the effect size between the eligible cohort and the study cohort, particularly for NZDep91 (the study cohort displays larger effect sizes). There was minimal difference for education. However, this may not necessarily indicate selection bias when income is the exposure of interest.

Whilst it is difficult to quantify the effect of selection bias, it can be of interest to inspect the distribution of demographic features for the eligible cohort and for the study cohort (seeTable 4). The distribution of covariates is similar for both groups. There is a slight under-representation of Māori and Pacific children, preschool children, and of households with nil adult education or of non-active labour force households. The most likely impact of this could be when calculating population attributable risks by underestimating the proportion of the population in low-income groups.

Table 5: Age-adjusted odds ratios (95% confidence interval) for injury mortality by education and NZDep91 for the eligible population and the study population

	Eligible population	Study population
Education	N=737 925	N=603,219
Tertiary	1	1
Trade	1.07 (0.78-1.49)	1.15 (0.80-1.64)
School	1.30 (0.94-1.81)	1.11 (0.76-1.64)
Nil	2.05 (1.51-2.77)	2.11 (1.50-2.96)
NZ Deprivation	N=741 780	N=603,219
Dep1&2 (least deprived)	1	1
Dep3&4	1.34 (0.87-2.06)	1.63 (0.98-2.74)
Dep5&6	1.41 (0.92-2.17)	1.82 (1.10-3.03)
Dep7&8	2.00 (1.35-2.98)	2.88 (1.80-4.61)
Dep9&10 (most deprived)	2.38 (1.64-3.47)	2.68 (1.68-4.25)

Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol, odds ratios calculated using exact data

2 The pattern of income distribution

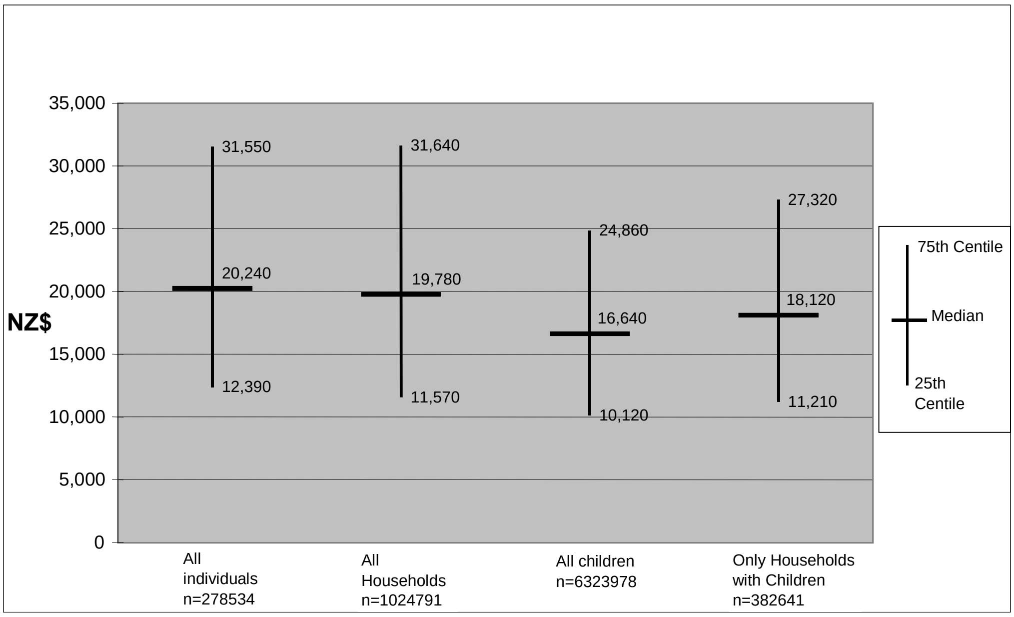
To calculate the exposure levels of household income in this dissertation, the median equivalised household income from the total number of households enumerated at the 1991 census is used as a benchmark. Figure 18 graphically illustrates the distribution of equivalised household income for each population of interest (note that all individuals and all households with a valid household income measure were included in this representation). There are two key messages from this diagram.

Firstly, the income distribution of children is substantially lower (an 18% lower median income) than that for all individuals. A more dramatic decrease is seen when comparing the 75th centile equivalised household income for each group; there is 21% lower value for children than for all individuals. There is a corresponding decrease in income distribution seen when comparing all households with only those households containing children although it is less marked in magnitude than for individuals.

Secondly, the household income distribution for individual children is notably lower than that of only the households with children (i.e. each household income counted only once). This may indicate, as one may expect, that those households with a greater number of children are more likely to be at the lower end of the equivalised income distribution. Households with a higher number of children are more likely to be poorer. This effect has been observed in other New Zealand studies of income ((Mowbray 2001; Ministry of Social Development 2003)) and internationally (Ridge 2002)p25.

The choice of equivalence scale might to some extent, influence the distribution of household income, particularly influencing the relative position of some population sub-groups. For instance, the LIS scale places one-adult and one-parent households lower in the income distribution than the 1988 Revised Jensen Scale. For other household compositions (two-parent plus children) there is much less variation on the relative position in the income distribution between both equivalence scales (Statistics New Zealand 1999). The clustering of households with children at the bottom of the income distribution has been observed in other work (Mowbray 2001), and this pattern has also been observed in the distribution of living standards in New Zealand (Krishnan, Jensen et al. 2002). For the same time period as this dissertation, Mowbray (Mowbray 2001) found the same pattern using the Revised Jensen equivalence scale which may underestimate the position of households with children (by according a lower weight to children). Whilst equivalisation may exert some influence on the distribution of household income, there is likely to be a true association between household income and the presence of children within the household.

Figure 18: Equivalised* household income distribution for the 1991 census population (usual resident and private dwellings): for individuals; households; children, and only households with children



*LIS equivalisation procedure. All individuals and households with a valid equivalised income were included.

Table 6 provides more detail on the distribution of household income by percentile income group for only households with children, and for all children. The use of seven income groups gives more definition to the spread of income, and will be used in the majority of analyses. Combining the highest two income categories (the six income grouping) to form a larger reference group, is for the purpose of increasing the stability of analyses by demographic strata where cell-sizes are smaller.

Table 6 : Equivalised household income distribution for 603 219 children (aged 0-14 years at census) and their households, expressed as percentile groupings of median LIS equivalised household income for all census dwellings

Income group (% median HH income)	Number of households	Number of children	Median Household income per category (1991 NZ$)
7 income groups	n=382 644	n=603 219	
<40% Median	44 496	88 392	6 189
>=40% - <50%	31 017	50 127	8 721
>=50% - <60%	32 346	58 680	10 620
>=60% - <80%	48 357	84 300	14 091
>=80% - <Med	50 643	84 774	17 700
>=Med -<150%	96 981	142 458	23 262
>=150%Median	78 804	94 488	38 361
6 income groups			
<40% Median	44 496	88 392	6 189
>=40% - <50%	31 017	50 127	8 721
>=50% - <60%	32 346	58 680	10 620
>=60% - <80%	48 354	84 300	14 091
>=80% - <Med	50 643	84 774	17 700
>=Med	175 782	236 949	27 318

Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol

The most striking finding in Table 6 is the high number of children in the lowest income group, those living in households earning less than 40% of the New Zealand median equivalised household income. 88,392 children or 15% of participating children (in 44,496 households) are in this category. The median equivalised household income for this group is NZ$6,189 (1991 dollars).

When considering the numbers of children in households earning less than 60% of the median household income, close to 200,000 (33% of study participants) are in these low-income groups. This is comparable to other estimates of child poverty in New Zealand that have used different poverty measures (Ministry of Social Development 2002; Ministry of Social Development 2003). Of the children in households earning <60% of the median household income, the majority are actually at the bottom end of the income distribution, under <40% of the median income. This description indicates not only the extent of the numbers of children living in relative poverty, but that the depth of poverty is profound. Only 40% of children lived in households earning greater than the median household income.

Consistent with the income pattern seen in Figure 18, the ratio of the number of children to the number of households tends to decrease with each step of increasing income. In the lowest income group the ratio of children to household is 2.0, and this decreases to 1.5 and 1.2 in the second to highest and highest income categories, respectively.

2.1 Distribution of Income and Covariates

The patterns of income distribution for children by demographic strata are presented in Table 7. The accompanying figures visually present the income distribution for some demographic strata of particular interest.

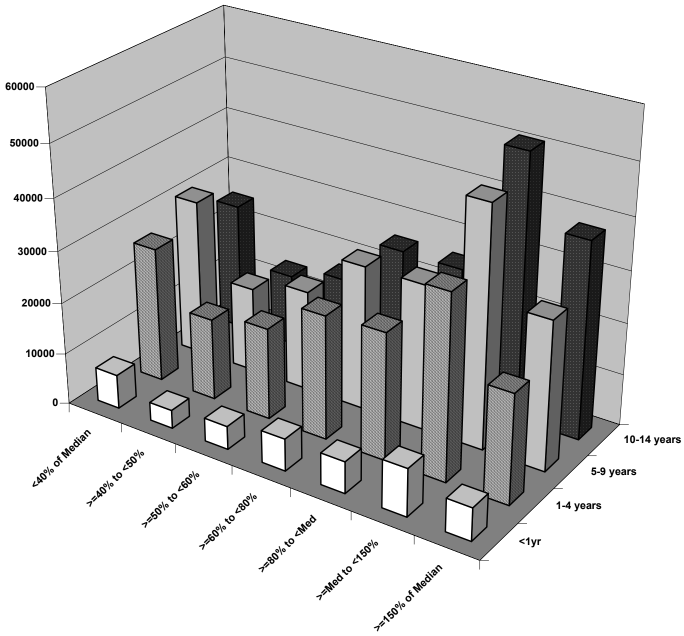
Table 7 : Number of children aged 0 to 14 years old per equivalised household income group by age, sex, ethnicity, labour force status, NZ Deprivation level and education

	Equivalised Household Income Level						
	<40% of Median	>=40% to <50%	>=50% to <60%	>=60% to <80%	>=80% to <Median	>=Median to <150%	>=150% of Median
Age at census							
< 1 yr	6 633	3 612	4 545	6 273	6 180	9 273	6 372
1-4 yrs	26 220	15 867	17 799	24 021	24 594	35 703	21 168
5-9 yrs	30 561	16 614	19 593	28 056	28 110	46 473	28 836
10-14 yrs	24 975	14 034	16 743	25 947	25 890	51 009	38 112
Sex							
Male	45 012	25 647	29 820	43 005	43 407	72 594	48 357
Female	43 377	24 483	28 857	41 292	41 367	69 864	46 134
Ethnicity							
Maori	32 571	14 718	14 553	18 234	13 773	18 108	7 374
Pacific	10 104	4 419	4 200	5 811	4 044	5 058	1 821
Non-M Non-P	45 711	30 990	39 924	60 255	66 957	119 295	85 293
Labour Force							
Employed	25 428	23 277	40 749	71 439	79 839	139 839	93 906
Unemployed	16 929	9 879	7 845	6 270	2 649	1 329	171
Non-labour force	46 032	16 971	10 083	6 588	2 286	1 293	411
NZ Dep91 Level							
Dep 1&2	4 512	3 108	5 829	10 887	15 339	37 800	39 771
Dep 3&4	8 967	6 264	9 714	15 363	18 357	33 300	22 902
Dep 5&6	12 855	8 754	11 664	17 301	18 135	28 725	15 381
Dep 7&8	19 611	12 201	13 677	18 939	17 058	24 306	10 584
Dep 9&10	42 441	19 803	17 793	21 810	15 885	18 327	5 853
Education							
Tertiary	10 779	7 701	10 824	18 900	25 341	59 184	56 895
Trade	15 957	12 081	17 217	27 426	29 364	44 298	20 961
School	21 240	13 059	15 378	20 997	19 512	27 780	13 446
Nil	40 410	17 286	15 258	16 974	10 560	11 196	3 186

Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol

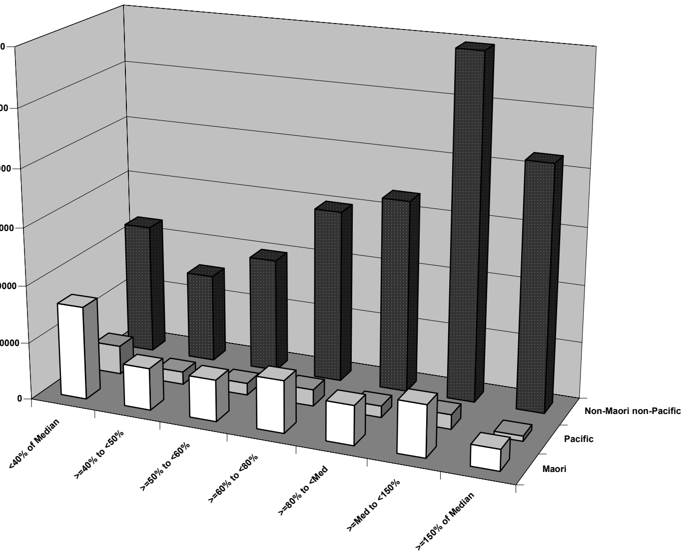
Figure 19 illustrates that there is not a strong correlation between age and income, although there is a tendency for older children (especially 10 to 14 year olds) to have higher household incomes. The pattern between the sex of the child and household income was impressive for the consistent proportion of each sex for each income group, confirming our theoretical supposition that sex cannot be a confounding variable.

Figure 19: Population distribution by equivalised household income category and age



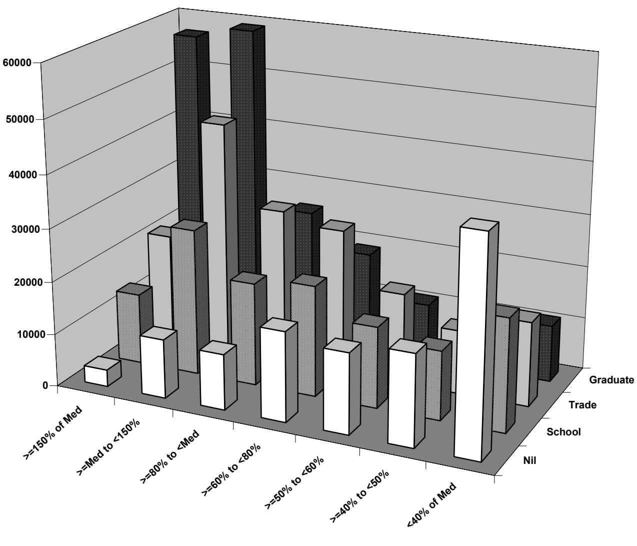
The variation of income by ethnic group is represented in Figure 20. There is a strikingly different pattern seen for non-Māori non-Pacific children when compared to Māori and Pacific Island children, a pattern consistent with other work describing the variation of NZDep by ethnicity (Salmond and Crampton 2000). Whilst there are greater proportions of non-Māori non-Pacific children in higher income groups, this is not the case for Māori and Pacific children. For these two population groups there is more of an even pattern across most income groups, but most notably and importantly, by far the highest proportion of these children are in the lowest income group (<40% of median income), and there are much fewer in the highest income category. 52% of Māori and 53% of Pacific children were living in households earning below 60% of the median household income, compared to 26% for non-Māori non-Pacific.

Figure 20: Population distribution by equivalised household income category and ethnicity



By education, there is a reasonably strong correlation between the highest household education level and the household income (see Figure 21)[7]. Most children living in graduate households were in the top two income categories. Those households with an adult with a trade qualification were also generally skewed towards the higher income groups. By contrast, the major proportion of children from those households with nil adult education was in the lowest income group.

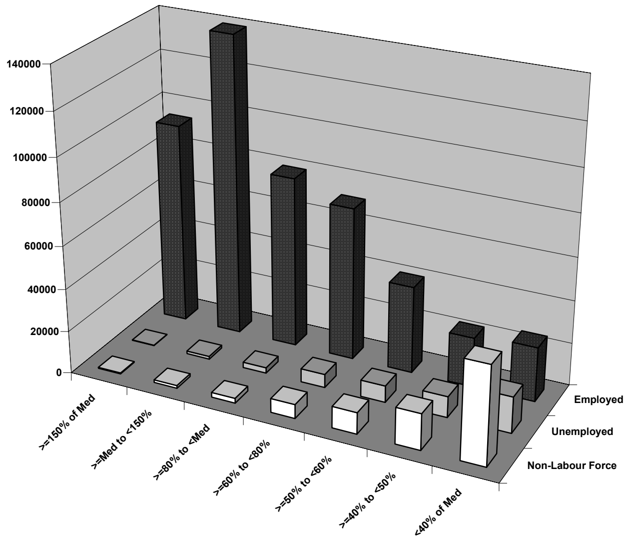
Figure 21: Population distribution by equivalised household income category and education



[7] Note that for ease of interpretation the income axis has been reversed in this graph compared to Figure 19 and Figure 20.

Of all the demographic characteristics, by the far the most extreme pattern is seen for labour force status (see Figure 22[3]). Labour force status is therefore highly correlated with income in this study population. There are very few children from unemployed or non-active labour force households that are in the top three income categories. The highest proportion for both these groups is seen in the lowest income category. This very dramatic pattern may be problematic when adjusting for labour force status in the regression analyses, but clearly, if labour force status is independently associated with the risk of injury death, there is potential for significant confounding. This will be discussed further in section 4.2, and some analyses will be restricted to employed households only.

Figure 22: Population distribution by equivalised household income category and labour force status



3 Observed injury mortality 1991-94

This section will describe the patterns seen in child injury mortality for the three-year period following the 1991 census night. The information presented here is derived from injury mortality records only (i.e using the NMDS mortality dataset and NHI data), and is not linked to the census record. Once a mortality record is linked to a census record it is not possible to access detailed cause of injury death information due to privacy reasons. Therefore, the numbers presented are for the total number of children that were alive on census night that died from an injury during the study period. The age has been presented as the age of the child on census night. For each demographic stratum, Table 8 presents the number (and proportion) of total eligible injury deaths for 1991-94, and the percentage of these mortality records successfully linked back to a census record.

Table 8: Total unintentional injury mortality (1991-1994) for eligible children aged 0-14 years at time of census, and percentage linked to a census record, by demographic strata

Demographic Variable	Number of injury deaths	% of total deaths	% successfully linked to census record**
Total	321	100	69.2
Sex			
M	199	62	69.3
F	122	38	68.9
Age at census			
<1 yrs	35	10.9	60.0
1- 4 yrs	87	27.1	72.4
5- 9 yrs	63	19.6	66.7
10-14 yrs	136	42.4	70.6
Ethnicity*			
Maori	57	17.8	57.9
Pacific	18	5.6	66.7
Non-Māori non-Pacific	249	77.6	71.1
NZDep91 Quintile			
1	27	8.4	66.7
2	36	11.2	75.0
3	39	12.1	76.9
4	51	15.9	64.7
5	99	30.8	75.8
Missing	69	21.5	56.5

* Note: ethnicity as recorded on mortality file and is different to the census recorded definition.
** Calculated using number of linked mortality records that had been random rounded to a near multiple of three as per SNZ protocol

Most notably, males make up almost two thirds of the injury deaths, substantially outnumbering females. This pattern is seen consistently in injury mortality both in New Zealand and internationally (UNICEF 2001). Also, there is a considerable variation of injury mortality by age group. The most striking feature is that 10 to 14 year old children make up almost a third of the eligible population, but 42% of all injury deaths. Infants are also slightly over-represented in injury deaths. Children aged 5 to 9 years of age make up the lowest proportion of injury deaths.

The ethnicity figures presented in Table 8 suggest that Māori and Pacific Island children appear to be slightly under-represented in injury deaths. However, this finding is unlikely to be true, rather reflecting the previously documented inaccuracies in the recording of ethnicity on mortality records prior to 1996 i.e. the substantial undercounting of deaths for Māori and Pacific people (Ajwani, Blakely et al. 2002; Blakely, Robson et al. 2002).

Mortality records prior to September 1995 used a definition of ethnicity based on 'ancestry' (greater than half Māori or Pacific blood) that was completed by the funeral director. This section of the death registration form was often not completed (and then coded as non-Māori non-Pacific), or incorrectly completed using an assumption of the decedents ethnicity. The undercount was most marked for children aged 0 to 14 years (Blakely, Robson et al. 2002). Note that the 1991 census determined ethnicity differently, using self-identified ethnic origin, and allowed for membership of multiple ethnic groups. By linking the death record to the census record, the NZCMS eliminates the problem of poor ethnicity recording on mortality records by using the census-reported prioritised ethnicity.

The pattern seen by NZDep91 indicates a greater proportion of children from NZDep91 quintile 5 making up injury deaths (30.8%), considering these children comprise slightly less than 25% of the eligible population. It is likely that many of the children with a missing NZDep91 variable on the mortality record are from quintile 5, possibly underestimating the proportion of deaths from this NZDep91 quintile.

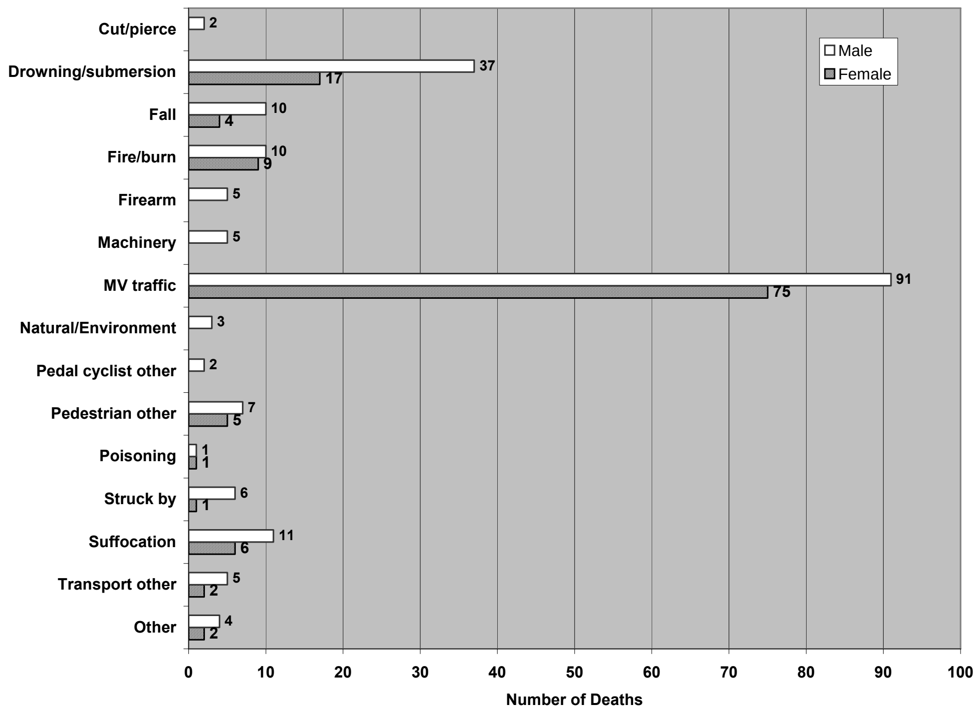
3.1 Cause of injury death

The causes of injury death for the children that died during the three-year follow-up period (including all eligible mortality records prior to the census linkage procedure) are presented in Figure 23. When considering all motor vehicle traffic related injuries together, this cause is responsible for over half (52%) of all childhood injury deaths. By far the most prominent type of traffic injury, motor vehicle occupant injuries, accounted for 29% (92 deaths) of the injury deaths. Child traffic pedestrian injury was the third most frequent cause of death, at 14% (45 deaths).

For New Zealand children, drowning and submersion injuries accounted for 17% of injury deaths. The other most frequent causes of injury death were fire/flame, suffocation, non-traffic pedestrian injury, and falls (each accounting for between 4 to 5% of injury deaths).

The pattern of cause of injury death was similar for both sexes. However, for almost every category of injury death, males substantially outnumbered females. Whilst overall males represented 62% of injury deaths, this ratio was even greater for some causes of injury death, most notably, drowning/submersion, falls, firearm, machinery-related, and cut/pierce injuries.

Figure 23: Total cause-specific injury mortality for 1991-94 for all eligible children aged 0-14 years old at time of census (n=321) by sex (using unlinked data from the total eligible mortality dataset)



* MV Traffic includes: traffic-related injury deaths for motor vehicle occupants, pedestrians, pedal cyclists, and motorcyclists.

For each age group, motor vehicle traffic injury deaths were the commonest cause of injury death. Generally, this was commonest cause of injury death by a large margin. However, for infants (< 1 year old at time of census) the number of children that died from drowning or submersion was very similar to the number that died from traffic injury. In this age group suffocation was also relatively common, accounting for 17% of deaths. The most striking age-differential by cause of injury death was seen for motor vehicle traffic injury deaths. Over half of the injury deaths for this category were for children aged 10-14 years old. The greatest number of deaths from drowning or submersion was seen for 1 to 4 year olds.

3.1.1 Linkage bias

Table 8 demonstrated the variation in linkage success seen for demographic strata. The overall proportion of eligible injury mortality records that were linked to a census record was 69%. There was little variation by sex and age. Infant mortality records were less likely to be linked (60%) although the numbers involved were smaller than for the other age categories.

There was much more variation when comparing linkage success between ethnic groups and NZDep91 level. Māori children were less likely to have a successfully linked mortality record (58%) than Non-Māori non-Pacific (71%). Linkage success for Pacific children was intermediate (67%) although numbers were small. There was much variation in linkage success by NZDep91 but these results were not suggestive of a strong pattern. Of note, those death records with a missing NZDep91 value were much less likely to be linked (57%). The pattern of cause of injury death is similar for both the total eligible mortality dataset, and the linked mortality dataset.

The weighting procedure (described in more detail in the methodology) is intended to adjust the linked number of deaths to be as closely representative of the true number of deaths as possible. This process aims to correct any potential bias in the cohort analyses that may be introduced by the variation in linkage success according to demographic characteristics. The linkage success for some specific causes of injury death varied slightly but was not included in the weighting process (figures not presented due to small cell size, SNZ confidentiality requirements). Much of the difference amongst smaller injury groups is likely to be due to random variation. It is unlikely that this will exert any significant effect on the analysis of injury deaths.

4 Income and child injury mortality association

This section will consider the effect of household income on child injury mortality. The results reveal an inverse association between income and injury. For each increase in household income grouping there was a decrease in the risk of injury mortality. This income effect was generally seen throughout demographic strata, and although attenuated, the effect persisted following the adjustment for confounding factors.

Section 4.1 will discuss the crude and age-adjusted associations of income and injury mortality. The possibility of effect modification by sex and age will be explored. Multivariable associations will be presented in section 4.2. The univariable and multivariable income-injury associations by ethnic strata and for children restricted to employed households will be discussed separately in more detail in sections 4.3 and 4.4 respectively.

4.1 Univariable associations of income and injury mortality

The results of the crude and age-adjusted household income and injury mortality analyses are presented in Table 9. Unweighted and weighted analyses are presented here to demonstrate the influence of linkage bias on the effect measure. Both methods of grouping the highest income categories are shown here as the analyses by demographic strata use six income categories. The associations by ethnicity and by labour force status will be presented in more detail in section 4.3.

Table 9: Crude and age-adjusted odds ratios (95% confidence intervals) for injury mortality (unweighted and weighted) by equivalised household income category among 603,219 children aged 0-14 years on census night 1991

Equivalised Household Income	Population (n=603 219)	Unweighted Analyses			Weighted Analyses		
		Linked Deaths (n=162)	Crude OR (95% CI)	Age-adjusted OR (95% CI)	Weighted Deaths (n=246)	Crude ORw (95% CI)	Age-adjusted OR_w (95% CI)
7 income groups							
<40% of Median	88 392	36	2.47 (1.38-4.45)	2.66 (1.48-4.79)	57	2.59 (1.60-4.20)	2.81 (1.73-4.55)
>=40% to <50%	50 130	18	1.89 (0.94-3.77)	2.02 (1.01-4.04)	24	1.95 (1.10-3.44)	2.10 (1.19-3.72)
>=50% to <60%	58 677	15	1.61 (0.81-3.22)	1.72 (0.86-3.44)	24	1.68 (0.96-2.97)	1.81 (1.03-3.19)
>=60% to <80%	84 297	24	1.54 (0.81-2.93)	1.63 (0.85-3.10)	36	1.62 (0.96-2.75)	1.72 (1.02-2.92)
>=80% to <Med	84 774	21	1.53 (0.80-2.92)	1.62 (0.85-3.09)	33	1.55 (0.91-2.63)	1.65 (0.97-2.80)
>=Med to <150%	142 458	33	1.41 (0.78-2.55)	1.45 (0.80-2.63)	48	1.37 (0.83-2.24)	1.41 (0.86-2.32)
>=150% of Median	94 491	15	1	1	24	1	1
6 income groups							
<40% of Median	88 389	36	1.98 (1.30-3.04)	2.09 (1.37-3.21)	57	2.12 (1.50-3.01)	2.26 (1.59-3.20)
>=40% to <50%	50 130	15	1.51 (0.86-2.66)	1.59 (0.90-2.79)	24	1.60 (1.01-2.53)	1.69 (1.06-2.68)
>=50% to <60%	58 677	18	1.29 (0.74-2.27)	1.35 (0.77-2.38)	24	1.38 (0.87-2.18)	1.45 (0.92-2.30)
>=60% to <80%	84 300	21	1.24 (0.75-2.04)	1.28 (0.78-2.12)	36	1.33 (0.88-2.00)	1.38 (0.92-2.08)
>=80% to <Med	84 774	21	1.23 (0.74-2.03)	1.28 (0.77-2.11)	33	1.27 (0.84-1.92)	1.32 (0.87-2.00)
>=Median	236 949	51	1	1	72	1	1

Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol; odds ratios calculated prior to random rounding

The table indicates that there is a distinctive non-linear inverse relationship between household income and the risk of injury death (see also Figure 25). The pattern of association is similar for all methods of analysis, whether or not weighted, or whether using a larger reference group (six income groups). The weighted age-adjusted seven income group analysis will be predominantly discussed, as this is the basis for the income modelling procedure in the next section.

There is a moderate increase in the risk of injury death when comparing the reference group to the next highest income category (Odds Ratio 1.41, 95% CI 0.86 to 2.32). The changes in odds ratios amongst the middle three income categories are consistent with an inverse relationship, although each relative decrease in income gives rise to a more modest increase in risk of injury death (from 65% up to an 81% excess risk of death compared with the reference group). However, there is a suggestion of a threshold effect with the children in the poorest two categories experiencing a much greater risk of injury death (Odds Ratios 2.10 95% CI 1.19 to 3.72, and 2.81 95% CI 1.73 to 4.55, for the second poorest and poorest household groups respectively).

The 95% confidence intervals for the poorest four household groups do not include one, and as such represent a high likelihood of a true inverse association between low income and injury mortality. The ranges contained within the 95% confidence intervals are moderately wide. For instance, for the poorest income category the true size of the association is likely to lie between a 73% excess to a greater than four-fold excess risk of injury mortality. However, the strong dose response is consistent with an underlying inverse association. Despite this study being based on the total New Zealand child population, injury death is a relatively uncommon outcome, thereby influencing the degree of statistical precision possible in these analyses.

For some of the odds ratios, the 95% confidence interval included one, although the lower confidence limit was often very close to one. The middle-income categories were created for the income modelling procedure and some are smaller than the income categories at the extremes. It is important to note that the effect size for each income category is calculated in isolation from that of the neighbouring income categories. The trend of the inverse association between income and injury mortality was statistically significant (p value < 0.01).

The difference in the income-injury mortality association observed between the unweighted and weighted analyses confirms the presence of a moderate linkage bias. Most notably, the unweighted analyses tend to proportionately underestimate the size of the association for the lowest four income categories by a magnitude of 5 to 12% (for 7 income categories) and 13 to 26% (for 6 income categories).

Table 9 also demonstrates that age was confounding the income-injury mortality association. The consistent uncontrolled effect of age was to underestimate the size of the association. This implies that age was a negative confounder i.e. lower income groups were more likely to have a greater proportion of children of ages associated with a lower risk of injury death. Performing the univariable analysis by age category suggested that there may be some interesting patterns, however the study was not sufficiently powerful to characterise the income-injury mortality relationship by age (results not presented). There was a suggestion of a stronger risk of injury death for infants <1 year old in the poorest income category, and children aged 5 to 9 years appeared to display the next strongest associations with income.

Whilst sex is not considered to be a potential confounder, there is a possibility of effect measure modification by sex. To explore this, the results stratified by sex are presented in Table 10 and in Figure 24. The seven-income categorisation analysis was problematic due to the small numbers of deaths in the reference category, most notably for females. The association by sex displays much more variation, and less of the distinctive non-linear pattern that was seen for the total population.

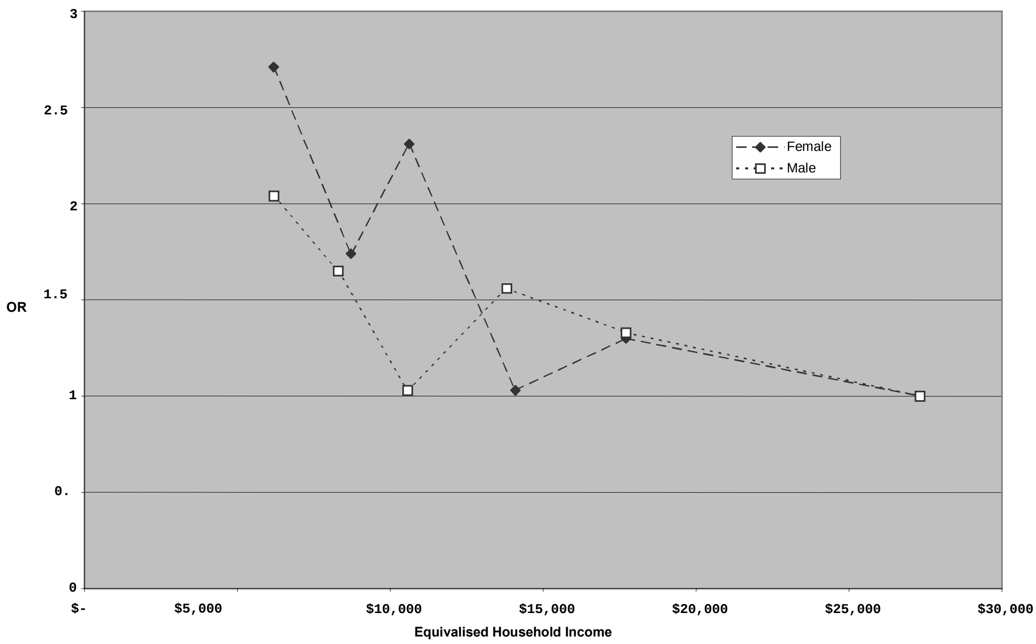
A closer inspection of the pattern of the association by sex in Figure 24 yields little to substantiate the presence of effect modification. Overall, the initial impression may be that there is a stronger association for females (Odds ratio 2.71 for the lowest income group) than males (odds ratio 2.04). However, this is only notable for two income categories, the lowest income category and the [>=50 % to <60%] category. The other income categories either have a very similar effect size for females and males, or males display a stronger effect. The confidence intervals are reasonably wide, particularly for females due to the smaller numbers of injury deaths.

Table 10: Age-adjusted odds ratios (95% confidence intervals) for weighted injury mortality among 603,219 children aged 0-14 years on census night by equivalised household income category by sex

Equivalised Household Income	Population (n=295 374)	Weighted Deaths (n=87)	Age-adjusted OR (95% CI)	Equivalised Household Income	Population (n=307 845)	Weighted Deaths (n=153)	Age-adjusted OR (95% CI)
Females				***Males***			
6 Income Groups				**6 Income Groups**			
<40% of Median	43 377	24	2.71 (1.51-4.86)	<40% of Median	45 012	33	2.04 (1.31-3.16)
>=40% to <50%	24 483	6	1.74 (0.78-3.87)	>=40% to <50%	25 647	15	1.65 (0.94-2.91)
>=50% to <60%	28 857	15	2.31 (1.17-4.59)	>=50% to <60%	29 823	9	1.03 (0.54-1.95)
>=60% to <80%	41 292	9	1.03 (0.47-2.29)	>=60% to <80%	43 005	27	1.56 (0.97-2.51)
>=80% to <Med	41 367	12	1.30 (0.62-2.70)	>=80% to <Med	43 407	21	1.33 (0.81-2.21)
>=Median	115 998	21	1	>=Median	120 951	48	1
7 Income Groups				**7 IncomeGroups**			
<40% of Median	43 377	24	5.56 (2.00-15.49)	<40% of Median	45 015	33	2.16 (1.23-3.80)
>=40% to <50%	24 483	9	3.58 (1.12-11.42)	>=40% to <50%	25 647	15	1.75 (0.90-3.41)
>=50% to <60%	28 857	12	4.75 (1.61-14.06)	>=50% to <60%	29 823	9	1.09 (0.52-2.27)
>=60% to <80%	41 295	9	2.12 (0.67-6.76)	>=60% to <80%	43 005	27	1.65 (0.91-3.00)
>=80% to <Med	41 367	9	2.66 (0.87-8.14)	>=80% to <Med	43 407	21	1.42 (0.77-2.62)
>=Med to <150%	69 864	18	2.75 (0.97-7.82)	>=Med to <150%	72 594	30	1.10 (0.62-1.96)
>=150% of Med	46 134	6	1	>=150% of Med	48 354	18	1

Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol; odds ratios calculated prior to random rounding

Figure 24: Odds ratios for injury mortality for children aged 0 to 14 years old (on census night 1991) by equivalised household income category (using median household income value in 1991 NZ$ for each category) by sex



To further scrutinise the effect by sex, linear regressions (using SAS v8.0) were performed to compare the slopes of the associations by sex (see Table 11). The median household income for each income category ($10,000 per unit) was the independent variable. Using the odds ratio as the outcome variable tested for additive effect modification. The natural logarithmic odds ratio was used as the outcome variable to test for multiplicative effect modification. In both cases no statistically significant effect modification was detected. For both outcomes, there was substantial overlap in the 95% confidence intervals by sex. Therefore the possibility that random variation is responsible for the differences by sex cannot be excluded. It is possible that the study power may have been insufficient to detect the presence of effect modification by sex.

Table 11: Test for effect modification of the income-injury mortality association* by sex: the slope estimate by outcome (odds ratio and natural logarithmic odds ratio)

Outcome	Sex	Slope (95% CI) per $10,000
Odds ratio (additive scale)	Female	-0.49 (-0.89 to -0.09)
	Male	-0.31 (-0.57 to -0.04)
Ln Odds ratio (multiplicative scale)	Female	-0.32 (-0.55 to -0.09)
	Male	-0.22 (-0.42 to -0.03)

* Note: performed on 6 income category analysis, only adjusted for age

4.2 Multivariable association of income and injury mortality

A crucial aspect of this dissertation is to isolate the independent effect of income, adjusting for the confounders for which data is available. Table 12 displays the effect that controlling for age plus one other variable has on the income-injury mortality association.

Table 12: Odds ratios (95% confidence intervals) for injury mortality by equivalised household income category among 603,219 children aged 0-14 years, controlled for age plus one further variable: ethnicity, education, family type, labour force status, NZDep91, car access or crowding*

Equivalised Household Income	Age-adjusted OR (95% CI)	Ethnicity OR (95% CI)	Education OR (95% CI)	Family Type OR (95% CI)	Labour Force OR (95% CI)	NZDep91 OR (95% CI)	Car Access OR (95% CI)	Crowding OR (95% CI)
<40% Med	2.81 (1.73-4.55)	2.59 (1.57-4.25)	2.24 (1.33-3.77)	2.49 (1.48-4.18)	2.14 (1.23-3.72)	2.06 (1.23-3.42)	2.45 (1.45-4.15)	2.86 (1.76-4.65)
40% -<50%	2.10 (1.19-3.72)	1.98 (1.11-3.51)	1.77 (0.98-3.20)	1.93 (1.07-3.46)	1.68 (0.91-3.09)	1.56 (0.87-2.82)	1.92 (1.06-3.49)	2.15 (1.21-3.81)
50% - <60%	1.81 (1.03-3.19)	1.72 (0.97-3.05)	1.59 (0.88-2.85)	1.72 (0.97-3.06)	1.58 (0.88-2.83)	1.40 (0.78-2.51)	1.74 (0.97-3.12)	1.89 (1.07-3.34)
60% - <80%	1.72 (1.02-2.92)	1.66 (0.97-2.82)	1.56 (0.91-2.68)	1.67 (0.99-2.84)	1.61 (0.94-2.74)	1.37 (0.80-2.35)	1.69 (0.99-2.90)	1.82 (1.07-3.10)
80% -<Med	1.65 (0.97-2.80)	1.61 (0.94-2.74)	1.55 (0.90-2.66)	1.62 (0.95-2.77)	1.61 (0.94-2.74)	1.37 (0.80-2.36)	1.65 (0.96-2.82)	1.75 (1.02-2.98)
Med -150%	1.41 (0.86-2.32)	1.39 (0.85-2.28)	1.37 (0.83-2.25)	1.40 (0.86-2.30)	1.41 (0.86-2.30)	1.26 (0.76-2.06)	1.42 (0.87-2.33)	1.47 (0.90-2.42)
>=150% Med	1	1	1	1	1	1	1	1

* Weighted analysis. Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol; odds ratios calculated prior to random rounding

Controlling for education, labour force, and NZDep91 resulted in the most notable reductions in the income-mortality association (Table 12). Adjusting for education reduces the excess risk of injury death for the lowest income groups by almost one third i.e. the proportional reduction in effect size is calculated as: (2.81-2.24)/(2.81-1)=32%. Along with the reduction in the size of the effect, only the confidence interval of the lowest income category did now not include one. Prior to the adjustment for education, the confidence intervals of the four lowest income categories did not include one. The proportional reduction in effect size once adjusting for labour force status and NZDep91 was 37% and 41% respectively.

There appeared to be some confounding by ethnicity, with a reduction in injury risk seen in the lowest four income categories of 6 to 12%. Adjusting for crowding modestly increased the association of income and mortality (by 3 to 7%). Crowding did not appear to act as a pathway variable from income to injury mortality.

Adjusting for car access attenuated the association of income with injury mortality by up to 20%. As described earlier in this dissertation, car access (a proxy for asset wealth and access to community resources) might be either a confounder or a mediating variable of the income-injury association.

I have previously discussed in the literature review the census-recorded variables that may be likely confounders. This is important for creating the most appropriate multivariable model for capturing, as close as possible, whether there is a true underlying independent effect of income on injury mortality. Ideally, the multivariable analysis will control only for those variables that confound the income association. Additionally, it is not desirable to control for the effect of a variable that may act as a pathway (or intermediary) variable, thereby reducing the effect that income has on injury mortality. Table 13 presents four multivariable models that adjust for the indicated variables. This table indicates the theoretically most preferred model, as well as a model that explores the potential effect of intermediaries.

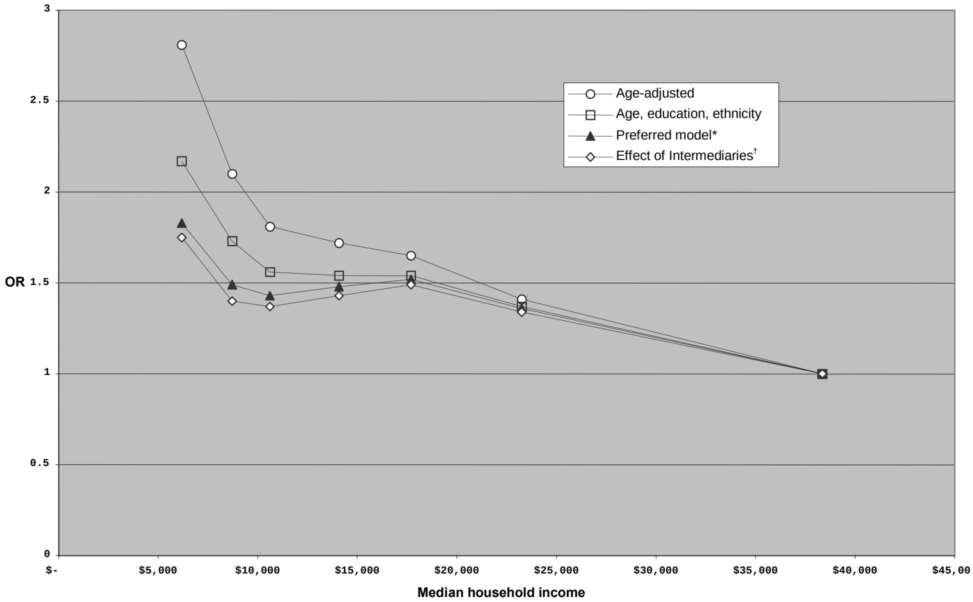
Table 13: Multivariable odds ratios (95% confidence intervals) for injury mortality among 603,219 children aged 0-14 years controlled for indicated variables †

	Single socioeconomic variable (age-adjusted)	MULTIVARIABLE MODEL			
		Age, income, ethnicity, education	Age, income, ethnicity, education, family type	PREFERRED MODEL (Age, income, ethnicity, education, family type, Labour force)	Plus Intermediaries*
Equivalised HH income					
<40% of Median	2.81 (1.73-4.55)	2.17 (1.29-3.68)	2.06 (1.19-3.58)	1.83 (1.02-3.28)	1.75 (0.96-3.21)
>=40% to <50%	2.10 (1.19-3.72)	1.73 (0.96-3.15)	1.67 (0.91-3.07)	1.49 (0.80-2.80)	1.40 (0.73-2.68)
>=50% to <60%	1.81 (1.03-3.19)	1.56 (0.87-2.81)	1.53 (0.85-2.77)	1.43 (0.79-2.60)	1.37 (0.74-2.55)
>=60% to <80%	1.72 (1.02-2.92)	1.54 (0.89-2.65)	1.53 (0.88-2.63)	1.48 (0.85-2.55)	1.43 (0.82-2.52)
>=80% to <Med	1.65 (0.97-2.80)	1.54 (0.90-2.65)	1.54 (0.89-2.64)	1.52 (0.89-2.62)	1.49 (0.86-2.59)
>=Median to <150%	1.41 (0.86-2.32)	1.37 (0.83-2.25)	1.36 (0.83-2.24)	1.36 (0.83-2.24)	1.34 (0.81-2.22)
>=150% Median	1	1	1	1	1
Ethnicity					
Maori	1.57 (1.18-2.09)	1.22 (0.90-1.65)	1.21 (0.89-1.64)	1.17 (0.86-1.60)	1.10 (0.79-1.52)
Pacific	1.13 (0.66-1.93)	0.90 (0.52-1.55)	0.90 (0.52-1.56)	0.89 (0.51-1.54)	0.81 (0.46-1.44)
NonMāoriNonPacific	1	1	1	1	1
Education					
Tertiary	1	1	1	1	1
Trade	1.15 (0.80-1.64)	1.02 (0.71-1.48)	1.02 (0.71-1.48)	1.01 (0.70-1.46)	0.97 (0.67-1.40)
School	1.11 (0.76-1.64)	0.95 (0.64-1.41)	0.94 (0.63-1.41)	0.94 (0.63-1.40)	0.89 (0.60-1.33)
Nil	2.11 (1.50-2.96)	1.54 (1.05-2.27)	1.51 (1.02-2.24)	1.48 (1.00-2.20)	1.36 (0.91-2.02)
Family type					
One Parent Family	1.62 (1.23-2.14)		1.12 (0.80-1.55)	1.09 (0.77-1.55)	0.91 (0.62-1.33)
Other Family Type	1		1	1	1
Labour force Status					
Employed	1			1	1
Unemployed	2.08 (1.42-3.06)			1.50 (0.96-2.35)	1.42 (0.90-2.23)
Non-Labour Force	1.80 (1.31-2.48)			1.14 (0.73-1.79)	1.06 (0.67-1.67)
NZ Deprivation					
Dep1&2 (least deprived)	1				1
Dep3&4	1.63 (0.98-2.74)				1.56 (0.93-2.63)
Dep5&6	1.82 (1.10-3.03)				1.66 (0.99-2.79)
Dep7&8	2.88 (1.80-4.61)				2.44 (1.49-4.02)
Dep9&10 (most deprived)	2.68 (1.68-4.25)				1.96 (1.16-3.31)
Car Access					
>=2 Cars	1				1
1 Car	1.11 (0.84-1.46)				0.84 (0.62-1.13)
Nil Cars	2.31 (1.60-3.34)				1.28 (0.80-2.03)
Crowding					
< 1 bdrm	1				1
>1 <=1.5 per Bdrm	0.75 (0.56-1.02)				0.77 (0.56-1.05)
>1.5 <=2 per Bdrm	0.70 (0.49-0.99)				0.62 (0.42-0.89)
>= 2 bdrm	1.12 (0.69-1.82)				0.85 (0.50-1.43)

*Preferred model (age, ethnicity, education, family type, labour force status) plus potential intermediaries: car access, crowding, and NZ deprivation level.

† Weighted analysis. Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol; odds ratios calculated prior to random rounding

Figure 25: Odds ratios for injury mortality among 603,219 children aged 0-14 years by equivalised household income category (using median household income value in 1991 NZ$ for each category), by indicated multivariate model



* Preferred multivariable model: adjusted for age, ethnicity, education, family type, labour force status.
† Effect of intermediaries: Preferred model plus car access, crowding and NZDep91 level.

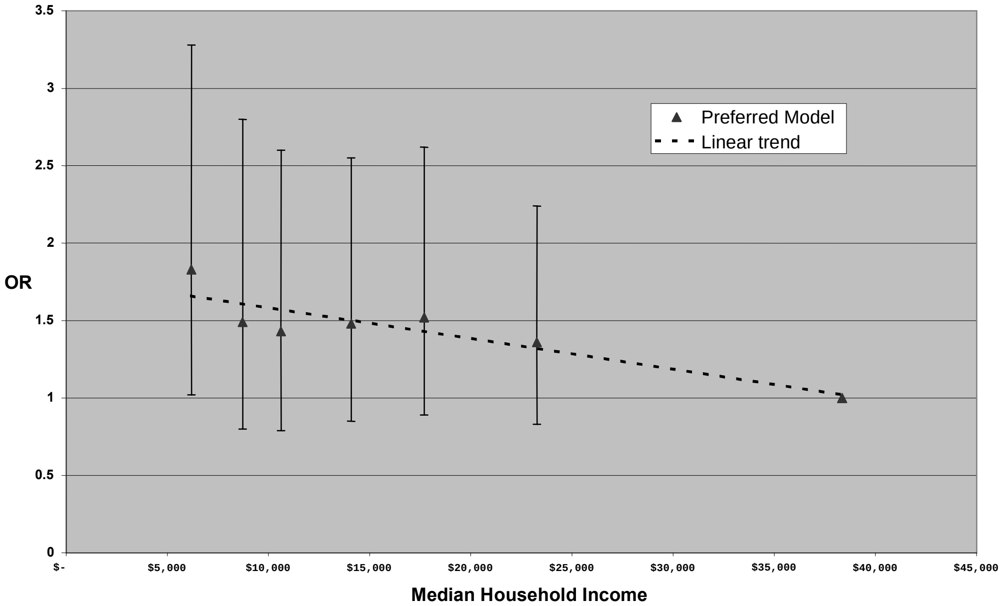
Adjusting for age, ethnicity and education substantially reduced the observed association between low income and injury mortality. The odds ratio for the lowest income category was reduced from 2.81 (age-adjusted) to 2.17 after also controlling for ethnicity and education. There was a further modest reduction in the size of the effect for the lowest three income categories after controlling for family type.

There is also substantial confounding by labour force status as demonstrated in the 'preferred model' in Table 13. This is particularly seen in the lowest four income categories. The odds ratio for the lowest income category is now 1.83, and the lower 95% confidence limit is slightly above one (95% confidence interval 1.02 to 3.28).

The overall shape of the association in the preferred model has changed slightly, compared to that seen when only adjusting for age. In relation to the reference group, all income categories have odds ratios that are substantially greater than one. There is a relatively big increase in risk from the reference group to the next highest income category [>= median to <150% of median]. Most interestingly, for the preferred model, there is little variation in the size of the odds ratios for the middle-income groups. However, it is important to note that the confidence intervals are relatively wide.

Although attenuated, there remains evidence of a threshold effect with a relatively greater increase in risk from the second poorest group [>=40% to <50% category] to the poorest income group. The trend of the 'preferred' multivariable association between income and injury mortality was statistically significant (p value < 0.01).

Figure 26: Odds ratios (95% confidence intervals) for injury mortality among 603,219 children aged 0-14 yrs by equivalised household income (using median household income value in 1991 NZ$ for each category): preferred multivariable model (adjusted for age, ethnicity, education, family type, and labour force status)



Interestingly, the effect of variables that may lie on the pathway from income to injury death, have relatively little impact on the income-injury association. Using the preferred model as a baseline, the possible effect of intermediaries ranges between a 6 to 18% further reduction in effect size. The intermediaries examined are car access, crowding and NZdep91. This suggests that these three variables do not provide the major explanation of how low income leads to a greater risk of injury death – at least that we can empirically determine. Crowding in particular does not appear to have an effect as an intermediary variable. The inclusion of these variables does reduce the lower confidence limit in the poorest income category to just below one.

There are other important observations to be made from Table 13. Māori children experienced a 57% higher risk of injury death (age adjusted) compared to non-Māori non-Pacific children. After adjusting for income, education, labour force status and family type, this excess risk reduced to 17% (with the confidence interval including one). For Pacific children, there was a 13% higher risk of injury death compared to non-Māori non-Pacific children, which on multivariate analysis reduced to an 11% lower risk of injury mortality compared to non-Māori non-Pacific children. Labour force status played some role in the higher risk for Māori children, but had little impact for Pacific children. Once car access, NZDep91 and crowding were adjusted for, the increased risk for Māori children reduced to 10% greater than Non-Māori non-Pacific. All confidence intervals included one; therefore one cannot exclude random variation as an explanation of these differences.

It is also worth noting that there may be some selection bias influencing the observed estimates of injury risk by ethnicity. Calculating the crude risk ratio for injury mortality for Māori children compared to non-Māori non-Pacific for both the eligible cohort and the study cohort (see Table 4) demonstrates risk ratios of 1.66 for the eligible cohort (i.e. RR=(93/150,738)/(201/540,147)), and 1.53 for the study cohort. This suggests that the observed relative risks from the study cohort by ethnicity may underestimate the true relative risk. Nevertheless, socioeconomic factors appear to explain much of the ethnic differences in mortality.

The relationship of education and injury mortality is suggestive of a threshold effect whereby nil household education was associated with an approximate 50% greater risk of injury. This effect persisted once controlling for age, income, ethnicity, family type and labour force status. The lower confidence limit was one for this model. Further controlling for NZDep91, crowding, and car access somewhat diminished the increased risk of child injury for those households with no adult education, however, a 36% excess risk persisted.

After adjusting for individual (and household) characteristics, small area deprivation was still strongly associated with injury risk. When compared to the least deprived quintile, all NZDep91quintiles had a substantially higher risk of death. The fourth quintile (NZDep91 quintiles 7 & 8) had the highest risk of injury death, with an odds ratio of 2.44 (95% CI 1.49 to 4.02). The most deprived quintile also had a statistically significant effect, 1.96 (95% CI 1.16 to 3.31).

The children from households of unemployed labour force status experienced a 50% greater risk of injury death when compared to households with at least one employed adult. Income, education, ethnicity, and family type were adjusted for in this model. The confidence interval was moderately wide, and included one. There was much less increased risk associated with non-active labour force households (14% excess risk).

There was little in the way of an independent effect of family type on the risk of injury. There was a slight increase in risk (9%) for children of one-parent families compared to other family types, once adjusting for income, education, ethnicity, and labour force. Adjusting for car access, crowding, and NZDep91 reduced the odds ratio to 0.91 (i.e. a 9% lower risk).

4.3 The association of income and child injury mortality by ethnic strata

The income-injury mortality associations for Māori and non-Māori non-Pacific children are presented in Table 14 and Figure 27. The analysis was too unstable for Pacific children to enable the association to be characterised.

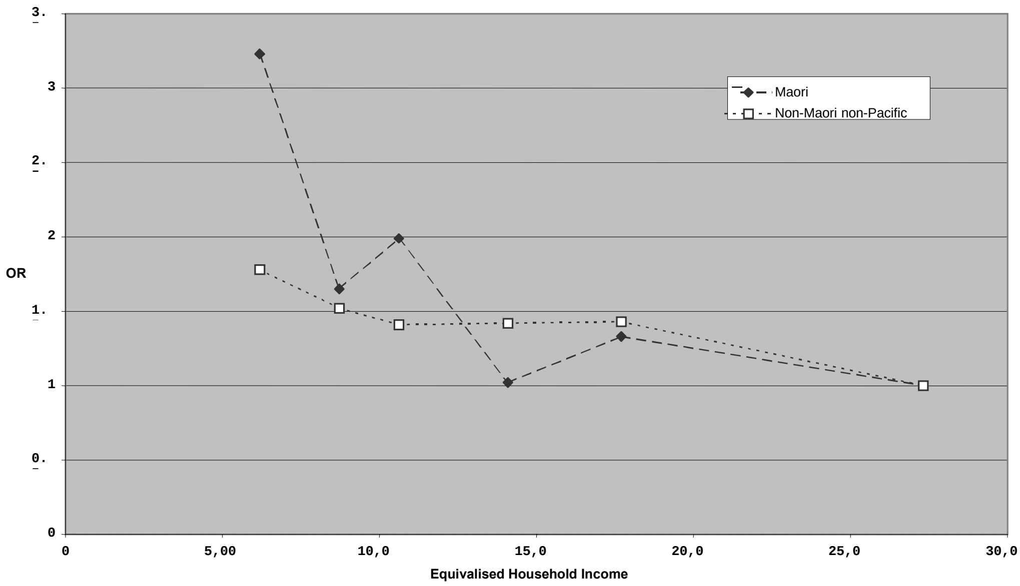
Table 14: By ethnic strata*, odds ratios (95% confidence intervals) for injury mortality by equivalised household income for children aged 0-14 years, controlled for indicated variables.(weighted analysis)

Equivalised Household Income	n	Weighted Deaths (n)	Age-adjusted OR (95% CI)	Age, education† OR (95% CI)	Age, education, Family type† OR (95% CI)	Age, education, Fam type, LFS† OR (95% CI)
Māori	**Total=119 331**	**n=72**				
<40% Median	32 571	33	3.23 (1.49-6.99)	1.75 (0.77-3.96)	1.52 (0.64-3.64)	0.94 (0.34-2.58)
>=40% - <50%	14 718	9	1.65 (0.61-4.49)	1.00 (0.36-2.80)	0.92 (0.32-2.61)	0.58 (0.18-1.82)
>=50% to <60%	14 553	9	1.99 (0.77-5.16)	1.32 (0.50-3.49)	1.25 (0.47-3.34)	0.88 (0.30-2.52)
>=60% to <80%	18 234	6	1.02 (0.35-2.96)	0.74 (0.25-2.17)	0.72 (0.24-2.11)	0.57 (0.19-1.73)
>=80% to <Med	13 773	6	1.33 (0.45-3.88)	1.08 (0.37-3.18)	1.07 (0.36-3.14)	0.99 (0.33-2.92)
>=Median	25 482	9	1	1	1	1
Non-Māori non-Pacific	**Total=448 431**	**n=162**				
<40% Median	45 711	21	1.78 (1.10-2.90)	1.78 (1.07-2.99)	1.73 (0.99-3.01)	1.73 (0.96-3.13)
>=40% - <50%	30 990	12	1.52 (0.83-2.77)	1.53 (0.83-2.84)	1.49 (0.79-2.82)	1.48 (0.77-2.85)
>=50% to <60%	39 924	18	1.41 (0.81-2.47)	1.43 (0.81-2.53)	1.41 (0.80-2.51)	1.39 (0.78-2.49)
>=60% to <80%	60 255	24	1.42 (0.88-2.28)	1.43 (0.88-2.32)	1.42 (0.88-2.31)	1.41 (0.87-2.29)
>=80% to <Med	66 957	27	1.43 (0.91-2.26)	1.45 (0.91-2.29)	1.44 (0.91-2.29)	1.44 (0.91-2.28)
>=Median	204 588	60	1	1	1	1
All	**Total=603,219**	**n=246**				
<40% Median	88 389	57	2.26 (1.59-3.20)	1.76 (1.19-2.61)	1.67 (1.09-2.56)	1.48 (0.93-2.37)
>=40% - <50%	50 130	24	1.69 (1.06-2.68)	1.41 (0.87-2.28)	1.36 (0.83-2.23)	1.21 (0.72-2.05)
>=50% to <60%	58 677	24	1.45 (0.92-2.30)	1.27 (0.79-2.04)	1.25 (0.77-2.01)	1.16 (0.71-1.89)
>=60% to <80%	84 300	36	1.38 (0.92-2.08)	1.25 (0.82-1.91)	1.24 (0.82-1.89)	1.20 (0.79-1.84)
>=80% to <Med	84 774	33	1.32 (0.87-2.00)	1.26 (0.83-1.91)	1.25 (0.82-1.91)	1.24 (0.82-1.89)
>=Median	236 949	72	1	1	1	1

* Small numbers precluded a separate analysis for Pacific Island children (n=35 460)
† Model includes adjusting for ethnicity for 'all' ethnic groups category
Note: All numbers are random rounded to a near multiple of three (minimum cell size 6) as per SNZ protocol; odds ratios calculated prior to random rounding

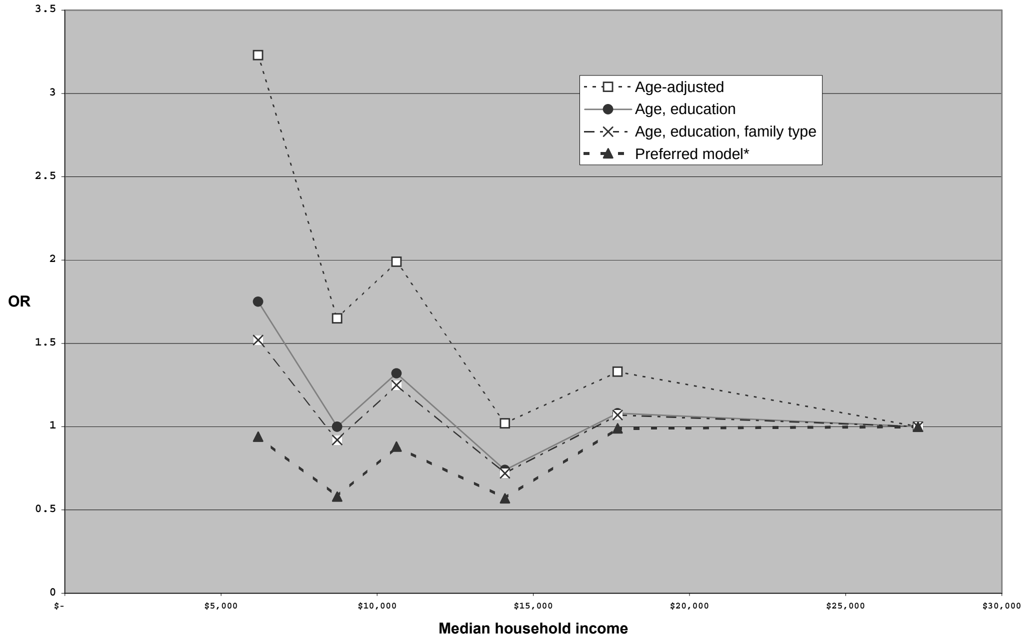
Adjusting for age, compared to non-Māori non-Pacific, there appears to be a steeper, although more erratic relationship between income and the risk of injury mortality for Māori children. The 95% confidence intervals are especially wide for Maori, due to the relatively smaller numbers in each category. The association is substantially stronger for the poorest, and third poorest income groups. Children from the poorest income category for Māori experienced an odds ratio of 3.23 (95% CI 1.49 to 6.99), compared to 1.78 (1.10 to 2.90) for non-Māori non-Pacific children. Compared to the income-injury relationship for all children, the association for non-Māori non-Pacific children was weaker. The <40% of median household income category for both ethnic groups was the only category where the confidence interval did not include one. The difference in the income-mortality association by ethnic group appears to be predominantly due to confounding as opposed to effect measure modification.

Figure 27: Age-adjusted odds ratios for injury mortality for children aged 0 to 14 years old by equivalised household income (using median household income value in 1991 NZ$ for each category) for Māori and Non-Māori non-Pacific children*



The effect of adjusting for confounding factors seems to be quite different by ethnicity (Figure 28). For non-Māori non-Pacific children, there is little change in the odds ratios when controlling for confounding by education, family type, and labour force status. For Māori children, the effect from confounding appears substantial. Controlling for education as a first step, the odds ratios for all income categories are substantially reduced, for example reducing the odds ratio of 3.23 to 1.75 for the poorest income group, a reduction in the income effect by two thirds. For the next highest income category, adjusting for education eliminated the increased risk by income. This is in stark contrast with non-Māori non-Pacific where education did not reduce the odds ratios at all. For Māori children, adding family type into the logistic regression model further reduced the effect size, particularly in the lowest income category. Once labour force status is included in the model, the inverse income-injury association is eliminated, or perhaps even slightly reversed.

Figure 28: Odds ratios for injury mortality for 119,331 Māori children aged 0 to 14 years by equivalised household income (using median household income value in 1991 NZ$ for each category) for indicated multivariate model



* Preferred multivariate model: adjusted for age, education, family type, and labour force status.

The differing effect sizes and the varying impact of confounders between Māori and non-Māori non-Pacific children may be purely due to statistical instability. However, it may also be of substantive importance. If so, then the variation is most notable for the lowest income group. The fundamental question is whether the true underlying association between income and injury mortality is the same for both ethnic groups, or whether this is different (effect modification). The confidence intervals are wide. The differences in effect size by ethnic group (Figure 27) may represent random variation. A comparison of the slope of the associations by ethnicity (using the same method as for sex described in Section 4.1) was performed to test this hypothesis. Table 15 presents these results for both an additive and a multiplicative scale. Whilst the slopes vary by ethnicity, all 95% confidence intervals substantially overlap.

Table 15: Test for effect modification of the income-injury mortality association by ethnicity: the slope estimate by outcome (odds ratio and natural logarithmic odds ratio)

Outcome	Ethnicity	Slope (95% CI) per $10,000
Odds ratio (additive scale)	Maori	-0.69 (-1.35 to -0.04)
	Non-Māori non-Pacific	-0.32 (-0.40 to -0.24)
Ln Odds ratio (multiplicative scale)	Maori	-0.40 (-0.73 to -0.07)
	Non-Māori non-Pacific	-0.25 (-0.31 to -0.19)

* Note: performed on 6 income category analysis, only adjusted for age

To further analyse the possibility of effect modification by ethnicity, the general form of the Wald statistic was used to test for homogeneity of the odds ratios by ethnic strata (Rothman and Greenland 1998)page 275. Using this test on the <40% income category where the difference in odds ratios was the most extreme, the hypothesis of the effect measure being homogenous across ethnic strata was not rejected (χ^2_{Wald}=1.73, p=0.19). Therefore, these tests do not provide the evidence necessary to support effect measure modification by ethnicity. However, it is important to note that these tests may not have the statistical power to detect heterogeneity if it is present.

For Maori, adjusting for labour force status has a dramatic effect on the odds ratio. This is not seen for non-Māori non-Pacific children and the total study population. This implies that for Māori much of the apparent effect of low income on injury mortality is due to confounding by labour force status. This result should be taken with extreme caution. As discussed previously in this dissertation (see chapter 4 section 2.1), there is a concern that a necessary association of labour force status and income makes it difficult to conceptualise their independent associations with mortality. Moreover, a statistical problem of collinearity between labour force status and income may violate the statistical assumptions of logistic regression. A general rule to test for collinearity violations in logistic regression is to inspect the percentage increase in the standard error of the coefficients of the variable of interest before and after controlling for a covariate that is (highly) correlated. A percentage increase of 50% or more in the standard error is indicative of collinearity. However, such a percentage change is rarely seen with large data-sets, suggesting that a lesser percentage increase in the standard error should be taken seriously (personal communication, Dr Tony Blakely, May 2003). The increase in the standard error for low-income groups after controlling for labour force status is notable among Māori (16% and 10% for the lowest and second-lowest income categories, respectively) but not particularly notable among non-Māori (7% and 3% for the two lowest income categories). Thus, it seems reasonable to conclude that the (necessary) correlation of income and labour force status may be a potential statistical problem among the low income groups for Māori. However, for non-Māori and the total population, any such problem is not too severe. Accordingly, we are unable to place much trust in the preferred model among Māori children.

4.4 The association of income and child injury mortality within employed families

The high correlation between income and labour force status has been highlighted as a potential problem when performing the regression analysis. To avoid confounding by labour force status, and to avoid the difficulties surrounding highly correlated variables in regression analysis, it is useful to examine the income-injury mortality association within a labour force status stratum. This analysis was unable to be performed for unemployed and non-active labour force families due to the low numbers. The income-injury mortality association within the stratum of children from employed families is presented in Table 16 and Figure 29.

Table 16: For children aged 0-14 years living in a household with at least one employed adult, odds ratios (95% confidence intervals) for injury mortality by equivalised household income for indicated multivariable model*

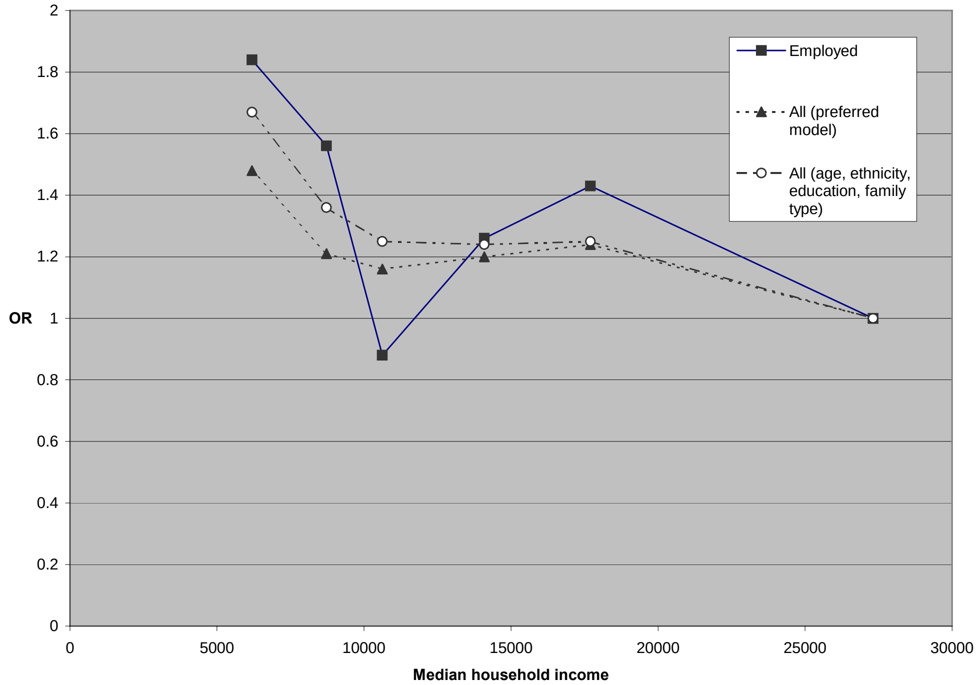
Equivalised Household Income Category	Number of Children	Number of Weighted Deaths	Age-adjusted OR (95% CI)	Age, Ethnicity, Education, Family type OR (95% CI)	Age, Ethnicity, Education, Family type, Labour force OR (95% CI)
Employed	**Total=474, 483**	**n=165**			
<40% Median	25 431	15	1.92 (1.08-3.41)	1.84 (1.01-3.34)	
>=40% to <50%	23 277	12	1.60 (0.84-3.06)	1.56 (0.80-3.03)	
>=50% to <60%	40 749	9	0.89 (0.46-1.72)	0.88 (0.45-1.71)	
>=60% to <80%	71 439	24	1.27 (0.81-1.99)	1.26 (0.79-2.00)	
>=80% to <Med	79 839	33	1.43 (0.94-2.16)	1.43 (0.94-2.18)	
>=Median	233 742	72	1	1	
All	**Total=603,219**	**n=246**			
<40% Median	88 389	57	2.26 (1.59-3.20)	1.67 (1.09-2.56)	1.48 (0.93-2.37)
>=40% to <50%	50 130	24	1.69 (1.06-2.68)	1.36 (0.83-2.23)	1.21 (0.72-2.05)
>=50% to <60%	58 677	24	1.45 (0.92-2.30)	1.25 (0.77-2.01)	1.16 (0.71-1.89)
>=60% to <80%	84 300	36	1.38 (0.92-2.08)	1.24 (0.82-1.89)	1.20 (0.79-1.84)
>=80% to <Med	84 774	33	1.32 (0.87-2.00)	1.25 (0.82-1.91)	1.24 (0.82-1.89)
>=Median	236 949	72	1	1	1

* Weighted analysis

Note: All numbers are random rounded to the nearest multiple of three (minimum cell size 6) as per SNZ protocol; odds ratios calculated prior to random rounding

Comparing the income-injury mortality association for children from employed households with that for all children, there is an overall similar inverse association although the [>=50% to <60%] income group appears to be an outlier (note small numbers of injury deaths). This indicates that there is a significant effect of income on the risk of injury mortality that is independent from labour force status. Adjusting for age, the association appears stronger for all children than for children in the employed stratum.

Figure 29: Multivariable odds ratio for injury mortality for all children and children from households with at least one employed adult by household income (using median household income value in 1991 NZ$ for each category) (model adjusts for age, ethnicity, education, family type, plus labour force status for 'All' children)



5 Modelling the effect of alternative income distributions

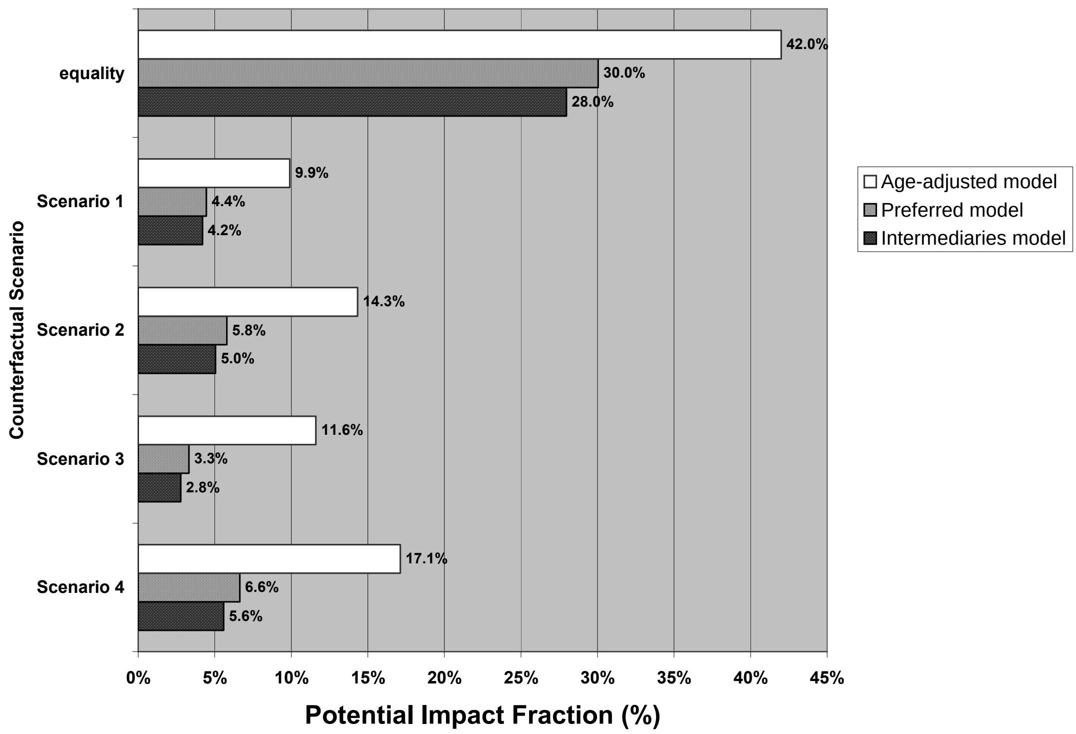
The central thesis of this dissertation is that income has an independent effect on the risk of injury mortality, and that household income can be altered by government policy and practise. This section describes the findings from a modelling exercise that explores the potential impact that different income distributions might have on childhood injury mortality for this study population.

5.1 The effect of alternate income distributions on child injury mortality

COUNTERFACTUAL SCENARIOS OF HOUSEHOLD INCOME CATEGORIES
Scenario 1
[<50% of median] income groups to increase income to [>=50% to 60%] category.
Scenario 2
[<50% of median] income groups to increase income, evenly distributed to other income groups.
Scenario 3
[<60% of median] income groups to increase income to [>=60% to <80%] category.
Scenario 4
[<60% of median] income groups to increase income, evenly distributed to other income groups.

Altering the distribution of household income substantially changes the incidence of injury mortality. The impact varies greatly according to the way the income distribution has changed, and the relative risk estimates used. Figure 30 summarises the proportional reduction in the total number of child injury deaths according to specific changes in the distribution of household income (5 scenarios), using the three modelled estimates of the income-injury mortality relationship. The PIF calculations are detailed in Table 18 (Appendix 2).

Figure 30: The modelled proportional reduction in child injury mortality for 5 alternative income distributions (Potential Impact Fraction) using 3 estimates of relative risks (age-adjusted; adjusted for age, ethnicity, education, family type, and labour force status, the 'Preferred model'; and 'intermediaries model' adjusting for aforementioned variables plus car access, crowding, and NZDep91)



5.1.1 The effect on injury mortality if all children were unexposed

The modelled proportional reduction in child injury mortality for the scenario where all children experience the same risk as the highest income category is substantial (see Figure 30). This indicates the extent of the effect that income contributes to child injury mortality in the total population. Depending on the set of relative risks used in the model, there may be a 28% to 42% reduction in child injury. The best estimate of the likely reduction in injury mortality is 30%. This corresponds to 96 lives that may not have been lost if the total population experienced the same risk of injury as the highest income population group.

5.1.2 The Effect of the Elimination of Child Poverty as Counterfactual Distribution

The effect of removing children from the lowest income groups by increasing income reduces injury mortality, but by a smaller magnitude than in the scenario where all children experience the risk of the wealthiest income category. Depending on the relative risk estimates used and the particular counterfactual scenario, the reduction in injury mortality is between 2.8% to 17% (see Figure 30).

Using the estimated reduction in child injury mortality for the 'preferred' model (i.e. the best estimate of the effect sizes), depending on the counterfactual scenario, there would be a 3.3% to 6.6% reduction in injury mortality. This would translate to a possible reduction of 10 to 21 deaths over the three-year study period.

This is substantially lower than the dramatic effect seen when the entire population has the risk of the highest income category. The reasons for this are: that the exposure (household income less than <150% of median) is present for most of the population; and the risks of injury for the middle-income groups (including the [>=Median to <150% of median] income group) are reasonably similar and all are higher than the reference group. Also, there is a comparably weak inverse income-injury association for these middle groups. Therefore, movement within this band of income groups results in a relatively small change in population injury risk.

5.1.3 The Effect of the Elimination of Poverty by Ethnicity

Assuming that the underlying risk of child injury death by income is the same irrespective of ethnicity, the impact of reducing the numbers of children in low-income groups will vary by ethnic group if there is variation in the distribution of income by ethnicity.

Māori and Pacific Island children are more likely to live in households with lower income, compared to non-Māori non-Pacific children. For both these population groups, the modelled impact of reducing low income is similar and greater than that seen for the total population (see Table 17). Conversely, compared to the impact on the total population, that for non-Māori non-Pacific children is of smaller magnitude. Table 17 also presents the modelled reduction in injury mortality for Māori and Pacific children had both populations experienced the same income distribution as non-Māori non-Pacific children. There may have been a 9% reduction in injury mortality for Māori and Pacific children, had all ethnic groups experienced the same income distribution.

Table 17: Potential Impact Fractions* for 6 counterfactual income distributions on child injury mortality by ethnicity

Counterfactual Scenario	Māori	Pacific Island	Non-Māori non-Pacific
All ethnic groups to experience same observed income distribution as Non-Māori non-Pacific	8.7%	9.3%	0%
Equality	34.5%	35.0%	28.3%
Scenario 1	7.6%	7.9%	3.2%
Scenario 2	8.5%	8.5%	4.4%
Scenario 3	5.9%	6.2%	2.3%
Scenario 4	9.0%	8.9%	5.2%

* Using total population 'preferred' model relative risk estimates.

Chapter 5: Discussion

This chapter will cover a range of issues that have arisen throughout the course of this dissertation. It is clear that the central topics of this dissertation are complex and are the focus of ongoing academic debate and research. This dissertation has concentrated on one aspect (income) of the socioeconomic determinants of childhood injury mortality. Understanding of the pathways of how distal socioeconomic influences determine injury is by no means complete, and is even less so when considering the role of interventions at this level to improve health. This is particularly true for understanding the complex relationships between household income, the individual, the environment and neighbourhood, and societal factors, that all play a role in determining injury mortality. In searching for interventions to reduce child injury mortality, income is one factor that can be modified.

This chapter will cover the following:

- A discussion on how poverty and injury mortality affect New Zealand children.
- The impact of income on child injury mortality in New Zealand from 1991 to 1994.
- The effect of eliminating child poverty and the policy implications from this research.
- The limitations of this study.
- Future areas of research on the issues of income poverty and/or injury using the NZCMS.

1 Poverty

Perhaps one of the most fundamental findings from this dissertation has been the description of the extent and depth of poverty for New Zealand children in 1991. In New Zealand, children are the population group with the highest incidence of poverty, and this increases with increasing numbers of children in the household (many of these families being Māori or Pacific) (Mowbray 2001). We know that children fared poorly over the course of New Zealand's reforms in the 1980s and 1990s, particularly children from one-parent families and Māori and Pacific children (Blaiklock, Kiro et al. 2002; Ministry of Social Development 2003). The proportion of children in one-parent households living in the lowest income quintile increased from 36% to a staggering 79% from 1988 to

1992 (National Health Committee 1998). A recent comparative study on state investment in children found New Zealand to be near the bottom of the league table compared to other OECD countries (Bradshaw and Finch 2002). This high degree of poverty that is a feature of many children's lives is due in part to the low level of state assistance provided to low-income families, particularly large families. New Zealand's social security system has been effective at reducing poverty in the elderly, but not for those with large families (Stephens and Waldegrave 1997; Waldegrave, Stephens et al. 2003).

Of major concern and importance is the disparity in the prevalence of poverty between Māori and Pacific children and non-Māori non-Pacific children. This is not a new finding. The strong association of ethnicity and socioeconomic position has been well documented in New Zealand (Reid, Robson et al. 2000; Salmond and Crampton 2000), particularly so during the period of major socioeconomic reforms in the 1980s and 1990s (National Health Committee 1998; Ministry of Social Development 2003). This was a time of rapidly increasing inequalities. The dramatic increase in the proportion of Māori households in the lowest income quintile from 26% to 43% (28 to 40% for Pacific households) from 1988 to 1992, much greater than that for non-Māori non-Pacific, bears testament to the marked (differential) impact that government policies can have on individual or household socioeconomic positioning (National Health Committee 1998). The disproportional rise in unemployment for Māori and Pacific people is considered a key driver of the rapid increase in the proportion of low-income households (National Health Committee 1998).

So whilst it may not be an unexpected to find that slightly over half of Māori and Pacific children were living in households that had an income less than 60% of the population median household income, it is nonetheless disturbing. One quarter of non-Māori non-Pacific children were living in these circumstances, also unacceptably high.

By focusing on the individual level income, the underlying structural determinants of a family's income level may be obscured. The rapidly changing inequalities in household income described in this section demonstrate how a household's socioeconomic circumstances can be changed by and are vulnerable to the effects (whether intended or unintended) of government policy. The issues facing Māori and the low priority accorded to children in our society are key for New Zealand to address, and remain pertinent to the current day. This will be discussed further with regards to the policy implications of this research (section 4). The changes in the distribution of income that stemmed from the reforms do indicate that there is potential for improvement in ameliorating these disparities.

2 Injury Mortality

Injury in childhood is an important public health issue for New Zealand. It is the most common cause of death for children aged 1 to 14 years (and one of the most common causes of hospitalisation), and New Zealand has high mortality rates compared to other OECD countries (UNICEF 2001). The mortality rates used for the UNICEF comparative study were calculated from 1991 to 1995, covering the period included in this dissertation.

Injury rates have been falling throughout the OECD over the last two decades, although less dramatically for New Zealand (UNICEF 2001). On the reasons for this decline, the UNICEF report postulates, '… *they have been reduced not by some invisible hand of progress but by a long process of research, lobbying, legislation, environmental modification, public education, and significant improvements in accident and emergency services.*' It is interesting that the term 'invisible hand'[8] has also been used in another UNICEF report looking at the negative impact that the economic reforms had on New Zealand children (Blaiklock, Kiro et al. 2002). It is important to point out that child injury mortality has reduced over the period of the reforms (IPRU 2003), despite the observed increase in adverse living standards for many children.

The decline in injury mortality over time may be associated with increasing inequalities in injury risk according to social position. This has already been documented in the United Kingdom (Roberts and Power 1996). This dissertation describes the income gradient in injury death for the early 1990s. Whilst there may now be a lower absolute risk of injury death, it may well have become increasingly socially patterned. Additionally, as injury exhibits one of the steepest social gradients, as injury makes up an increasing proportion of all child deaths due to decreasing mortality from other causes, overall social gradients in total child mortality may increase (Roberts and Power 1996).

As discussed previously, the reduction in injury mortality that has been witnessed over recent years has been due to a number of different interventions. Social inequality in injury is important to monitor to ensure that gains made in injury prevention at least occur for all social groups or disproportionately favour those in low socioeconomic groups who experience the highest risk.

3 Income and Injury mortality

This dissertation finds that income is strongly associated with child injury mortality. Children living in the poorest households experience almost three-fold the risk of injury mortality to children from the wealthiest households. There is a gradient of decreasing risk with each step of increasing income. After adjusting for confounding, the association is somewhat attenuated, but is still present. Children in the poorest households experience an 80% higher risk compared to children from wealthy households.

These findings suggest that money is an important determinant of the social gradient in injury mortality. Disentangling the ‘independent effect’ of income is not easy. How much uncontrolled confounding, bias and chance account for this association will be discussed in the next section. The true income-injury association for this study population may be more or less than that described from this observational study, however it is the most accurate estimate possible with the available data, and it is reassuring that the effect sizes are similar in magnitude to other studies (Singh and Yu 1996).

Mechanisms

So what are the mediating factors in the probable causal relationship between income and injury? They are not restricted to children living in poverty alone; they are also relevant for middle-income households. This dissertation does not fully answer this

[8] Referring to the costless mechanism of market that brings benefits to both consumer and producer, from economist Adam Smith’s 1776 ‘The Wealth of Nations’ economic theorem (Donaldson and Gerard 1993).

question. Adding in possible intermediary variables to the analysis (car access, crowding, NZDep91) made little difference, suggesting that these are not the major explanations for the income-injury association (although the way these variables are measured may influence their effect, for instance NZDep91 may not capture the area-level effects relevant to injury). Other possible mechanisms were suggested in the introductory chapter (see page 17). The literature suggests that these questions are also important for other countries.

Roberts (Roberts and Power 1996) has postulated that the increasing social differential in child injury is due to the differential exposure to injury promoting or injury-protective physical and social environments '*resulting from greater inequalities in income*' and predicts increasing injury differentials with increasing income inequality. Roberts (Roberts 1997) discounts the arguments of artefact, health related social mobility, health related behaviours, differential access to and utilisation of health services or biological factors as adequate explanations of the injury social gradient. Roberts postulates that the low child injury rate in Sweden may be due to their egalitarian society; deducing that tackling socioeconomic inequality itself may be effective in reducing child traffic injury (Roberts, Norton et al. 1996). Whilst Sweden has less inequality and protects those in lower socioeconomic positions, there is still an injury social gradient, although this may be less marked than the social gradient in other less egalitarian countries (Laflamme and Diderichsen 2000; Engstrom, Diderichsen et al. 2002).

Injury is heterogeneous, with a different constellation of causes and potential interventions for different types of injury; there may be some specific types of injury that are more or less strongly socially patterned. Child pedestrian injury, poisoning, and fire injury deaths are likely to have a strong social patterning. These differences could not be specifically explored in this dissertation.

As in England, most child injury deaths in New Zealand are traffic-related. Roberts suggests many mediating factors in this income-injury pathway, for example, there are lower death rates in large, heavy cars and in newer cars with air bags or other safety features. For traffic-related injury, Roberts puts it simply, safety of vehicles is '*rationed on the willingness and ability to pay*' (page 786 Roberts and Power 1996).

Roberts also believes that the social gradient in child injury may partly be mediated by differential exposure to dangerous urban environments, for example from higher traffic volumes and speeds (Roberts, Norton et al. 1996). Roberts states '*children from families with no access to a car receive none of the benefits of car travel, but a greater share of the disadvantages of car travel*' (Roberts, Norton et al. 1996). However it has also been found that there is still an effect of socioeconomic position when adjusting for speed and traffic volume; other mechanisms are working to mediate the socioeconomic position-injury relationship (Roberts, Norton et al. 1995). Nersesian suggests that perhaps poorer emergency infrastructure in poor areas eg fire service and rescue services may also have a role to play (Nersesian, Petit et al. 1985). Alcohol consumption and vehicle age have also been positively associated with motor vehicle death rates, and these factors may be mechanisms through which income can impact on injury (van Beeck, Makenbach et al. 1991).

It has been observed that there are high social gradients in fire-related mortality (Duncanson, Woodward et al. 2002). The type and quality of housing is related to the risk of fire death, there are higher rates of fire death in council housing and temporary accommodation (Duncanson, Woodward et al. 2002). It plausible that crowded living conditions (especially combined with portable heating or unsafe heating appliances) may increases the fire risk. This may be one intervention point to reduce the gradient in injury deaths as housing is also amenable to changes in social policy.

The role of adult supervision may have a role to play in the social gradient of injury. A case control study in Auckland from 1992 to 1994 found a significant effect of adult accompaniment and a reduced risk of child pedestrian injury for children aged 5 to 15 years walking to and from school (Roberts 1995). One may postulate that different employment patterns, for instance shift work or less flexible working conditions may influence the degree of adult supervision available.

The effect of other socioeconomic factors on injury

Whilst income was the socioeconomic factor of interest for this dissertation, there were some interesting findings for other socioeconomic variables. This is particularly so for household education; there was an association of nil household education and a higher risk of injury mortality. There was little social gradient by eduction on injury mortality, rather a threshold effect. This finding suggests that the presence of any level of education is protective.

There also appeared to be a substantially higher risk of injury death for children living in all areas other than the least deprived small-area quintile. This appears to be independent of household socioeconomic circumstances, although there may be some residual confounding. There was a suggestion of a gradient of increasing risk with increasing deprivation, although the highest risk was seen for NZDep91 level 7&8.

Children living in an unemployed household had a much greater risk of injury mortality; this risk persisted once other socioeceonomic factors were taken into account. The higher risk associated with living in a non-labour force household almost disappeared after controlling for other socioeceonomic factors. The higher risk associated with living in a one-parent family also virtually disappeared after adjusting for other socioeceonomic factors.

Ethnicity and injury mortality

It is known that Māori children (and to a lesser extent Pacific children) experience higher rates of injury mortality (Ajwani, Blakely T et al. 2003). This dissertation also found that Māori children had an almost 60% greater risk of injury death than non-Māori; Pacific children had a minimally increased risk. More than two-thirds of the excess risk for Māori children appeared to be due to confounding or mediation by socioeconomic status. For this study, after adjusting for socioeconomic status, Pacific children had a lower risk of injury death compared to non-Māori non-Pacific. This is a complex area. Perhaps the higher rate for Māori children may be related to other factors such as the ongoing effects of colonisation and dispossession from culture. The discussion in Robert's article on the risk of sole parenthood and child pedestrian injury may be relevant to the lower risk for Pacific children found in this dissertation. Robert's postulates that the reduced risk for Pacific children from one-parent families may be related to a protective extended family effect (Roberts 1994).

The effect of income on injury mortality by ethnic group was unable to be sufficiently analysed in this dissertation due to the study power, and issues surrounding collinearity in the regression analyses. Māori children in the poorest income category had a much higher risk of injury than non-Māori, although the risk was similar for other income categories. Once adjusting for confounding, the analysis did not find an association between income and injury among Māori, although this finding should be taken with extreme caution. There is evidence to suggest that controlling for labour force status in this analysis violates the statistical assumptions necessary for logistic regression. Education appears to be especially important for Māori. For non-Māori non-Pacific children there is very little change in the association between income and injury mortality following adjusting for confounding. This dissertation cannot make any robust conclusions on the independent effect of income on injury by ethnic group.

The effect of child age

The term 'childhood' refers to very heterogenenous developmental stages. Developmental stages may occur at different ages for different children. This brings with it different exposure to injury risks which can be seen in the patterns of injury death. For example, infant drowning occurs most commonly in a bathtub; preschool children drown in home pools; adolescent males have the highest rate of drowning of any age-group (possibly due to greater exposure to risk from risk-taking activities; for example, 18% of all 13 to 17 year old drownings are associated in some way with alcohol (WSNZ 2003)); the highest rates of pedestrian injury are seen for 5 to 9 year old children; the peak age for non-traffic pedestrian injury is 2 years; and children aged 5 to 9 years have the highest rate of cyclist injury per kilometre travelled (children aged 10 to 14 years have the highest rates of cyclist injury due in part to the high numbers of kilometres travelled) (IPRU). Traffic-related injury is the most common cause of injury death for all New Zealand children (IPRU 2003).

This dissertation was unable to sufficiently explore differences in the effect of income on injury for children of different ages or of different causes of injury. It is quite possible that there may be variations by age, particularly when considering the different pattern of exposure to risk and the different types of injury that happen at different ages.

Eliminating child poverty

Eliminating child poverty in not an unachievable utopia. It is possible in theory, we know that Sweden has very low rates, and eliminating child poverty is a part of current

Government policy (Ministry of Social Development 2002) (albeit, a policy that is not yet being systematically implemented).

The proportion of child injury mortality attributable to income (i.e. any income category other than the highest) was substantial; approximately one third of injury deaths. This corresponds to a large number of injury deaths, and suggests that with effective interventions, the burden of injury mortality could be significantly reduced. However, the main results of this dissertation would suggest that eliminating poverty alone will not bring about a large reduction in child injury mortality; from 3 to 7% (depending on the way income is changed). The implications of these findings will be discussed in detail in the following section.

Eliminating poverty will have a greater effect for reducing Māori and Pacific child injury death rates due to the greater exposure to poverty that Māori and Pacific children experience. The reduction in injury mortality Māori and Pacific children may be between 6 to 9%. If Māori and Pacific children experienced the same income distribution as non-Māori non-Pacific children, we may expect to see an almost 10% reduction in injury mortality.

The reasonably small reduction in injury mortality from eliminating poverty is perhaps less than one may have expected. The only other study identified that has specifically looked at the impact of low-income (and the effect of eliminating poverty) on the burden of disease was a Canadian study (the Ontario Child Health Study) that investigated the potential effect of eliminating poverty on a large number of child psychosocial outcomes (from ages 6 to 16 years). Their conclusions were that the effect varied for different outcomes and different ages; whilst in general the effect was modest (and less than expected) it was substantial for some specific disorders (conduct disorders, emotional disorders, and psychiatric disorders), with attributable risks up to one third (Lipman, Offord et al. 1996). This study does not appear to have taken the effect of confounding into consideration.

4 Policy Implications

The determinants of injury mortality, and interventions to reduce injury mortality are complex and multi-level and require multi-faceted interventions. The policy implications of the findings presented in this dissertation are complex. Children living in the poorest households have a much higher risk of injury compared to other children. As opposed to a threshold effect alone, where a higher risk of injury is only found below a particular level of income, there is a higher risk of injury for children in all households other than those in the richest income category. Children in households earning incomes just above the poverty line, or in households on middle-incomes have a higher risk of injury mortality compared to children in the highest income category. This means that there is no easy solution for reducing the differences in risk of injury death that is seen for households of different income levels. It is also important to note that the findings of this dissertation are based on using the mortality risk of the highest income category as the reference group. There is potential for imprecision in estimating the mortality risk for this group.

The fundamental conclusion to draw from this research is that money is important in determining the risk of child injury. As a result of living in poverty, some children will die of unintentional injury that would not have, had their household had an adequate income. Eliminating poverty is therefore likely to exert some, albeit modest, effect on reducing injury mortality. Eliminating poverty will bring greater benefits for Māori and Pacific children, and will contribute to reducing ethnic inequalities in injury.

However, eliminating poverty will not be enough to reduce the risk of injury for children living in other income categories; strategies reducing the population risk for injury will also be required. Whilst it is outside the scope of this dissertation to confidently state the place of more specific injury prevention strategies, the rest of this section will speculate on some of these issues in more detail.

Universal or targeted strategies?

These findings lead in to the discussion of the relative merits of population-based intervention strategies (i.e. a universal approach) or high-risk strategies (i.e. a targeted approach). Targeted strategies relevant to this dissertation may be varied, for example, it may involve a targeted increase in income alone; addressing the correlates of low income (broader strategies to address the effects of multi-disadvantage) or a targeted approach at an intermediary step in the income-injury mortality association. Similarly, a population-based approach may involve strategies that modify income per se (such as to reduce income inequality); or population-based strategies working at an intermediary level (such as specific injury prevention programmes). This dissertation suggests that a combined approach using both a targeted (eliminating poverty) strategy together with population-based strategies will be required to reduce inequalities in injury death according to household income.

It is useful to consider the work of Rose (Rose 1985) in discussing these issues. As mentioned, a targeted poverty reduction approach will have some effect on reducing injury mortality. One may speculate that targeted policies addressing the multi-disadvantage that some groups experience may be another approach, although this is outside the scope of this dissertation. For example, this approach may include a range of interventions to address the multi-disadvantage that children in the poorest income categories may experience, for example income support, strategies that encourage a return to education; better systems of parental support; and home visiting by health workers.

There are some disadvantages to a high-risk injury prevention approach. It is reliant on the identification of the high-risk group. New Zealand has not effectively implemented some targeted policies in the past; for example, the uptake of the supplementary special benefit is greatly lower than the numbers of those eligible (Howell, Simmers et al. 2000), and there has been a low uptake of the community services card for subsidised health services for low-income families (National Health Committee 2000). A further major limitation is the limited potential for reducing the population burden of injury (Rose 1985).

This dissertation does indicate that there is a need for population-based strategies if the population burden of injury mortality is to be substantially reduced. Population strategies are especially appealing in that there may be greater potential for improving population health. A population approach helps address the fact that a large number of children (in middle income groups) are exposed to a small increase in risk of injury thereby contributing more to the population burden of injury mortality than the smaller numbers at higher risk (Rose 1985). Population-based strategies have the potential to address a risk factor (in this case having any household income that is lower than the highest income category) that is continuously distributed throughout the population (i.e. there is no threshold above which there is zero associated risk). Population-based strategies are also advantageous in that there is no stigma attached to an intervention; there is no 'victim-blaming' that may be associated with a targeted approach. One disadvantage of a population-based strategy is the 'prevention paradox' i.e. there is only a small benefit for each individual (Rose 1985). This is especially so for a relatively uncommon outcome such as child injury mortality.

What kind of population-based strategies may be beneficial to address the risk of injury associated with every income category other than the wealthiest? This dissertation has modelled a high-risk approach to modifying a risk factor that is distributed throughout the much of the population. Should we modify the population distribution of income as a more effective population strategy? A radical approach to a population strategy to reduce injury mortality would be to move the curve of income distribution for children, to the right. Is this a feasible solution? It could be, given that the New Zealand state has had a history of good family support (including a universal child benefit) until 1986, but now provides comparably less support for children and families (St John 2003). This approach may potentially have a large impact on the population. This population approach 'seeks to control the causes of incidence' as opposed to protecting individuals at high risk (Rose 1985). If this scenario were to occur, an assumption would be that the relative risk estimates calculated for the observed income distribution remain valid for this counterfactual distribution of income.

A further potential limitation of this 'radical' approach, or of an approach to reduce income inequalities by narrowing the distribution of income, may occur because the association of income and injury appears to flatten for the middle-income categories. Movement between these income categories may bring only a small risk reduction. This relatively flat association for the middle-income categories may be artefactual, this study may not have been sensitive enough to detect incremental changes in risk for these income categories.

Given that altering income for the total population may not be practical in the short term, other population-based strategies will be required. This requires greater knowledge of the intermediary steps along the income-injury pathway. Simply put, what is it about living in a wealthy household that keeps children safe, and how can we introduce these measures to less wealthy households? This dissertation cannot answer this, but raises it as a crucial question to be answered if we are to reduce inequalities in injury death by income.

A potentially effective population-based strategy for injury prevention may concentrate on modifying the exposure to risk that is patterned by income. This may include strategies at an urban-planning level that determine traffic calming measures around schools, ensuring that this occurs not only for wealthy neighbourhoods; or in ensuring safe walking or cycling routes to school or reduced speed limits around schools are available in all neighbourhoods. If the intermediary step is predominantly mediated by access to safer vehicles, how can we ensure that all children can be transported in safer vehicles?

Population strategies will need to ensure that they disproportionately benefit the children from the lowest socioeconomic groups and Māori and Pacific children, otherwise social and ethnic inequalities may increase. The previous examples may benefit children from low socioeconomic groups if schools in more socioeconomically deprived areas are more exposed to greater traffic volumes and speeds, with less safe road-crossing options.

If it is found in New Zealand, as in the United Kingdom (Roberts and Power 1996), that the decline in injury mortality over time has disproportionately benefited higher socioeconomic groups, it is worth considering what factors were responsible. An analysis such as this will be especially important for future injury prevention interventions to develop appropriate strategies to reduce risk for low-income groups.

Other considerations

The wider social context is also likely to be important in influencing the income-injury relationship. The different mix of the causal components of injury mortality is likely to vary by population and country. For instance, in an equalitarian society, a supportive and cohesive society with a strong public sector (health, education, welfare) and perhaps a strong safety-promoting culture, individual income may appear to have a lesser role to play in determining injury. The context within New Zealand may be particularly important, particularly around the time of this study with the implementation of major socioeconomic reforms.

The policy implications from this dissertation are relevant only to eliminating poverty as a preventive strategy for reducing child injury mortality. It has not considered the impact that reducing poverty may have on other health or social outcomes, for instance morbidity from infectious disease, or on educational achievement. Similarly, this dissertation has not considered the life-course effects of child poverty on a number of different outcomes. One may speculate that the elimination of poverty may influence a number of different outcomes over a period of time, and perhaps generations. A large number of small effects may add up.

Although the findings are for the period of 1991 to 1994, they provide an indication of the possible magnitude of future reduction in injury mortality that may accompany the successful elimination of child poverty. Whether they are observed across time will be of much interest, particularly if the observed reduction in injury risk over time is associated with increasing inequalities.

Eliminating child poverty

In their paper 'Poverty, Income Inequality and Health', Judge and Paterson conclude that there is clear evidence that poverty is damaging to health, and is especially harmful for children (Judge 2001). They state that '…*practical policies to reduce poverty, especially for families with children, should be an essential ingredient in any concerted effort to tackle health inequalities*'. They also conclude that because of the role of other factors in reducing health for people living in disadvantaged circumstances, that as well as strategies of poverty alleviation, other policies are also required, such as improving education, increasing parental support, and improving employment opportunities. On reviewing the evidence for policy interventions to reduce health inequalities, the authors think '*that the links between individual poverty, community deprivation, and poor health are sufficiently well established to justify a range of measures to reduce the prevalence of low income and worklessness among adults, to tackle child poverty and to regenerate disadvantaged neighbourhoods*.'

This dissertation does not specify the exact way in which poverty should be eradicated. Benzeval and Webb (Benzeval and Webb 1995) state '*any serious attempt to tackle poverty and deprivation in Britain will require a wide range of radical social policy interventions*', and this is also likely to be true for New Zealand. One can conceptualise two approaches: strategies that prevent poverty (i.e. by addressing the causes of poverty), and strategies that mitigate the consequences of poverty (Benzeval and Webb 1995). Strategies that prevent poverty may include policies on the minimum wage; opportunities for training and employment for those who are unemployed; or reducing barriers to employment for single parents (policies addressing the level of abatement of benefits, costs of childcare and so on) (Benzeval and Webb 1995). Benzeval and Webb consider the social security system as a method of reducing the consequences of poverty, but believe this should also be an important component of any poverty reduction strategy. Many families and children will still require social assistance, even if the above strategies are implemented. There are many ways in which social security could be improved to mitigate child poverty, which are outside the scope of this dissertation.

The cost of poverty eradication required for the counterfactual scenarios has not been considered in this dissertation. The amount of increased income necessary to be able to realise the counterfactual scenarios in this dissertation can only be very loosely calculated. The increased income would need to occur for the entire three-year period of interest. Using the median equivalised household income for each household in each income group of interest, the total necessary increase in (equivalised) income can be calculated. To increase all households to the category of 60% to 80% of the median household income, the total annual increase in income would need to be at least $630 million. One may postulate that this amount could be derived from either altering priorities of government expenditure (i.e. necessitating reduced expenditure in other sectors) or increasing total government expenditure, for instance from greater redistribution with a more progressive taxation structure. There will be associated costs from either approach; for example, a reduction in disposable income for the wealthiest families may be associated with a slightly higher risk of injury mortality.

Using the data available in this study to provide a limited insight into the extent of redistribution necessary, a very crude estimation of the reduction in income for those households in the highest income category can be calculated. Redistribution in the real world would not involve only those households with children. 53% of households in the highest income category (>= 150% of median, n= 41,754) would need to move to the next highest category (100% to 150% of median) in order to fund the required increase to eliminate poverty. These children may then be exposed to a higher risk of injury mortality, thereby partly countering the reduction from increasing the incomes of the poorest children. If 41,754 children from the highest income category had the same risk as the second highest category, overall there would be a 1.6% reduction in injury mortality as opposed to a 3.3% reduction without modelling the redistribution of income. However, these analyses are particularly vulnerable to the jump in child injury risk from the [>=150% of median] category to the [100 to 150% of median] category.

5 Limitations of this study

In considering the limitations of this study, this section will first consider in detail the appropriateness of the methodology used, particularly a counterfactual model. Following this, the roles of confounding, bias, and chance on the observed income-injury association, and the areas where the study power was limited will be reviewed.

The counterfactual model

There is a large literature on the theory and methodology of infering causality from observational studies, such as this dissertation (Kaufman and Poole 2000). This dissertation is placed firmly within a 'counterfactual definition of causality' philosophy. Causation is inferred from the difference in effect from changing an observed exposure level to an alternative scenario if all other variables were held constant.

This dissertation looks at how altering an isolated factor, such as household income, may influence child injury mortality. This leads into a complex and controversial area that has featured in the epidemiological literature of late. Many commentators argue that our current conceptual framework for epidemiology is insufficient to describe disease causation and limits the potential to improve public health, requiring a new paradigm (Susser 1998). Those that do not subscribe to this view contend that whilst change may be required, a process of innovative evolution will continue (Winkelstein 1996).

The critique is that modern 'risk factor' epidemiology has focused almost entirely at the individual level of causation. This paradigm is often referred to as the 'causal web', whereby disease causation is conceptualised as multiple proximal risk factors originating at a single (individual) level (Diez-Rouz 1998; Susser 1998). The critique centres on the limitations of 'reductionism', i.e. the search for causal explanations by breaking down complex issues into small 'atomistic' components, assuming that the sum of the individual causal components equals the whole. The search for 'independent' effects, after controlling for confounding factors, may ignore wider and more complex causal phenomena. It is argued that there is a focus on individual, proximal causes at the expense of distal and social causes (Pearce 1996; Susser and Susser 1996; Susser and Susser 1996; Diez-Rouz 1998; Susser 1998; McMichael 1999; Stanley 2002). A further limitation is that if a risk factor (at an individual level) is ubiquitous in the study population, it will not be discovered if only concentrating on the difference risk factor profile of individuals within that population (Schwartz and Carpenter 1999).

So it is argued that a reductionist approach ignores the broader social and ecological context in which disease originates; that is the context in which risk factors arise (Schwartz and Carpenter 1999; Stanley 2002). Whilst I have focuses on a distal determinant of health, (i.e. income), this implies that for this dissertation, individual incomes should not be viewed in isolation from the wider context. Marmot (Marmot 2002) presents an example of this by comparing the high infant mortality rates in York in 1900 for the wealthy classes, compared to infant mortality rates many times lower than this for the lowest socioeconomic groups in 2000. The conditions that the wealthy people in 1900 were exposed to would have been worse than those experienced by the poorest social groups today. The community is richer, and has been able to invest in ways that improves conditions that are important for infant mortality, independent to individual income. Marmot argues that concentrating on individual income alone misses aspects of the standard of living that are available from living in a richer community (Marmot 2002). The challenge is therefore, to develop conceptual models that incorporate the complex and dynamic multi-factorial and multilevel determinants of disease (Diez-Rouz 1998; Susser 1998).

There has been progress in considering causal processes at a group level in social epidemiology, with the large body of literature discussing the role of income inequality over and above individual income. There is also increasing research into neighbourhood effects, adjusting for individual level characteristics (Mackenbach 1998). However, multilevel analysis is complex, and is associated with a number of theoretical and methodological problems (Diez-Roux 1998; Blakely and Woodward 2000; Kaufman and Poole 2000).

Kaufman and Poole (Kaufman and Poole 2000) argue that there has been little progress in formalising an alternative ecological approach to causal analysis. Kaufman and Poole argue '*The emergent properties of causal systems, as distinct from the consideration of multiple discrete actions, remain largely undescribed in any formal sense in the epidemiologic literature, with the possible exception of the population dynamics of infectious disease*'. The authors also propose that a 'diffuse' ecological definition of causation is 'incompatible with the counterfactual definition of causality' (Kaufman and Poole 2000).

The arguments are complex and a full discussion is beyond the scope of this dissertation, however, they do raise interesting questions. A counterfactual model may be appropriate for a study observing the effect on child injury mortality of altering income, as the potential causal factor. It is possible to imagine household income changing with all other variables held constant, such as in the event of an increase in social assistance payments, or by receiving an inheritance or winning a lottery (Rodgers 2001).

However, it may still be argued that using a counterfactual model of causal inference which concentrates on the independent effect of variables does not take into account population dynamics and the 'ecological perspective'. Rather than concentrating on the independent effect of income alone, it would be ideal to include all the complex processes that determine a population's child injury mortality rate (Diez-Rouz 1998). For example, altering income may lead to other changes that influence injury risk for the population, in either direction. The effect on income inequality from altering income distribution may also have an additional effect on the risk of injury over and above the effect at an individual level.

Whilst this dissertation is concerned with the socioeconomic origins of child injury, which may be seen as 'macro level', the task of isolating the effect of low-income as a risk factor for injury could be considered a 'reductionist' approach, and therefore lends itself vulnerable to criticism on the limitations inherent in such a practise. Income may be a little less proximal on the causal pathway than other so-called 'modifiable' risk factors (such as smoking), but remains an individual level risk factor nevertheless. However, this dissertation does move beyond the description of an individual-level risk factor, to explore the impact on the population of a potential policy intervention. The increased risk associated with (low to moderated) income is seen throughout the population. In this way, this dissertation is less susceptible to the criticisms of 'modern' risk factor epidemiology where individual-level risk factor-outcome associations are described, with little regard to a population perspective, and with minimal relevance to improving the public health (Pearce 1996).

A criticism of the empirical 'black box' paradigm is that there is a preoccupation with describing risk factor associations at an individual level without clear understanding of the intervening causal processes (Susser 1998; Schwartz, Susser et al. 1999). Income as a risk-factor for injury mortality may be less prone to this criticisms as it is possible to imagine the causal pathways from income to injury with intervening variables.

Exchangablility

There are other limitations as to the validity of the assumptions inherent within the counterfactual model used in this dissertation. These are issues common for observational studies, as opposed to experimental study designs. The counterfactual model implies that if those people in the lowest income group experienced an increase in income that moved them to a higher income category, ceteris paribus, they would experience the same risk of injury mortality as other people in that group. It is impossible to directly test this hypothesis. Rather, an assumption is required whereby the study individuals are 'exchangeable' i.e. having adjusted for confounding, then any change in the risk of the outcome for an individual from a different level of income exposure is due to this factor alone (Kaufman and Cooper 1999; Blakely and Woodward 2000). Residual (and resonant) confounding can render this assumption invalid i.e. where the observed effect is not due to the change in exposure of interest, but rather occurs because of the effect unmeasured (or mis-measured) confounders. There may well be unmeasured (and mis-measured) confounders in the NZCMS. This dissertation could only adjust for the potential confounders that were measured in the census form.

It is difficult to determine the likely effect of unmeasured confounding in this study. Other measures of social class were not included in the study. Teasing out the effect of income separate to the effect of social class is a difficult task. It may be that other dimensions of social position (for instance occupation) account for some of the changes in effect size that have been attributed to income. Changing income may not alter the change in risk for injury as, although whilst likely to be very correlated, the underlying position in the social hierarchy (and concomitant psychosocial stressors) may not be altered in a way that is associated with injury risk. However, it may also be possible that income is the key aspect of social position that determines injury risk.

There may be unknown individual characteristics that are associated both with an increased likelihood of low income and higher risk of injury. It is impossible to quantify the size of this potential confounding, although this effect is likely to be small and not account for most of the income association found in this dissertation. One characteristic that may be associated with injury death is risk-perception. New Zealand research has found that there was not a difference in risk perception by social class (Roberts and Norton 1994). Where there is a high prevalence of poverty, and difficult economic circumstances (as in New Zealand at the time of this study), there is likely to be less inherent differences between those who are poor, and those who are not (Mayer 1997; Mayer 2002).

There are other potential confounders. Rurality may fulfil the criteria of a confounder: rural versus urban dwelling is likely to be associated with income, it may be independently associated with injury mortality, and may come prior to income on the causal pathway. Urbanisation may confound an income-traffic injury relationship because of better infrastructural road safety measures or medical care in urban areas (van Beeck, Makenbach et al. 1991). Housing is not captured in the study other than overcrowding. As discussed in 1.3.7 as for overcrowding, the type and quality of housing is also likely to reside somewhere along the pathway from income to injury, thereby being an intermediary rather than a confounder. Maternal age was not included in the multivariable models. Maternal age potentially could confound the association between income and injury mortality. For example, young maternal age has been associated with risk of child injury mortality (Scholer, Hickson et al. 1999; Brenner, Overpeck et al. 1999). Young maternal age is also likely to be associated with low income due to either the association with socioeconomic position or from younger women being earlier along in the career path. There may be a small degree of residual confounding by number of children in the household, (for more detail see page 67).

The effect of income on injury mortality is likely to have a shorter time lag than many other disease outcomes that are socially patterned, such as cardiovascular disease. The benefits of an increase in income may be more immediately observed in the case of injury mortality. For instance, increased income may allow for immediate access to safety promoting goods or services, such as being able to afford a current vehicle warrant of fitness. However, it is difficult to assess 'risk reversibility' reliably. At what point does the risk associated with the lowest income group reach that of a higher income group, after an intervention of increasing income?

As well as confounding violating the 'exchangeability' assumption, and the effect of a timelag, there may be other reasons why the risk of injury death may not be reduced as expected following an increase in income. An important assumption is that eliminating poverty will act on all mechanisms through which income causes injury mortality. Which aspect of low-income determining the increased risk of injury will be modifiable by simply giving income? This dissertation assumes that exposure to risk or differential susceptibility can be altered by an increase in income. One can speculate that mechanisms such as altering access to safety-promoting material resources (such as a safer, maintained car) will be modifiable with increased income. The example of a neighbourhood effect, such as poor urban planning and lack of safe playing environments, may not change by increasing an individual family's income. An increase in income that can enable a change in neighbourhood may work to reduce injury risk for that family. However, this solution may not be optimal should the neighbourhood environment be an important cause of injury mortality. Whilst income may determine the exposure, it may be more appropriate to work at a neighbourhood level to reduce the exposure to risk in this situation.

It is also plausible that an increased income may enable greater access to health care services. This may increase exposure to injury prevention messages. It is also plausible that a higher income may reduce psychosocial stress, and enhances the implementation of injury prevention practises, and perhaps enhance the quality of child supervision.

Bias

This dissertation may be prone to a small degree of selection bias, although the magnitude is difficult to quantify. There were different education and NZDep91 associations with injury mortality between the eligible and study population which may suggest that selection bias may be modestly influencing the observed effect sizes in the study population.

As I have discussed earlier (page 72) there is significant potential for misclassification bias, particularly for household income. The census income measurement is assessed from only one census question, and categorised (and assigned the midpoint income of the category) in two different stages, and then equivalised. There is limited definition possible for those households at the top end of the income distribution. Measuring 'current' income at one point in time also introduces greater risk of misclassification. It does not capture long-term income well. This may lead to non-differential misclassification bias, which may bias the effect towards the null.

An additional limitation that may exert a substantial impact is that disposable income after housing costs was not measured on the census and therefore not able to be used as the income measure. New Zealand research has indicated that poverty levels significantly increase once housing costs have been taken into account. For instance, in 1993 using the New Zealand Poverty Measurement Project's definition of poverty, the prevalence of household poverty increased from 10.8% to 18.5% of households after adjusting for housing costs. Sole parent households had poverty levels of 46%, increasing to 72% once housing costs were included (Stephens and Waldegrave 1997). This could significantly underestimate the proportion of households who are living in impoverished circumstances. Many households at the bottom of the income distribution have above average housing expenditure. Additionally, the policy of the socioeconomic reforms that lead to the introduction of market rentals for state houses occurred following the 1991 census was responsible for increasing poverty levels. This would not have been captured in the 1991 census, but will have had a major impact on many of the households in this study (Stephens and Waldegrave 1997).

A household measurement of income does not necessarily mean that resources are appropriately shared amongst household members. There is evidence that females may be disadvantaged in the sharing of household resources, children may also be relatively disadvantaged (Daly, Duncan et al. 2002).

It is also important to note that the income measured for this study happened immediately before significant changes occurred in New Zealand society. The April 1991 benefit cuts that stemmed from the 1991 Budget took effect soon after the census (Blaiklock, Kiro et al. 2002) i.e for many of the households in this study the measured income may well have been higher than what their true income was to be for the following three years. Additionally, the introduction of user-pays for public services, such as tertiary education and outpatient health services, will also have had an impact on the disposable income available. These changes highlight the limitations of using an income measure at one point of time. Around the time of this study, real median equivalent household disposable incomes were decreasing, especially for low-income (and middle-income) households. From 1984 to 1993 the real median equivalent household disposable income reduced by over 17% (mean income by 5.4%). The widening of the income distribution was seen by the increase in the Gini coefficient from 0.255 to 0.303 from the early 1980s to early 1990s (Stephens and Waldegrave 1997).

All of these influences on the accuracy and meaning of the income measurement are likely to have biased the income-injury association towards the null i.e. and underestimate the true income-injury association.

Misclassification of the injury mortality outcome is an uncommon occurrence in children, and is particularly unlikely in this dissertation as all analyses group all specific causes of unintentional injury together (Moyer, Boyle et al. 1989; Roberts 1997). An accurate and complete death certificate is important in ensuring accurate injury mortality data. Misclassification may occur, but this is usually more of a problem for the elderly, and is more likely to occur in the more detailed coding for specific causes of unintentional injury death (for example, the fourth digit of the ICD-9 code) (Moyer, Boyle et al. 1989; Roberts 1997). Misclassification of the socioeconomic census variables is more likely to be a significant issue.

Chance

The role of chance in generating the observed income-injury association has already been discussed in the Results chapter. Whilst some of the point estimates of injury risk for each income category included one, the statistical test of trend for the association was highly statistically significant. The results are also consistent with and similar in magnitude to other studies that have investigated this association.

The main limitation in study power has meant that the 'independent' income-injury association has not been able to be well characterised for different demographic strata, particularly by ethnicity, and also age. The influence on labour force status, particularly for Maori, has proven to be most complex. This dissertation has reached the limit on what can be achieved in exploring these important areas.

Conclusion

In summary, despite the limitations of the counterfactual model used in this dissertation, in the absence of an alternative well-formed systems-based method to test these hypotheses from observational studies, there remains an important role for counterfactual methodology. Until social epidemiology has further developed more sophisticated methods of analysing observational studies, pervasive social inequalities in health remain and demand action. Whilst there are limitations on the estimating the exact magnitude of risk reversibility from an increase in income, it does enable greater understanding on the influence of household income on injury mortality. It helps predict the likely effect of interventions that increase income on child injury mortality. This is important for public health where there are many different options for interventions, and finite resources available. It is also useful to remember that not only could the income effect be overestimated (from residual and resonant confounding) but it could also be underestimated due to non-differential misclassification bias that reduces the effect size towards the null.

6 Conclusion

This dissertation finds that household income is a risk factor (and potential intervention point) for child injury mortality. Whilst those children living in poverty have the highest risk of injury death, they make up a relatively small proportion of all injury deaths that can be attributed to having an income below the highest level. This suggests that interventions to reduce injury deaths should include a balance of targeted and universal strategies. Eliminating child poverty is likely to have a modest impact on reducing child injury mortality, but there are other reasons why our society should be striving to eliminate child poverty.

Future directions

Possible future directions in using the NZCMS to investigate child injury and/or income as a determinant of mortality include:

- Monitoring socioeconomic gradients in child injury mortality over time.
- Further analyses of socioeconomic gradients in injury mortality to provide better definition of the slope and shape of the gradient; particularly by sex, age, ethnicity or by cause-specific injury (this may be possible by pooling all four census cohorts to increase study power).
- Investigating the contribution of inequalities in injury mortality to the socioeconomic gradient in total child mortality.
- Linking NZCMS findings to intervention-based research to mitigate socioeconomic gradients in injury. This may include further work on the effect of neighbourhood on injury mortality.
- Investigating the role of income on other outcomes, such as adult injury mortality or other causes of child mortality.
- Developing more sophisticated income modelling procedures.
- Supporting further longitudinal studies using improved income and other socioeconomic data.

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Appendix 1

CDC Framework for presenting injury mortality data*

Mechanism/Cause	**E code**
Cut/pierce	E920.0-.9
Drowning/submersion	E830.0-.9, E832.0-.9, E910.0-.9,
Fall	E880.0-E886.9, E888
Fire/burn *Fire/flame* *Hot object/substance*	E890.0-E899, E924.0-.9 *E890.0-E899* *E924.0-.9*
Firearm	E922.0-.9
Machinery	E919.0-.9
MV traffic *Occupant* *Motorcyclist* *Pedal cyclist* *Pedestrian* *Unspecified*	E810-E819 (.0-.9) *E810-E819 (.0-.1)* *E810-E819 (.2-.3)* *E810-E819 (.6)* *E810-E819 (.7)* *E810-E819 (.9)*
Pedal cyclist, other	E800-E807 (.3); E820-E825 (.6); E826.1,.9; E827-E829 (.1)
Pedestrian, other	E800-E807 (.2); E820-E825 (.7); E826-E829 (.0)
Transport, other	E800-E807 (.0,.1,.8,.9); E820-E825 (.0-.5,.8,.9); E826.2-.9; E831.0-.9, E833.0-E845.9
Natural/environmental	E900.0-E909, E928.0-.2
Overexertion	E927
Poisoning	E850.0-E869.9
Struck by/against	E916-E917.9
Suffocation	E911-E913.9
Other specified, classifiable	E846-E848, E914-E915, E918, E921.0-.9, E923.0-.9, E925.0-E926.9, E929.0-.5
Other specified, not elsewhere classifiable	E928.8. E929.8
Unspecified	E887, E928.9, E929.9

*CDC National Center for Injury Prevention and Control, source: Centres for Disease Control 1997

Appendix 2

Table 18: The effect of four different counterfactual income distributions on child injury mortality, using three models of relative risk estimates. Potential impact fraction (PIF) calculated as: (observed $\sum P_x RR_x$ - counterfactual $\sum P_x RR_x$)/observed $\sum P_x RR_x$

Equivalised household income	*OBSERVED*			*SCENARIO 1*		*SCENARIO 2*		*SCENARIO 3*		*SCENARIO 4*	
	Population distribution (P)	**RR Estimate**	**P*RR**	**Population distribution (P_1)**	**P_1*RR**	**Population distribution (P_2)**	**P_2*RR**	**Population distribution (P_3)**	**P_3*RR**	**Population distribution (P_4)**	**P_4*RR**
Age-adjusted model											
<40% Median	0.147	2.81	0.412	0	0	0	0	0	0	0	0
>=40% - <50%	0.083	2.10	0.175	0	0	0	0	0	0	0	0
>=50% - <60%	0.097	1.81	0.176	0.327	0.592	0.126	0.229	0	0	0	0
>=60% - <80%	0.140	1.72	0.240	0.140	0.240	0.181	0.312	0.467	0.803	0.208	0.357
>=80% - <Med	0.141	1.65	0.232	0.141	0.232	0.182	0.301	0.141	0.232	0.209	0.345
>=Med - <150%	0.236	1.41	0.333	0.236	0.333	0.307	0.432	0.236	0.333	0.351	0.495
>=150% Median	0.157	1	0.157	0.157	0.157	0.203	0.203	0.157	0.157	0.233	0.233
$\sum P_x RR_x$			1.724		1.554		1.477		1.524		1.429
PIF (%)					9.9%		14.3%		11.6%		17.1%
Preferred Model†											
<40% Median	0.147	1.83	0.268	0	0	0	0	0	0	0	0
>=40% - <50%	0.083	1.49	0.124	0	0	0	0	0	0	0	0
>=50% - <60%	0.097	1.43	0.139	0.327	0.467	0.126	0.181	0	0	0	0
>=60% - <80%	0.140	1.48	0.207	0.140	0.207	0.181	0.268	0.467	0.691	0.208	0.307
>=80% - <Med	0.141	1.52	0.214	0.141	0.214	0.182	0.277	0.141	0.214	0.209	0.317
>=Med - <150%	0.236	1.36	0.321	0.236	0.321	0.307	0.417	0.236	0.321	0.351	0.477
>=150% Median	0.157	1	0.157	0.157	0.157	0.203	0.203	0.157	0.157	0.233	0.233
$\sum P_x RR_x$			1.429		1.366		1.347		1.382		1.335
PIF (%)					4.4%		5.8%		3.3%		6.6%
Intermediaries Model‡											
<40% Median	0.147	1.75	0.256	0	0	0	0	0	0	0	0
>=40% - <50%	0.083	1.40	0.116	0	0	0	0	0	0	0	0
>=50% - <60%	0.097	1.37	0.133	0.327	0.448	0.126	0.173	0	0	0	0
>=60% - <80%	0.140	1.43	0.200	0.14	0.200	0.181	0.259	0.467	0.667	0.208	0.297
>=80% - <Med	0.141	1.49	0.209	0.141	0.209	0.182	0.272	0.141	0.209	0.209	0.311
>=Med - <150%	0.236	1.34	0.316	0.236	0.316	0.307	0.411	0.236	0.316	0.351	0.47
>=150% Median	0.157	1	0.157	0.157	0.157	0.203	0.203	0.157	0.157	0.233	0.233
$\sum P_x RR_x$			1.388		1.33		1.318		1.35		1.311
PIF (%)					4.2%		5.0%		2.8%		5.6%

† Preferred regression model: adjusted for age, ethnicity, education, family type, labour force status.
‡ Intermediaries regression model: preferred model plus adjusting for car access, crowding, NZ Dep.