TRAFFIC RELATED INJURIES AMONG YOUNG PEOPLE IN SCOTLAND – AN EPIDEMIOLOGICAL PERSPECTIVE

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ABBREVIATIONS

ACT	Australian Capital Territory
BAC	Blood alcohol concentration
CHIRPP	Canadian Hospitals Injury Reporting and Prevention Project
DALY	Disability adjusted life year
EU	European Union
EURORISC	European Review of Injury Surveillance and Control
GRO	General Registrar's Office
HIH	Highest income householder
ICD	International Classification of Disease
ICE	International Collaborative Effort (on injury statistics)
IRTAD	International Road Traffic Accident Database
ISD	Information and Statistics Division
NTS	National Travel Survey
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
PAF	Postcode address file
PHRED	Public Health Research Education and Development
RCT	Randomised controlled trial
SCIEH	Scottish Centre for Infection and Environmental Health
SHS	Scottish Health Service
SMR1	Scottish Morbidity Record 1
STATS19	Statistics 19
SWOT	Strengths, Weaknesses, Opportunities, Threats
TRI	Traffic related injury
WHO	World Health Organisation

SUMMARY

Introduction Traffic related injury (TRI) is a common cause of mortality and morbidity among young people in the industrialised world. However, there are few epidemiological studies specifically examining TRIs among young people to establish whether this is also the case in Scotland. Further, there has been recent interest in the injury field in developing new methods of data synthesis and analysis using existing data sources. There are two population-based official data sources in Scotland that could be used to build an epidemiological picture of TRIs among young people.

Aim The aim of this study was to examine the trends and patterns of TRIs among young people (15-24 years) in Scotland. The study had four key objectives. Firstly, to examine the temporal and socio-economic trends in TRIs among Scottish young people. Secondly, to compare TRI rates in Scottish young people with their European Union counterparts. Thirdly, to establish the location, time and circumstances in which TRIs occur. Lastly, to establish the completeness of official data sources using capture-recapture and to calculate ascertainment-corrected rates. Ten research questions were formulated to address these objectives.

Method Mortality and hospital discharge (SMR1) data coded as injuries were obtained from the Registrar General for Scotland and the Information and Statistics Division (ISD) of the Scottish Health Service for 15-24 year olds between 1986 and 1995. STATS19 data were obtained for the last study year (1995) for all police-reported TRIs occurring in Scotland for casualties aged 15-24 years. Corresponding data on fatal TRIs for other countries in the European Union (EU) were also obtained. A range of analytical techniques was used including linear regression to examine trends in TRIs, bivariate analysis and logistic regression to examine the characteristics of fatal (compared to non-fatal) injuries. The two-list capture-recapture technique was used to assess the completeness of the datasets and to calculate ascertainment-corrected rates of TRIs among young people in Scotland.

Results TRIs accounted for over one third of all injury deaths (39%) between 1986 and 1995. However, there was a significant linear decrease in these fatalities over the study period. Rates in Scotland appear to be around average for the EU, but are higher than those observed elsewhere in the UK. Motor vehicle occupant (driver or passenger) fatalities accounted for more than half of the TRI fatalities. A disproportionate number of males and young people

residing in more affluent areas sustained TRIs. However, those residing in areas of relatively greater deprivation were more likely to sustain TRIs as pedestrians. Traumatic brain injury was the principal diagnosis among young people admitted to hospital and the leading cause of death after admission to hospital. Two-thirds of fatalities received multiple injuries. Logistic regression shows that fatalities were more likely to occur in fine weather, when the roads were wet, and when the speed limit was either 60 or 70 miles per hour. Ecological epidemiology suggested that a decline in pedestrian injuries may be associated with a decline in exposure to risk. A decline in non-fatal TRIs among vehicle occupants was evident despite an increase in annual journeys and annual distance travelled.

Capture-recapture analysis conducted for the final study year 1995 (using a justifiable relaxation of matching criteria) suggested that the data on fatal injuries are over 90% complete for both the Scottish Health Service and STATS19 data sources. The procedure generated an ascertainment-corrected rate of fatal TRIs of 104 (CI95 103-105), only slightly higher than the cases identified in the two datasets (97 and 99 respectively). However, the completeness of the non-fatal TRI data was 74% for the Health Service Data and 66% for the STATS19 data. The ascertainment-corrected number of non-fatal TRIs was calculated as 1969 (CI95 1932, 2006). This compares to 1458 in the Scottish Health Service data and 1290 in the STATS19 data. There were some biases identified in the data sources. Females and cyclists were under-represented in the STATS19 database.

Conclusions The study clearly demonstrates that TRIs were the leading cause of injury mortality and a significant contributor to injury morbidity in Scottish young people between 1986 and 1995. This reflects findings from elsewhere in the industrialised world. There appear to be sound economic and social reasons for investing in TRI prevention and the study identified those most at risk. The available evidence on approaches to prevention is relatively weak. Some of the environmental approaches and multi-disciplinary approaches to prevention show promise and could potentially be used to tackle further the relatively high rates of TRIs among young people identified in this study.

The capture-recapture exercise clearly demonstrated that data on fatalities from either official source can be used with confidence. However, the databases holding information on non-fatal (serious) TRIs are less complete and users of these data should be aware of this limitation and the biases inherent in each data source. The ascertainment-corrected rates calculated using the

capture-recapture technique should be viewed with caution. Using capture-recapture in human epidemiology challenges some of the underlying assumptions associated with the technique including the need for a 'closed' population, the relationship between the datasets and requirement for equal probability from capture to recapture.

ACCOMPANYING MATERIAL

The publications listed below were produced by the author while preparing this thesis. The thesis disaggregates and analyses data collated by the author for the purposes of the European Commission funded European Review of Injury Surveillance and Control (EURORISC) study. These data (on injury mortality among young people in the European Union) were published in the Journal of Adolescent Health in 1999. The second publication is a direct result of the capture-recapture exercise undertaken for the purposes of this thesis. Both papers were peer reviewed. These are provided in Appendices 1 and 2.

Morrison A, Stone DH and the EURORISC Working Group (2000) Trends in injury mortality among young people in the European Union: A Report from the EURORISC Working Group. Journal of Adolescent Health 27 (2): 130-135.

Morrison A, Stone DH. (2000) Capture-recapture: a useful method for counting traffic-related injuries. Injury Prevention 6: 299-304.

PREFACE

This thesis comprises 10 chapters.

Chapter 1 provides a general overview of the global trends and patterns of injury experienced during the twentieth century. The key determinants of injury are described, and the effectiveness of preventive measures is discussed.

Chapter 2 specifically addresses traffic-related injuries (TRIs). Key determinants of TRIs are discussed, including the respective roles of alcohol and other drugs. The economic and social costs of TRIs are considered and a brief overview of the principal prevention approaches and their known effectiveness is presented.

Chapter 3 identifies the data available on TRIs and transport in Scotland. It also describes the international data sets that include information on Scotland. Sources of exposure data are also explored.

Chapter 4 introduces the capture-recapture technique and charts the development of the technique in human epidemiology and injury epidemiology specifically. A brief overview of the specific studies that have adopted this technique in the field of injury research is provided. There is also a discussion of the strengths and weaknesses of the technique and their relative impacts on its use.

Chapter 5 sets out the study aim and objectives. The objectives are supported by ten key research questions with associated null hypotheses. The rationale for the study is also presented.

Chapter 6 identifies the data sources and the techniques used to answer the ten key research questions set out in the previous chapter. A summary of the data used in the study is provided in this chapter.

Chapter 7 comprises the results of the epidemiology completed to answer the first four research questions. It examines the trends in total fatal and hospitalised TRIs between 1986 and 1995. Age specific rates of TRIs are then presented to allow comparison of Scottish rates

with those of other countries in the European Union. The Scottish data are disaggregated further to examine TRI trends by road user type. Finally, patterns in rates by sex and socio-economic status are examined for all TRIs and for motor vehicle occupants and pedestrians specifically.

Chapter 8 presents the results of further analyses to answer research questions 5-8. It examines the types of injuries sustained, the location, timing and circumstances around fatal and non-fatal TRIs and attempts to identify the factors that characterise fatal injuries. Finally, an exploratory examination of the correlations between TRI incidence and transport trends is presented.

Chapter 9 comprises the results of the final two research questions. Using the capture-recapture technique, it examines the extent to which the two official data sources on TRIs overlap and calculates ascertainment-corrected rates of TRIs. An analysis of the 'Strengths, Weaknesses, Opportunities and Threats' (SWOT) of the capture-recapture procedure is also presented.

Chapter 10 draws together the results of the study, discusses these in the context of the international research literature and takes a critical view of the study methods. Eight key recommendations are presented.

A SHORT NOTE ON TAXONOMY

'Accident' or 'Injury'?

A shift in the taxonomy used to describe externally caused physical injuries has occurred in recent years. The use of the term 'accident' is now considered detrimental to the aims of injury prevention professionals. The term 'accidents' suggests these are chance, random, and unpredictable events. However, the early work in injury research clearly demonstrated that injury has an epidemiological pattern that requires a structured preventative approach (Haddon 1970; Gordon 1949; Press 1948). More recent research evidence confirms that seasonal, geographical and socio-demographic variations in injury incidence are consistently observed in Scotland and other countries (Morrison, Stone and the EURORISC Working Group 1999a; Murray, Lopez, 1997b; Singh, Yu 1996). Increasingly 'accident' has been replaced by the term 'injury', which is neutral with respect to cause, intention and predictability.

Injuries can be described as 'intentional' or 'unintentional'. The use of the term 'injury' rather than 'accident' also affects the range and scope of study. 'Accident' suggests a lack of intent. However, injuries are sometimes the result of an intentional event. The term 'injury' encompasses a wider range of events, to include intentional injuries such as suicide and self-inflicted injuries, assault and homicide. Moreover, 'accidents' refer to a large number of varied events that do not necessarily result in physical injury.

Conceptually, the public and the media strongly differentiate between 'accidental' and 'non-accidental' injury. However, recent advances in the injury field have encouraged the conceptualisation of a continuum between these. Thus, for the purposes of this thesis, the term 'unintentional injury' rather than 'accident' is adopted as far as possible throughout. Further, instead of the traditional 'road traffic accident' (RTA) the phrase 'traffic related injury' (TRI) is preferred and used throughout.

Chapter 1 OVERVIEW OF INJURY

'Injury is probably the most under recognised major public health problem facing us today' National Committee for Injury Prevention and Control, USA (1989)

This chapter provides a brief overview of the global trends and patterns of injury experienced during the Twentieth Century. The key determinants of injury are described, the estimated costs of injury are outlined and the effectiveness of preventive measures is discussed.

1.1 The Epidemiology of Injury

The Oxford Dictionary of Epidemiology defines 'epidemiology' as the study of the distribution and determinants of health and disease in human populations (Oxford University Press 1995). With increasing awareness that injuries are not simply random events, but are predicable and preventable, the epidemiology of injury has increasingly been practised. Press, Gordon and Haddon clearly demonstrated that injury has an epidemiological pattern that requires a structured approach to its prevention (Haddon 1970; Gordon 1949; Press 1948).

There are a number of recent examples of national and international epidemiological studies that have examined the phenomenon of injury in a European and world-wide context. These studies concur with earlier research that shows injury does indeed have an epidemiological pattern. The International Collaborative Effort (ICE) on Injury Statistics has studied the epidemiology of injury in an international group of representative countries. The WHO Global Burden of Disease study examined mortality and morbidity from all causes worldwide, including injury. Finally, a component part of the European Commission funded 'European Review of Injury Surveillance and Control' (EURORISC) was to describe the epidemiology of injury in European Union (EU) Member States.

The Global Burden of Disease study clearly demonstrated that injury is indeed a global public health problem. In 1990, an estimated five million people world-wide died as a result of an injury or poisoning (Murray, Lopez 1997a). This accounted for 10 per cent of deaths from all causes that year and over half of the estimated 898 million years of life lost in 1990 due to premature death (Murray, Lopez 1997b). Mortality rates for ischaemic heart disease, cerebrovascular disease and cancer are higher, however the average age of those

dying from these diseases is substantially higher than for injury. In 1990, five of the twenty-five leading causes of mortality world-wide were externally caused injuries: traffic-related injuries (TRIs), self-inflicted injuries, violence, drownings and war injuries (Murray, Lopez 1997b). The importance of TRIs, suicides and violence as causes of mortality is projected to rise by 2020 (Murray, Lopez 1997d).

The decline of communicable disease as a major cause of mortality has contributed to the emergence of injury as a major cause of premature mortality in many countries, particularly among young people (Berger, Mohan 1996). However, the decline of these diseases is not the sole reason injury has emerged as an important cause of both mortality and morbidity. In the Twentieth Century, the processes of urbanisation, industrialisation and motorisation have occurred in many countries of the world, resulting in an increase in injuries such as TRIs, occupational injuries and house fires. This may be a particular problem in low income countries because these processes have occurred without the associated and necessary improvements in economic conditions, health and safety legislation and national infrastructure (Berger, Mohan 1996).

World-wide, the major causes of injury are TRIs, falls, drownings, poisonings, suicides and other violent causes (World Health Organisation 1995). However, the nature, extent and severity of injury varies according to socio-demographic, cultural and geographical differences (Murray, Lopez 1997b). For instance, while TRIs are the major cause of death among young people, falls are the major cause of death in the elderly. Suicide is a major cause of death in Northern Europe, Australia and China, while in the United States, Latin America and the Caribbean, homicide and other violent causes are more common (Murray, Lopez 1997b; U.S Department of Health and Human Services 1997; Day, Sherrard 1996; World Health Organisation 1995). Intentional injuries resulting from war are the leading cause of death from injury in sub-Saharan Africa (Murray, Lopez 1997b).

As part of the aforementioned EURORISC study (undertaken by the present author and colleagues) an analysis of injury mortality in the EU between 1984 and 1993 was completed. This demonstrated a decline in all-age injury mortality (including both intentional and unintentional injury) between 1984 and 1993 in all 15 EU member states (Morrison, Stone and the EURORISC Working Group 1999a). Approximately 190,000 deaths are caused each year in the EU by injuries, and many more non-fatal injuries result in either permanent or temporary disability. Despite the declining trend, the study highlighted the importance of injury as a cause of mortality in the EU. The majority (72%)

of injury fatalities were as a result of an unintentional injury, a further quarter died as a result of suicide or self-inflicted injury, and the remaining fatalities were due to homicide and other violent causes. An examination of the contribution of each age group to the overall age-standardised injury mortality rate showed that adolescents, and those over the age of 65 years, were at relatively greatest risk of sustaining a fatal unintentional injury.

Injury is not only a major cause of mortality, but also of long and short-term disability. Globally, an estimated 78 million persons are disabled annually as a result of sustaining an injury (Berger, Mohan 1996) and represent 14.5% of disability adjusted life years (DALYs) in developed areas and 15.2% of DALYS in developing areas (Murray, Lopez 1997c). By the year 2020, DALYs due to both unintentional and intentional injuries are projected to increase from 11.1% to 13% and 4.1% to 7.1% respectively of the world-wide total (Murray, Lopez 1997d). In the United States, for every one death due to an injury in 1992, 19 people were admitted to hospital, 233 were given treatment at an emergency department and 450 were treated by their physician after sustaining an injury (US Department of Health and Human Services 1994). This brought the total to over 100 million medically attended injuries. Over a quarter of all physical impairments were due to injuries in the US in 1990 (National Center for Health Statistics 1991). The EURORISC study estimated that there were approximately 4.5 million hospital admissions due to injury in the EU annually (EURORISC Working Group 2000).

1.2 Determinants of injury

1.2.1 Age

Age plays a major role in determining the nature, frequency and severity of injury. In most countries of the world where injury incidence has been calculated or estimated, injury incidence is highest among children, young people and the elderly. (Berger, Mohan 1996; World Health Organisation 1995). The leading causes of injury death vary widely by age group, probably reflecting both risk exposure and risk behaviour.

Injury is the commonest cause of sudden death and hospital attendance among children in the UK (Jarvis, Towner 1998). Injury and poisoning deaths accounted for nearly one in five of all childhood deaths in England and Wales in 1995 (Roberts, DiGueseppi, Ward 1998) and one in seven deaths in Scotland between 1981 and 1995 (Morrison, Stone, Redpath et

al 1999b). Studies suggest that children have a unique profile of risks because they are unable to recognise and avoid many potential hazards on their own. The major causes of fatal injuries among children are TRIs (predominantly pedestrian injuries), drowning, fire and flame-related injuries, falls and poisonings and ingestions. (Morrison et al 1999b; Roberts et al 1998).

Injuries are also the leading cause of mortality and morbidity among young people in many industrialised countries, including the UK (Morrison, Stone and the EURORISC Working Group 2000; Laraque, Barlow, Durkin 1999; Langley, Smeijers 1997; Fraser 1996; Fingerhut, Annest, Baker et al 1996; Wayne Sells, Blum 1996; Singh, Yu 1996; Barker, Power 1994). In the United States, injuries account for 80% of all deaths among young people aged 15-24 years and constitute the single most expensive health problem (U.S. Department of Health and Human Services 1997). In the European Union, injuries represent over two-thirds of fatalities in 15-24 year olds, with TRIs causing over 80% of all fatal injuries between 1984 and 1993 (Morrison et al 2000).

TRIs are frequently cited as the most common cause of fatal injury in adolescents (Langley, Smeijers 1997; Fingerhut et al 1996; Wayne Sells, Blum 1996; Paulson 1988). A downward trend in TRIs has, however, been observed in many countries (Singh, Yu 1996; Elmen 1994). In contrast to the child population, TRIs among young people are predominantly sustained by vehicle occupants and by motorcyclists (Langley, Smeijers 1997, Fingerhut et al 1996). Reasons given for the high rates of injury incidence among this age group include risk behaviour, inexperience and stress (Spirito, Rasile, Vinnick et al 1997; Slap, Chaudhuri, Vorters 1991; Farrow 1985).

Surveys of injuries in adolescence also show that a relatively high proportion of adolescents sustain minor injuries (Currie, Williams, Wright et al 1996; Fraser 1996; Yacoubovitch, Lelong, Cosquer et al 1995). A longitudinal study conducted in Paris schools showed that 10% of those surveyed had sustained an injury that resulted in absence from school for at least two days or non-participation at physical education classes for at least 14 days (Yacoubovitch et al 1995). After a year, 13% of these students were still impeded by their injury. In a survey of Scottish students aged 11,13 and 15 years, over

90% reported sustaining an injury in the past year (Currie et al 1996). Forty-two percent received formal medical attention (either at a hospital or from a medically qualified person).

Injury mortality and morbidity rates are also relatively high in the elderly (World Health Organisation 1995). The normal ageing process appears to lead to an increase in injury risk, particularly in relation to falls. Between 1984 and 1993, almost half of all injury deaths recorded in the European Union were sustained by those over 65 years of age (Morrison, Stone 1998). Falls were the major cause of these injuries, accounting for almost two-thirds of fatalities. Co-morbidity and recurrent trauma are further problems among the elderly population (McMahon, Schwab, Kauber et al 1996; Gubler, Maier, Davis et al 1996). Research suggests that previously injured elderly people are at greater risk of further injury than their non-injured counterparts (Gubler et al 1996). The problem of injury amongst the elderly is particularly pertinent in the industrialised world, which is facing the social and health dilemmas brought with an ageing population.

1.2.2 Sex

In many countries of the world, a higher incidence of injury among males has been observed (Morrison et al 1999a; U.S. Department of Health and Human Services 1997; Currie et al 1996; Jarvis, Towner, Walsh 1995; Alexander, Somerfield, Ensminger et al 1995; Nixon, Clacher, Peam et al 1987). World-wide, approximately 75% of injury victims are male, with injuries accounting for approximately 12% of male deaths and 7% of female deaths (Murray, Lopez 1997b). Studies examining gender differentials for specific injury causes have also concluded that a disproportionate number of males sustain injuries at all ages up to 65 years, (Morrison et al 1999a; Rivara, Thompson, Thompson 1997; Kraus, Gerken Hooten, Brown et al 1996; Robertson 1992) and in both rural and urban settings (Alexander et al 1995).

The reasons for this remain unclear. Explanations have ranged from biological to social (Womens Unit 2000). Some authors argue that males are hormonally primed to be more active and aggressive, while others consider the key to lie in risk behaviour and risk exposure. The latter explanation suggests that males, throughout life, take more physical risks, both recreational or occupational. A cohort study of rural high-school students in

Maryland showed that gender was a risk factor for injury and that this was explained partly by risk-taking behaviours, school-related delinquency and levels of physical exercise (Alexander et al 1995).

1.2.3 Socio-economic status

Despite remarkable improvements in health for the population as a whole in the twentieth century, inequalities in health remain (Mackenbach 1995). The association between health and socio-economic status is well established. Socio-economic status also plays a major role in determining the nature, frequency and severity of injury (MacIntyre 1994).

Research from England and Wales suggests that child fatality rates from injury and poisoning have fallen in both sexes and all social classes (Roberts, Power 1996). However, the decline in those of lower social class has been much smaller, resulting in widening socio-economic differentials in injury mortality. Data suggest that this may not be the case in Scotland (Morrison, Stone, Redpath et al 1999c). While there appears to be no widening of the differentials in injury rates between the most and least deprived in Scotland, a significant difference in mortality rates between these groups persists. In most studies of the relationship between socio-economic status and non-fatal injuries in children, an association has been observed, while in a minority of studies such a relationship has not been found, or is only found in cases of severe injury (West 1997).

In studies of adolescent injury, there is no conclusive evidence that socio-economic differences in incidence exist. In a survey of Scottish school children there was no significant difference in total injury incidence between social groups (Williams, Currie, Wright et al 1996). A prospective cohort study of 1245 students aged 12-16 years old in Pennsylvania found no differential risk of injury by socio-economic group (Anderson, Dearwater, Olsen et al 1994). Information on socio-economic status for this study relied upon census information on township of residence and self-reported parental occupation. The same result was observed when examining injury location and injury type. In a longitudinal study of adolescent injury and 'close calls' in Carolina, USA, no significant relationship was found between risk-taking behaviour and socio-economic status (Cobb, Cairns, Miles et al 1995). In this study, gender, ethnicity and aggressive behaviour in childhood were risk factors for unintentional injury.

A possible explanation for these findings has been offered (West 1997). While health inequalities are often regarded as a constant and immovable feature of the life course, West has suggested that these inequalities 'equalise' in early youth due to the effects of secondary schooling, peer group and youth culture at this stage of a young person's development. It is proposed that this 'equalisation' is short-lived, with inequalities once again evident in later youth (post-school). This may (at least partly) explain why mortality due to injuries is less social class differentiated in early youth compared with all other stages of the life-cycle.

It should be noted that these studies employ different definitions of 'social class' and 'socio-economic status'. The main difference is that some studies use individual measures (frequently using classifications of occupation) of social class, while other studies use area-based measure of social class (frequently assessed using a number of individual and area characteristics). This may, in part, account for the differences in findings between studies. In Scotland, the Carstairs system adopts a measure of area deprivation and is, to a great extent, considered a more useful measure of socio-economic status (Carstairs 1991). Critics of the area-based measure point to the confounding caused by group characteristics ascribed to those who are not necessarily part of that group. For example, in rural areas of Scotland car ownership is high, but not necessarily a marker for 'higher' socio-economic status. Rather, car ownership is a necessity. However, the area-based measures do address some of the difficulties with individual measures using classifications based on occupation, in particular the classification of single parents.

1.3 Economic costs

The economic costs arising from injury appear to be high. In the United States, the annual cost of injuries in 1987 was estimated at 133 billion dollars (National Committee for Injury Prevention and Control 1989). The economic costs of injury in the EU are also substantial. A Norwegian study of a random stratified sample recruited from the only hospital in Stavanger found that the average cost of health care per injury was $614, with a hospitalised injury costing $4005, and a non-hospitalised injury costing $163 (Kopjar 1997). The average cost per injury was substantially higher among patients 65 years and over ($2488) when compared with patients aged 0-64 years ($348). This was primarily due to the greater severity of injury in the elderly group. In Scandinavia, the development of

injury prevention programmes has been spurred on by the national cost of unintentional injuries, estimated to be equal to 4% of Gross National Product (GNP) (Lindqvist, Timpka, Schelp 1996). Similarly in the Netherlands, the estimated medical costs and the economic production losses caused by unintentional injuries have encouraged policy makers to rank injury prevention as a high priority (Van Beeck, Van Riojen, Mackenbach 1997).

In the UK, it is estimated that the direct costs of injury are in excess of £1.6 billion annually (NHS Executive 1996). The annual cost to the National Health Service for childhood injuries alone is estimated at over £200 million (Jarvis et al 1995). However, when an alternative method of analysis is used, in this case 'willingness to pay', the costs are 20 times greater (Ward, Christie 2000). This approach involves asking the public to express how much they would be willing to pay to avoid injury.

1.4 Prevention

A number of reviews (some of which are systematic reviews) have examined the effectiveness of injury prevention measures. (PHRED 1999; Kemp, Sibert 1997; Forjouh, Guoha 1996; Dowswell, Towner 1996; Munro, Coleman, Nicholl et al 1995). The review conducted by Dowswell and Towner was subsequently updated in 2001 (Towner, Doswell, Mackereth et al 2001). Most of these reviews are aimed specifically at children and young people. One review examines injury prevention for all ages for the developing world (Forjouh, Guoha 1996). Further, the Working Group for the Health Evidence Bulletin in Wales has completed a number of reviews covering childhood injuries, injuries among older people, road traffic accidents, sports injuries, work and general environment (Health Evidence Bulletin Wales, 1998). The reviews of TRIs specifically are discussed further in Chapter 2.

Systematic reviews of health promotion interventions to reduce childhood unintentional injuries have highlighted a number of interventions which have been successful in reducing such injuries (Towner et al 2001; Health Evidence Bulletin Wales 1998; Dowswell, Towner 1996). Initiatives specific to TRIs, where there is some evidence to support effectiveness, include: bicycle training, bicycle helmet legislation, bicycle helmet education, area-wide urban safety measures (such as right hand turn prevention, right turn bays and central road dividers), 20 mile per hour zones, child restraint legislation, child

restraint loan programmes, child restraint educational campaigns, seat belt educational campaigns and pedestrian education (when aimed at the child and /or parent). These are further discussed in Chapter 2. Interventions in the home environment that are deemed to be (at least to some extent) effective in reducing injury include: smoke detector promotion programmes, tap water temperature reduction, window guards or bars and child-resistant packaging.

The Public Health Research, Education and Development (PHRED) programme emphasised the paucity of randomised controlled trials (RCTs) in injury prevention, and specifically noted the lack of evidence on injury prevention among young people (PHRED 1999). There was a general consensus that community-based interventions may be reasonably effective in reducing injuries and stimulating behavioural change (PHRED 1999; Munro et al 1995). These community interventions frequently include designing and operating local injury surveillance systems, targeting specific groups and specific injury types and evaluating the impact of the intervention.

Munro and colleagues' review focused on the effectiveness of interventions to reduce accidental injury among 15-24 year olds specifically (Munro et al 1995). This review was conducted as part of the Department of Health's 'The Health of the Nation' strategy and used the grading scheme utilised in the UK needs assessment programme. In addition to the paucity of RCTs, this review also noted that where such trials had been completed, few interventions had been evaluated as effective. Overall, the review suggested that legislative and regulatory controls were most effective in reducing injury. In some cases injury reduction may be due to discouraging some risk activities such as cycling. Environmental engineering initiatives were also highlighted as more effective than educational measures. Stand-alone educational initiatives were rarely evaluated as effective. These authors (as with the PHRED review) identified multi-disciplinary strategies (such as the Safe Communities projects) as having potential.

Overall, environmental interventions are cited as more successful in reducing injuries than educational initiatives. However, the effect of using interventions in combination is stressed by most authors (Towner et al 2001; Kemp, Sibert 1997; Dowswell, Towner 1996; Munro et al 1995). This is sometimes referred to as the 'three-prong approach' or the 'three E's'. These refer to engineering/ environment that can develop safe products (e.g.

car safety seats, airbags, safe road design), enforcement (e.g. mandatory seat belts, drink driving legislation) and education (e.g. pedestrian education, cycle training).

Key points

- Injury is a leading cause of mortality and morbidity world-wide.
- The importance of injury as a cause of mortality is projected to rise in the Twenty-First century.
- The principle causes of injury mortality in industrialised countries are TRIs, suicides, drownings, fire and flame-related injuries, poisonings and other violence.
- Age, sex and socio-economic status are major determinants of injury incidence.
- The evidence on the association between injury and socio-economic status is inconclusive for the adolescent age group.
- Economic costs of injury appear to be high.
- Prevention appears to be most effective when a multi-disciplinary approach is adopted, but there is a lack of strong evidence for most injury prevention measures.

Chapter 2 TRAFFIC RELATED INJURIES

This chapter outlines the trends and patterns in TRIs in the twentieth century. Key determinants of TRIs are discussed, as are the respective roles of alcohol and other drugs. The economic and social costs of TRIs are also considered. Finally, a brief overview of the prevention approaches and their effectiveness is presented.

2.1 Trends in TRIs and transport

With a rapid increase in exposure to motor vehicles in many parts of the world, TRIs have become a major cause of death and serious injury throughout the life-cycle. These injuries have been an enduring feature in mortality and morbidity statistics during the Twentieth Century, and their importance is unlikely to be diminishing. In 1990, TRIs ranked 9th in the world as a cause of mortality, but are projected to have a ranking of 6th by the year 2020 (Murray, Lopez 1997d). The global impact of TRIs on mortality and morbidity is estimated at 300-500,000 deaths and 10-15 million persons injured annually (Barrs, Smith, Baker et al 1998). The number of non-fatal injuries resulting in permanent impairment is thought to be approximately equal to the number of fatalities (Barrs et al 1998). In the absence of specific government policy to promote safer methods of transport and viable alternatives to private motor vehicle use, motorisation will continue and likely spread. In broader public health terms such an increase in motorisation will also result in an increase in noise and environmental pollutants (Tapia Granados 1998).

In many developed countries, mortality from TRIs per unit of travel has decreased dramatically in the Twentieth Century (Vulcan 1995). Factors contributing to this decrease are thought to include the increased use of safety equipment, a decrease in drink driving, a decrease in vulnerable road users, changes in travel patterns, better road design and improved vehicle crash resistance. However, the fatality rate due to TRIs is much higher in the developing world than in the developed world (Barrs et al 1998). This is due (at least in part) to the larger proportion of 'vulnerable' road users. A paper from Brazil vividly describes the increase in accident rates since the 1960's (Vasconcellos 1999). It was in this decade that road transportation became the dominant mode of transport in South America. Vasconcellos cites fast and uncontrollable urban growth as one of the major contributory factors in the increasing TRI problem.

In most countries private, independent travel in a motor vehicle tends to be the most hazardous, although the case-fatality rate can vary substantially between regions and countries. Factors likely to affect case-fatality ratios include access to medical treatment, the traffic mix, speed restrictions and compliance and the number of police in the area (Barrs et al 1998).

In Scotland there has been an increase in car ownership, road network length and possession of full driving licences since the 1970's (Scottish Office 1998). Public road length in kilometers has increased from 51,219 in 1987 to 53,149 in 1997. The number of motor vehicles licensed in Scotland has risen 32% between 1987 and 1997 to a total of 2 million. In 1987, 49% of households had no regular use of a car. This compares to 28% by 1996. The proportion of young people holding full driving licences has also increased from 28% in 1985/86 to 41% in 1995/96 among 17-20 year olds and from 57% to 73% among 21-29 year olds. This generally reflects the trends in transport and travel observed in other developed countries, referred to by Potter as 'the personal mobility explosion' (Potter 1997) and by Patel and colleagues as the 'romance with the automobile' (Patel, Greydanus, Rowlett 2000). In contrast, passenger journeys on local bus and coach services have fallen; in 1996/97 there were 28% less than in 1986/87 (Scottish Office 1998). Passenger journeys on rail services originating in Scotland have remained constant.

The proportion of TRIs that are sustained by pedestrians varies between countries. In general, countries in the developing world have higher proportions of vulnerable road users (such as pedestrians) sustaining TRIs (Forjouh, Guoha 1996). In developing countries pedestrians are involved in approximately 70% of all traffic injury events (Barss et al 1998). According to Forjouh and Guoha, the reasons for the high rate of pedestrian injury in these countries are likely to include lack of awareness of appropriate behaviour in traffic (both for drivers and pedestrians), poor visibility for pedestrians, poor vehicle design and poor pedestrian protection.

In Scotland, the average number of journeys made on foot has decreased in recent years (Scottish Office 1998), although the average distance travelled by this mode has increased. Scotland has a higher rate of pedestrian injury than England and Wales (Scottish Office 1994). Further investigation of this difference showed that the higher rate in Scotland could chiefly be explained by the level of exposure. When Scottish districts were matched with other districts in the UK, after weighting for levels of exposure and car ownership, less disparity was observed (Harland, Halden 1996).

It is difficult to estimate the number of cyclists and motorcyclists injured in many countries due to the under-reporting of such accidents involving these types of road users. As with pedestrian injuries, injuries sustained by cyclists and motorcyclists are often due to a lack of protection, low visibility relative to four wheel vehicles and the combined presence of modes of transport with different speeds, lateral mobility and vulnerability (Barss et al 1998). Alcohol may also be an important risk factor, although this has been seldom investigated. Major issues with respect to equipment include increasing visibility and the use of appropriate helmets. The issue of efficacy of cycle helmets continues to be debated. However, the weight of evidence suggests that cycle helmets can reduce the incidence and severity of head injury in cyclists (Thomas, Acton, Nixon et al 1994; Thompson, Rivara, Thompson 1996; Dowswell, Towner 1996).

A study of fatal motorcycle accidents in South-East Scotland over an eleven year period showed that these injuries tend to be severe and 'unsurvivable' (Wyatt, O'Donnell, Beard et al 1999). In almost half of the fatalities, the motorcyclists sustained injuries that are commonly acknowledged to be 'unsurvivable'. These injuries have an Injury Severity Score (ISS) of over 75. The authors stress that the greatest potential to reduce these fatalities lies in *primary* prevention, rather than in improving medical treatment for these injuries. This again highlights the importance of effective protective equipment and a safe driving environment.

2.2 Determinants of TRIs

TRIs are not distributed evenly throughout the population. Drivers' characteristics are an important contributory factor in TRIs including age sex, socio-economic status and level of education. Other risk factors include alcohol and drug use, fatigue and visual acuity (Barrs et al 1998). Disparities in demographic characteristics may be related to increased exposure, or to other environmental factors that place certain groups at increased risk.

2.2.1 Age

Age is a major determinant of TRIs. The EURORISC study showed that TRIs were the leading cause of unintentional injury fatalities among children (aged 0-15 years) between 1984 and 1993 in the member states of the EU, accounting for 45% of deaths in this age group (Morrison et al 1999a). This is comparable to findings from elsewhere in the world (Langley, Smeijers 1997; Moller, Kreisfield 1997; Fingerhut et al 1996). Children appear to be at greatest risk of a TRI as pedestrians, with peak incidence at age 5-7 years. A multitude of risk factors has been identified for childhood pedestrian injury. These include: male gender, non-white ethnicity, deprivation, lack of car ownership, residing in areas with high volume or high speed traffic and higher than average mean number of streets to cross when walking to school (Kraus et al 1996; Roberts, Norton, Taua 1996).

The EURORISC study also demonstrated that the proportion of injury fatalities caused by TRIs was much higher among adolescents (Morrison et al 2000). Over 80% of unintentional injury fatalities among 15-24 year olds in the EU were the result of a TRI. Adolescents are frequently cited as the group with the greatest relative risk of injury from TRIs, particularly in relation to injuries involving motor vehicles and motorcycles. A sharp rise in fatal and non-fatal injuries as a result of TRIs is commonly reported in 15-19 year olds. In the Scotland, rates of death and serious injury among car and motorcycle users increase dramatically after the age of 14 years, while rates of pedestrian, bicycle and home injuries decrease at this stage in the life-course (Scottish Office 1994). Between 1985 and 1996, 76% of unintentional injury deaths among teenagers aged 15-19 years in the UK involved road users (DiGuiseppi, Li, Roberts 1998). Goldstein and colleagues described the disproportionate numbers of 16-19 year olds injured in road traffic crashes in the United States as a 'persistent and pervasive problem' (Goldstein, Spurlock, Kidd 1997).

The reasons cited for the disproportionate number of young people injured are numerous. They include: young people's propensity to use alcohol or drugs, their propensity to drive under the influence of alcohol or drugs, their relative inexperience as drivers, their preference for late night driving (in particular the use of a car as a social meeting place) and their propensity for risky driving (Lang, Waller, Shope 1996; Farrow 1987a; Farrow 1987b; Farrow 1985). Adolescents are frequently injured in cars belonging to other people and in cars older than a decade and in some disrepair (Farrow 1985). Farrow suggests that

both driver characteristics and situational factors contribute to adolescents driving under the influence of alcohol and/or drugs. Lang and colleagues showed that for young men, the availability of substances, driving frequency, alcohol misuse and propensity toward cannabis use were related to single-vehicle crashes (Lang et al 1996).

One study showed that while teenage drivers drove less than older drivers, they drove mostly at night (Williams 1985). Overall, rates of fatal crashes were higher (based on miles driven) than for the adult driving population. Time was found to be a major variable in adolescent driver accidents, with high-risk time periods identified on both school and non-school days (Alexander, Kallail, Burdsal et al 1990). Young people may also have unrealistic beliefs about their driving skills compared to the driving skills of others and may as a result take more risks (Robertson 1992).

In the middle years of life, injury rates appear to be low for most injury types, including TRIs. The reasons proposed for this include a greater awareness of the risks and a reduction in risk-taking behaviour (Robertson 1992). However, those in the elderly age group appear to suffer a greater number of severe injuries. An Australian study demonstrated that drivers over 70 years were involved in relatively higher numbers of crashes resulting in fatalities and hospital admissions than younger drivers (Ryan, Legge, Rosman 1998). A retrospective study of pedestrian motor vehicle traffic victims at a trauma centre in Los Angeles county found that significantly more children and elderly people sustained such injuries (Kong, Lekawa, Navarro et al 1996). The elderly patients in the study had a higher mortality rate, were more frequently admitted to the intensive care unit, and had significantly longer hospital stays. Similarly, a Danish study demonstrates that TRI victims aged over 65 years sustain higher rates of severe TRIs due to pedestrian injuries compared to those under 65 years (Larsen, Poulsen, Johannsen 1995). So, while some exposures are less frequent among the elderly, the consequences of injury (when it occurs) tend to be more severe.

2.2.2 Sex

As with injuries generally, studies world-wide show that a disproportionately high number of males are involved in or at risk of a TRI than their female counterparts (Morrison et al 2000; Li, Baker, Frattaroli 1995; Cobb et al 1995; Banahan, McCaffrey 1993; Thouez,

Joly, Rannou et al 1991). Males appear to be at higher risk of motor vehicle occupant, motorcyclist and cyclist injuries at all ages, and at higher risk of pedestrian injuries at all ages over 5 years (Barss et al 1998).

Banahan and McCaffrey's study of rural students' exposure to car travel showed that male students were significantly more likely to have driven (in any circumstances) in the last 30 days than females (Banahan, McCaffrey 1993). Over 70% of males reported driving compared to 62% of females. However, amongst all students who reported driving, a significantly higher proportion of males than females reported driving under the influence of alcohol and drugs. There were no significant differences between males and females with respect to exposure to risk as a passenger when the driver was under the influence of alcohol or drugs. Similarly in Cobb's study of adolescent injury and risk behaviour, males appeared to be more willing to take risks than their female counterparts (Cobb et al 1995).

2.2.3 Socio-economic status

The association between socio-economic status and childhood TRIs is particularly well documented. Between 1988-1990, a significantly higher rate of TRIs was observed in deprived areas of Nottingham, England than in more affluent areas (Kendrick 1993). In Montreal, Quebec, the risk of pedestrian injury was 2.5 times higher for children of parents who had not completed secondary education (Joly, Foggin, Pless 1991). Lack of supervision on the way to school increased the risk of injury three times, and lack of supervision after school, 11 times. A community-based study in New Zealand found the risk of injury at sites with the highest traffic volume was 14 times greater than at the least busy sites (Roberts et al 1996). A Canadian study highlighted three significant factors: increased traffic flow in the area (particularly between 15-1700 hours), the greater the distance a child must travel to find a protected play space and the proportion of the area's population classified as social class IV or V (Bagley 1992). Finally, another North American study showed that the absence of a play area adjacent to the home was associated with a five-fold increase in risk of pedestrian injury (Mueller, Rivara, Shyh-Mine et al 1990).

One of the most comprehensive examinations of the relationship between TRI rates and socio-economic status was reported from Lothian, Scotland. The authors compared two

groups using road casualty and census data: residents in postcode output areas designated as the 15% most socially deprived and residents in the areas designated as the 15% most affluent (Abdalla, Raeside, Barker et al 1997). Significantly higher rates of road incident casualties were observed in the areas of relatively greater deprivation. This significant association between deprivation and overall casualty rate was observed in all age groups. However, when vehicle driver casualties were examined as a subset, residents in the more affluent areas had higher casualty rates at certain ages. Car drivers in the 17-24 year age group resident in the more affluent areas experienced higher, but non-significantly different, casualty rates than for those in the most deprived areas. Similarly, drivers aged over 60 years residing in the more affluent areas had significantly higher casualty rates than their contemporaries in the most deprived areas. The authors assumed that this was the influence of car ownership. Car ownership and access to a car is strongly associated with increased income (Potter 1997). Results from Scottish Household Survey demonstrate that over half of those in the lowest income bracket had no access to a motor vehicle (Scottish Executive 1999).

2.2.4 Alcohol

Alcohol is frequently cited as the major contributory factor in injury mortality. In the UK, an estimated 50,000 deaths and up to 500,000 hospital admissions annually (for all causes) are associated with the use of alcohol (Glucksman 1994). The association between TRIs and alcohol is particularly well recognised (Mayou, Bryant 1995; Wagenaar 1995; Gloag 1995; Raffle 1989). In Scotland, approximately 20% of injury events are attributable to alcohol (Braddick 1995). The intoxicated driver is likely to be affected by decreased reaction times and impaired control of the vehicle.

Research evidence also suggests that alcohol intoxication is associated with more severe injuries. TRIs (in which alcohol plays a role) tend to be associated with increased mortality, and decreased time to death (Glucksman 1994; Board of Science and Education 1988). In Switzerland, a cross-sectional study of male TRI victims showed that intoxicated drivers had significantly longer hospital stays and a higher prevalence of serious injuries than non-intoxicated drivers (Yersin, Wyss, Koehn et al 1992). Similarly, a case-control study (often referred to as the Grand Rapids Study) from the United States showed that with an increase in the concentration of alcohol in the blood, there is an increasing risk of an injury event

(Allsop 1988). Thus, the use of alcohol impairs the driver and increases the risk of a crash and the risk of death from a crash.

There is also evidence to suggest that those with alcohol problems are at particular risk of TRIs. A prospective cohort study conducted in Michigan showed that almost a quarter of motor vehicle crash patients attending an Emergency Department had current alcohol abuse or dependence problems (Maio, Waller, Blow et al 1997). However, blood alcohol concentration tests did not necessarily identify these drivers accurately. In Massechusetts, a study of male drivers showed that those fatally injured were mostly heavy drinkers who may suffer from serious drinking problems or alcoholism (Kennedy, Isaac, Graham 1996). A prospective cohort study of TRI victims in Oxford, UK classified 20% of respondents as 'problem' drinkers. At one-year follow-up (after the injury event) few changes in alcohol consumption or drinking and driving behaviour were identified. The authors stressed the importance of introducing interventions to control drinking at early stages of convalescence. The respondents in this study were offered no specialist help either at immediately after the event, or at follow-up hospital care (Mayou, Bryant 1995).

Studies on adolescent TRIs have largely focused on the role of alcohol. Alcohol use has been identified as a major risk factor for injury by several recent studies of young people (Chliaoutakis, Darviri, Demakakos 1999; Mao, Zhang, Robbins et al 1997; Holubowycz, McLean 1995; Maio, Portnoy, Blow et al 1994; Fahrenkrug, Rehm 1994; Banahan, McCaffrey 1993; Hicks, Morris Jnr, Bass et al 1990). A Swiss study comparing young male drivers involved in alcohol-related accidents with accident-free controls showed that the risk of TRIs increased up to six-fold when the driver had a heavy drinking style. A risky driving style, regular drinking and enjoyment from risk-taking were also associated with increased risk of TRI (Fahrenkrug, Rehm 1994). A study conducted in greater Athens showed that young drivers whose dominant lifestyle trait is 'alcohol consumption' have a high risk of a TRI. This study used a ten factor scale to capture the basic lifestyle traits of young Greek drivers (Chliaoutakis et al 1999).

Alcohol also plays a major role in pedestrian injuries. A prospective study of 231 injured pedestrians in a South African trauma unit found a positive blood alcohol concentration (BAC) in 62% of subjects (Peden, Knottenbelt, Van der Spuy et al 1996). BAC positive patients sustained more severe injuries, had a higher admission rate and a higher fatality rate. In South Australia, a study found higher levels of BAC among fatally injured pedestrians when compared with fatally-injured drivers, passengers and motorcycle riders

(Holubowycz 1995). Elderly sober pedestrians, young and middle-aged intoxicated males and teenagers of both sexes were found to be those groups at greatest risk of pedestrian injury.

Despite the illegality and increasing social unacceptability of driving under the influence of alcohol, studies show that drink driving persists. A Spanish study demonstrated widespread consumption of alcohol among Spanish drivers, in spite of an awareness that their driving ability was affected by the consumption of alcohol (Alvarez, Del Rio 1993). A third of drivers reported ever driving while a 'little merry' or a 'bit tipsy', and 8% while drunk. This study is based upon a self-completion questionnaire with a response rate of less than 50%. While under-reporting (self-reporting) is a potential methodological flaw of the study, the authors state that the study sample is representative of the Spanish driving population for age and gender. Drink driving in the UK is reported to have decreased dramatically in the last decade. In the UK, 990 fatalities were a result of drink driving in 1986 compared to 540 in 1996 (Department of the Environment, Transport and the Regions 1997). Moreover, a 19.5% breath test failure rate in 1986 dropped to 5.1% in 1996.

2.2.5 Drugs

Relatively few studies have examined the role of either prescribed or illicit drugs in TRIs. Driving under the influence of drugs is often cited as a growing cause of concern, particularly for young people. Certainly drug use appears to be more prevalent among young people in recent years. This in itself does not support the hypothesis that more TRIs are a result of driving under the influence of drugs. It is difficult to evaluate with precision the contribution drug use may have. Although studies suggest that 6-10% of injured drivers test positive for drugs, it is impossible to know whether these substances had any causal effects. This is made more difficult because drugs are often used in conjunction with alcohol.

A Norwegian study showed that cannabis in conjunction with other drugs (including alcohol) is a more frequent reason for driver impairment than cannabis alone (Gjerde, Kinn 1991). The National College Health Risk Behaviour Survey (1995) data in the United States shows that college students who are substance users are more likely to engage in behaviours that increase their risk for TRIs (Everett, Lowry, Cohen et al 1999). This study also found that episodic heavy drinkers, cannabis users and those using illicit drugs in

conjunction with alcohol were more likely to drive under the influence and less likely to wear seat belts. A Finnish study found that the use of drugs by drivers was less common than expected. The main findings were that taking diazepam may increase the risk of being involved in an injury event, but that alcohol was the most powerful risk factor (Honkanen, Ertama, Linnoila et al 1980). Overall, evidence suggests that cannabis and other drugs pose a real, but only secondary threat when compared with alcohol, which represents the major risk factor for injury in both pedestrians and car occupants.

Research evidence also points to the risk of driving while taking prescribed drugs. Benzodiazepines have attracted particular interest. A sizeable proportion of the elderly population use benzodiazepines and these may affect the ability to drive, increasing the risk of a motor vehicle crash (Hemmelgarn, Suissa, Huang et al 1997). This study showed an increased risk of motor vehicle crash involvement with exposure to long half-life benzodiazepines. Users of benzodiazepines in Tayside, Scotland, were also found to be at increased risk of a road traffic accident (Barbone, McMahon, Davey et al 1998). These authors conclude that users of anxiolytic benzodiazepines and zoplicone should be advised not to drive. Other studies, however, have shown no statistically significant evidence to substantiate the hypothesis that benzodiazepines are a risk factor for TRIs (Benzodiazepine/Driving Collaborative Group 1993).

A recent survey of the prevalence of driving under the influence of recreational drugs among young people (17-39 years) in Scotland found that 9% of respondents had ever driven under the influence of a drug (Scottish Executive 2001). This proportion fell to 5% when respondents were asked if they had done so in the previous 12 months. Driving under the influence of cannabis was most common, accounting for 68% of 'drug-driving' events. The next most commonly used drug when driving was ecstacy. This drug had been used in 7% of 'drug-driving' events. Males were significantly more likely to have driven under the influence of drugs than their female counterparts.

2.2.6 Other risk factors

One group of authors demonstrated a 'time-of-day' effect (Schwing, Kamerud 1988). They showed that night-time driving is particularly risky. Overall, a third of fatalities due to motor vehicle accidents occurred in hours when only 5% of driving occurred. A high risk

on Sunday, 3am, was observed (43 times the average). Pedestrians (particularly adult pedestrians) also appear more likely to be injured during night-time hours, and at weekends.

A retrospective review of 273 pedestrian motor vehicle trauma cases in a Los Angeles trauma centre found that half of such injuries occurred at weekends, with the greatest number on Saturdays (Kong et al 1996). There was also an excess in these injuries between October and December, with one-third of accidents occurring in these months. A study of the contribution of risk exposure, weather, randomness and daylight on the accident toll in the four Nordic countries found that most of the variance in accidents between the countries could be explained by randomness and risk exposure. The authors concluded that a reduction in traffic volume is necessary before any significant reduction in the accident toll is likely (Fridstrom, Ifver, Ingebrigtsen et al 1995).

Other studies have highlighted differences in motor vehicle crash rates and severity of injury between urban and rural settings. Mortality rates for TRIs tend to be higher in rural areas than in urban areas where speeds tend to be lower (Robertson 1992). In Quebec, analysis of insurance records showed that while urban municipalities showed higher risk of non-severe injuries, risks of severe injury were higher in rural areas (Thouez et al 1991). The accessibility of health care in rural areas was cited as a partial explanation for this difference.

2.3 Economic costs

Several studies have attempted to calculate the economic costs of TRIs. These studies vary in the definition of a TRI, and differ in the method of calculation, making firm comparisons difficult. What is certain is that the economic costs of injury appear to be very high. A study conducted using the theory of optimum road pricing advocated by Jansson calculated external cost estimates of TRIs in 14 European countries (Persson, Oedegaard 1995). This method of calculation includes costs for loss of productive capacity (net), loss of human consumption, loss of human value, medical and other costs. The average cost per person of TRIs in the EU in 1990 was 828,000 ECU. The highest costs were experienced in Switzerland at 2,165,000 ECU per person, the lowest in Spain at 235,000

ECU. A TRI in the UK cost slightly above the European average at 931,000 ECU. The study also showed that lorries and buses generate higher external costs than passenger cars.

The financial costs of TRIs are high compared to other injury causes, partly because of the higher proportion of severe injuries. In 1994/5, the total cost of TRIs in the UK was estimated at £9.3 million (DETR personal communication, 1999). On average, the cost of a fatal accident was £913,000, a serious accident was £108,000 and a slight accident £10,630. In 1991, the annual cost of TRIs in Scotland was estimated at £608 million (Braddick 1995). Therefore, a small reduction in the rates of TRIs (particularly in fatal TRIs) would result in substantial cost savings. Few studies have attempted to calculate the economic costs of adolescent TRIs specifically. In Kentucky, the total estimated cost of teenage vehicle crashes in 1994 was almost $410 million (Goldstein et al 1997).

At the time of writing there was little information available on the cost-benefits of TRI prevention. However, in the future it is likely that Road Safety Impact Assessments and Road User and Safety Audits will be given greater priority (RoSPA website 2000). A cost benefit would depend upon a prevention initiative being effective in either preventing or reducing the severity of injury. Data from RoSPA suggest that a number of prevention initiatives may be cost-effective. For example, for the cost of one fatal injury (around £1 million), ten local safety schemes could be constructed, or over twenty area traffic calming schemes could be introduced, or over fifty sets of speed cameras could be installed. It appears that the construction and engineering industries are the ones most likely to be able to deliver the most cost effective prevention measures (RoSPA website 2000).

2.4 Social costs

TRIs as a major cause of death, serious injury and long term physical disability are well documented. Less well established are the psychological and social consequences of such events. The frequency of post-injury psychological problems remains controversial.

A prospective study of children in Glasgow observed symptoms of moderate or severe post-traumatic stress disorder in 36% of TRI victims shortly after the accident (2-16 days) and in 14% of victims at follow-up (12-15 weeks) (DiGallo, Barton, Parry-Jones 1997). Although there was a decrease in symptom severity and frequency between the two measures, parents reported increased mood disturbance at follow-up compared to the pre-

accident period. The authors stress the importance of health care workers being aware of the possible psychological consequences of such TRI events.

A case-control study of the effect of fatal accident involvement on subsequent driver behaviour was reported from Finland (Rajalin, Summala 1997). Approximately half of drivers decreased their driving, although the largest reductions were observed in those drivers more seriously injured. A further prospective study of 188 TRI victims, reported that almost a quarter displayed psychiatric problems (Mayou, Bryant, Duthie 1993). Three main categories of problems were identified: mood disorder (depression, anxiety), post-traumatic stress and travel phobia.

A further study interviewed young people who had sustained a serious head injury about the impact of the injury on their lives (Bogan, Livingston, Parry-Jones et al 1997). Almost half of these young people had been involved in a TRI, either as a pedestrian or a vehicle occupant. While most had a predominantly positive attitude towards life as assessed by the Offer Self-Image (OSI) Questionnaire, the injury had limited their day-to-day activities, employment opportunities, educational opportunities and had affected their relationships.

Psychological debriefing has been widely advocated for injured victims. However, a RCT of psychological debriefing for TRI victims in England showed no effect at 3 months and at 3 year follow-up the intervention group had significantly poorer outcomes in general psychiatric symptoms, travel anxiety, general pain, physical problems and general functioning (Mayou, Ehlers, Hobbs 2000). A further RCT examined the impact of debriefing in TRI victims (Conlon, Fahy, Conroy 1999). These patients were assessed at 7 days, then at 3 months. At 3 months there were no significant differences between the intervention and control groups. No further follow-up in this study has been reported.

2.5 Prevention

The reviews cited in Chapter 1 highlight the effectiveness of a number of prevention measures in reducing TRIs or modifying risk behaviour. These include: bicycle and motorcycle helmet legislation, bicycle helmet education campaigns, area-wide urban safety measures, child restraint legislation, child restraint loan programmes, child restraint educational campaigns, seat belt educational campaigns and pedestrian education (when

aimed at the child and/or parent) (Towner et al 2001; PHRED 1999; Health Evidence Bulletin Wales 1998; Dowswell, Towner 1996; Munro et al 1995).

Evaluations of the impact of educational interventions and information campaigns for road users have generally been disappointing or produced conflicting results. Enhanced driver education, rehabilitation for drink drivers, and school-based programmes are notable examples. Although changes in self-reported behaviour, knowledge and attitudes have been demonstrated, commonly no objective behavioural changes were achieved (or were not measured). A meta-analysis of remediation therapy for drink driving offenders suggests that it reduces recidivism by 7-9% (Wells-Parker, Bangert-Drowns, Williams 1995). Studies into the effects of media campaigns on seat belt use have produced (at best) weak results (Scottish Office 1997).

Environmental measures that have been advocated include safer design of roads, roadside guard-rails, area-wide traffic management schemes, speed bumps and permanently switched on head lights (Health Evidence Bulletin Wales 1998). Stricter enforcement of speed limits may result in fewer injuries. The overall contribution of speed in fatalities is only an estimate, but the general consensus among injury experts is that speed is the major contributory factor in up to one third of fatalities (Health Evidence Bulletin Wales 1998). There is some evidence from a meta-analysis of evaluation studies to suggest that roadside guard-rails can reduce injury severity, by up to 45% of fatalities (Elvrik 1995). The same meta-analysis suggests that permanently switched on lights can reduce multi-party daytime crashes by 1-15%. There is also some evidence for prohibiting 'bull bars' on vehicles (Hardy 1996). These environmental interventions are likely to be the most cost effective interventions.

Avoiding alcohol before driving is desirable and very probably prevents TRIs (Wagenaar 1995, Gloag 1995). A reduction in the permitted Blood Alcohol Concentration (BAC) is also likely to lead to a reduction in the severity of injuries. Research evidence from the Australian Capital Territory (ACT) showed that a 30mg reduction in the legal limit (from 80mgs to 50mgs) led to a 41% reduction in the incidence of drink driving on over 150mgs. Moreover there were one third fewer drivers injured with a BAC of over 80mgs (BMA Board of Science and Education 1996). A further paper suggests that extending the practice of random breath testing (with publicity) will lead to a reduction in TRIs (Peacock 1992).

There are a few evaluations describing the effects of TRI interventions in young people specifically. Multi-factorial educational interventions that seek to change several aspects of young people's skills, values and beliefs are likely to be more effective than those interventions which focus on just one of these aspects (Munro et al 1995). Some legislative measures have indicated that they may be effective in reducing road accident rates. Cross-sectional studies from the US suggest that lower legal driving age (as well as experience) is associated with an increase in accident rates (Laberge-Nadeau, Maag, Bourbeau 1992). However, as a preventive strategy, this has yet to be thoroughly evaluated.

Although there are no environmental measures that have been shown to reduce rates of TRIs in the 15-24 year age group, community environmental schemes (sometimes referred to as traffic calming) have been effective in reducing rates generally. These measures appear to be particularly effective among vulnerable road users including child pedestrians and cyclists (Towner et al 2001; PHRED 1999, Dowswell, Towner 1996, Munro et al 1995). These measures have also been evaluated as cost effective (Towner et al 2001).

Key Points

- TRIs are expected to rise to rank 6th as a cause of mortality globally in 2020 from a rank of 9th in 1990.
- The importance of TRIs as a cause of death and disability is unlikely to diminish significantly in the Twenty-First century.
- Young people are at greatest relative risk of sustaining a TRI, particularly as motor vehicle occupants
- Alcohol consumption is associated with more severe injuries, but it is difficult to evaluate the role of other drugs in TRIs.
- Few injury prevention measures have been evaluated as effective. A multi-disciplinary approach looks most likely to be effective.

Chapter 3 REVIEW OF SCOTTISH DATA SOURCES

This chapter documents and examines the data available on TRIs and transport in Scotland. The chapter ends by highlighting those sources considered most useful for the purposes of the present study.

3.1 TRI data

Population-based numerator data on TRIs in Scotland are available from two official sources. The Scottish Health Service (SHS) records data on fatalities (also held by the General Registrar's Office) and hospital admissions due to all causes, including injuries. Secondly, the STATS19 database, archived at the University of Essex, holds information on police-reported TRIs in the UK as a whole, including Scotland.

These data sources contribute to two international systems that collect information on TRIs: the World Health Organisation (WHO) Mortality Database and the Organisation for Economic Co-operation and Development (OECD) International Road Traffic Accident Database (IRTAD). Data on TRIs are also available from two national surveys; the Scottish Health Survey and the Scottish Household Survey. These data sources are described in detail below and summarised in Table 3.1.

Data on transport trends (sometimes referred to as exposure data) are available from two main sources: the National Travel Survey (and Scottish subset) and a recent study of travel patterns in Scotland using travel diaries. The travel diary study helped develop a module of questions on travel that is now incorporated into the Scottish Household Survey. These data sources are also discussed below.

3.1.1 General Registrar Office Mortality Data

Death records certified by a doctor and coded using the International Classification of Diseases (ICD) are available from the General Registrar's Office for Scotland (GRO). The Tenth Revision of ICD is now in use. At the time the data for this study were collected, the Ninth Revision was in use. The relevant codes for injury were E800-999. These codes include deaths from all externally caused physical injuries causes including unintentional

injuries and adverse effects, suicides and self-inflicted injuries, homicides and other violent causes. A link number is included which allows linkage with the hospital discharge (Scottish Morbidity Record 1) data held by the Information and Statistics Division (ISD) described later. This is only for cases where death occurred after admission to hospital. The link number is crucial to avoid double-counting of cases.

The GRO also include a measure of socio-economic status on their mortality database, calculated using patient postcodes. The Carstairs deprivation categories (based on characteristics of Scottish postcodes sectors) provide a measurement of area-based socio-economic status (Carstairs 1991). These scores are calculated using four standardised variables: male unemployment, car ownership, household occupancy and social class. A continuous scale of 1-7 is used, where one is most affluent, and seven is most deprived. These categories provide a baseline for analysis of health differences within Scotland. Scores derived from the 1991 census data were used in Carstairs original classification of deprivation and are used in this study.

GRO mortality data are also entered into the WHO Mortality Database and published annually in the WHO Annuals. These data are firstly sent to the Office for National Statistics (ONS) in London, where the UK-wide mortality figures are compiled. In most countries of the world, mortality data are collected routinely and submitted to the WHO. These data provide a source of population-based data that are frequently used for priority setting and monitoring progress towards health targets. Standardised procedures for analysing and presenting injury mortality data for comparative purposes were published in the late 1990s by the US government-sponsored International Collaborative Effort (ICE) on Injury Statistics. This internationally agreed reporting framework facilitates the comparison of national mortality rates (McLoughlin, Annest, Fingerhut 1997).

3.1.2 Scottish Morbidity Record 1 (SMR1) Data

National data on hospital discharges (Scottish Morbidity Record 1) due to all externally caused physical injuries are available from ISD. The Scottish Morbidity Record (SMR1) is a record of non-obstetric, non-psychiatric discharge from Scottish hospital completed on death, discharge, transfer or change of consultant. These data refer to episodes of care rather than individual patients. As with mortality data, all SMR1 records due to injury are coded using ICD9 codes E800-999. A link number and a Carstairs deprivation category are recorded (Carstairs 1991). In addition, the type of admission and discharge are coded

and a principal ICD9 Nature (N-code) of injury diagnosis and up to five further diagnosis (or N-codes) are included.

3.1.3 STATS 19 Data

The second official source of data on TRIs is the police. Police departments in the UK collect data on all police-attended TRIs occurring in their locality where at least one vehicle and one human casualty is involved. Casualties include injured drivers, riders, passengers and pedestrians. Scottish data are submitted to the Department of Environment, Transport and the Regions (DETR) for inclusion in the UK-wide STATS19 database held at the Data Archive, University of Essex. Fatal injuries are defined as cases where death occurs within 30 days of the injury event. Serious injuries are defined as detentions in hospital as an inpatient either immediately after the injury event, or have any of the following injuries: fractures, severe concussion, internal injuries, crushings, severe cuts and lacerations, severe shock requiring medical treatment. Most of these injury types result in hospital admission. These data are based upon information available to the police within a short time of the incident, and do not include results of a medical examination.

These data provide additional detail about the location and circumstances of the crash not available in the SHS data. Data on 'slight' injuries are also recorded in STATS 19. However, the definition is likely to be highly subjective and the degree of under-reporting increases greatly as the severity of injury decreases (Adams 1988). There are no corresponding national data available from health service sources, for example TRI-related injuries presenting to accident and emergency departments or to primary care facilities. The data collected for the STATS19 system are collected on three main reports and entered onto three databases; an accident report (describing the accident circumstances), a vehicle report and a casualty report. These data also contribute to the IRTAD operated by the OECD as part of their Road Transport Research Programme.

There are 30 participating countries in IRTAD including the 15 member states of the EU. Data collected by police forces in each participating country feed into IRTAD. STATS19 data from the UK are included. IRTAD collates information on fatal and non-fatal injury events, driver populations, vehicle populations and the length of the road network. There are three definitions of injury; fatal, seriously injured and slightly injured. The IRTAD group are confident about the comparability of fatal TRIs because most countries use a

standard definition. The IRTAD Working Group monitor data quality and consistency and apply correction factors where possible. However, due to the lack of a internationally accepted definition of 'non-fatal' TRI, comparisons between countries may be problematic. Definitions of serious and slight injuries appear to vary according to injury type and medical characteristics (IRTAD Working Group personal communication 1999).

3.1.4 Scottish Health Survey

The Scottish Health Survey is designed to collect information on the health of the working age (16-64 years) population of Scotland. Interviews are completed by trained nurses over a 12 month period. The first survey was conducted in 1995-1996 and is the only one available for the present study. A random sample of addresses were selected from over 300 post-code sectors. The response rate was 81%. The interview includes questions on general health, cardio-vascular disease, use of health services, physical activity and exercise, nutrition, risk behaviours, dental health, family history and psychosocial factors. Information was collected about prescription medicines being taken. Blood pressure, lung function, waist and hip measurements were also completed.

The questionnaire has a module of 13 questions dedicated to 'accidents'. This module asks about accidents that occurred in the last 12 months and resulted in consultation with a health professional. Information on the accident cause, type, location, time off work, treatment sought and the respondent's perception of the preventability of the accident are collected. Fatal accidents are (by definition) excluded. Furthermore, accidents that lead to a move from a household into an institutional facility would have been potentially excluded. The under-estimate due to this factor is likely to be very small.

These survey data may provide useful contextual information for studies such as the one completed for this thesis. The survey results provide comparative data on the type and causes of injury across age groups and socio-economic status. The survey data can also be manipulated to examine the type of treatment sought by accident type and regional variations in accident rates. However, the numbers of TRIs among young people ascertained by this study is relatively low, making further analysis of these data inappropriate. There were 10 young people in the survey that reported a TRI in the previous 12 months. This is from an unweighted base of 223 young people aged 16-24 years who reported any type of accident in the previous 12 months.

3.1.5 Scottish Household Survey

The Scottish Household Survey is a major continuous survey funded by the Scottish Executive. The survey is expected to contact 62,000 households over its first four years (Scottish Executive 1999). The survey instrument is designed to elicit information on a wide range of issues including housing, health, education and employment, crime, transport, environment, neighbourhoods and community participation. The survey provides household and individual information not previously available in Scotland.

The interview is in two parts. The first is conducted with the Highest Income Householder (HIH) or his/her spouse/partner. The second part is completed with an adult householder selected at random. These data are weighted to account for unequal probabilities inherent in the sample design. The sample is drawn from the small user file of the Postcode Address File (PAF). The overall design of the sample is to pursue a wholly random sample where fieldwork conditions allow (namely in areas of high population) and to cluster interviews in the remaining areas (also on a random basis).

There are two questions in the survey relating to TRIs. The first asks 'have you been injured in a road accident in the last year?' A positive response is followed by a question to determine whether the injured person was a driver, passenger, pedestrian, cyclist or other road user. These questions provide researchers with further survey-based data on TRIs, but do not discriminate in terms of severity or required medical treatment. As with the Scottish Health Survey, the number of cases of TRIs among young people is unlikely to prove viable for further analysis. However, there is potentially useful transport-related information collected in the survey. This includes availability and accessibility of motor vehicle, driver license information, and extensive information on travel patterns for work and leisure. These data were not available at the time the analysis for this study was completed. The first annual data set for the Scottish Household Survey became available in September 2000.

3.1.6 Other sources

There are a small number of specially designed injury surveillance systems operating in Scotland. They are not, however, potential sources of TRI data for young people. The Home and Leisure Accident Surveillance System (HASS) and Leisure Accident

Surveillance System (LASS) collect data at one Scottish site. This is a UK-wide surveillance system that collects data at a sample of 18 accident and emergency departments. TRIs are not included in the system. The emphasis is firmly on home and leisure accidents.

The Canadian Hospitals Injury Reporting and Prevention Programme (CHIRPP) was imported to the accident and emergency department at the Royal Hospital for Sick Children in Yorkhill, Glasgow. This system does collect information on TRIs that present to the department, but the system (by virtue of its location) only collects information on 0-15 year olds. Further, there are some problems with using the data for epidemiological studies because they are not population based. The hospital primarily serves the North and West of Glasgow. In an extension of the CHIRPP concept, a minimum injury data set was piloted in four accident and emergency departments across Scotland in 1999 by the Scottish Centre for Infection and Environmental Health (SCIEH). Again, the focus of data collection was the age group 0-15 years.

3.1.7 Summary

In summary, there are five potential sources of data on TRIs in Scotland (Table 3.1). Three of these sources were deemed to be of further use in this study: GRO mortality data, SMR1 data and STATS19 data. Data extraction is described in Chapter 6.

Table 3.1 Summary of the national sources of TRI data

Source	Name	Data Coverage	Method	Frequency
General Registrars Office	Mortality data	All deaths recorded	Population-based	Continuous
Information and Statistics Division	Scottish Morbidity Record (SMR) 1	All hospital discharges	Population-based	Continuous
Police Authorities	STATS19	All police-attended road traffic events resulting in injury	Population-based	Continuous
Scottish Executive	Scottish Health Survey	Wide-range of health topics including TRIs	Random sample survey	Every 3-4 years
Scottish Executive	Scottish Household Survey	Wide range of social topics including TRIs and transport	Random sample survey	Continuous

3.2 Data on transport trends

Data on transport trends disaggregated to the Scottish level are currently limited. However, the Scottish Household Survey will provide further information on transport trends post 1999. The two sources available in the course of this study were the GB National Travel Survey (and Scottish subset) and the Scottish Office Travel Diaries study.

3.2.1 The GB National Travel Survey (and Scottish subset)

Conducted by the Office for National Statistics (ONS) on behalf of the Department of the Environment, Transport and the Regions (DETR), the National Travel Survey (NTS) covers a representative sample of households across Great Britain. The survey collects data on personal travel to work, for education and private purposes. Commuting is included in the definition of 'travel'. Travel in the course of employment is excluded (e.g. lorry drivers, postal services).

The NTS is not designed to produce annual figures for Scotland. Each year's sample includes approximately 300 Scottish Households, so the Scottish figures are often presented as three yearly data, and are probably subject to sampling variability. Some Scottish data are included in the annual GB-wide DETR publication. However, since 1998 the Scottish Executive have published the Scottish data in separate bulletins. The aforementioned Scottish Household Survey launched in 1999 is designed to include information on travel patterns and will provide a more valuable source of data on travel patterns in the future.

3.2.2 Scottish Office Travel Diaries Study

A study was commissioned by the Scottish Office in 1997 to examine travel patterns in Scotland. The study was designed to collect information from respondents about all recorded journeys in a 7 day period, excluding walks of less than half a mile in distance. A total of 630 travel diaries were completed by a random sample of adults (aged 16 years and over), representing a response rate of 40%. Questions were generated to allow comparison between these data and that collected in the aforementioned GB-wide National Travel Survey. Weighting was applied for sex, age and economic activity to correct for any imbalance in the profile of respondents in comparison to the adult population. This study

provides information on journey frequency, journey length, total distances travelled, mode of transport and purpose of journey by socio-demographic characteristics. This study provided useful methodological input when the Scottish Executive were designing the travel book component of the aforementioned Scottish Household Survey.

For the purposes of this study, data from the GB National Travel Survey and the Scottish subset are used. Data from the Scottish Executive Travel Diaries Study (and the recently developed module of questions this study has informed in the Scottish Household Survey) will be potentially useful in the future. However, currently data are only available for a single calendar year and this does not allow the examination of trends in exposure data and TRI incidence.

Key Points

- Population based numerator data for fatal and non-fatal TRIs are available from the Scottish Health Service and the STATS19 database of police-reported incidents.
- Two new Scottish surveys (the Scottish Household Survey and Scottish Health Survey) collect data on TRIs but do not provide adequate sample sizes for further analysis in the age group of interest in this study.
- Limited exposure data are available through the NTS and a recent study of travel diaries in Scotland. The Scottish Household Survey should prove a more useful source of information on travel patterns in the future.

Chapter 4 INTRODUCING CAPTURE-RECAPTURE

'With careful and appropriate use, capture-recapture methods will provide a new approach that can considerably improve our ability to monitor disease'.
International Working Group for Disease Monitoring and Forecasting, 1995a

This chapter describes the capture-recapture technique used in this study and charts the development of the technique in human epidemiology and injury epidemiology specifically. A brief overview of the specific studies that have adopted this technique in the field of injury research is provided. Finally, the strengths and weaknesses of the technique and their relative impacts on its use are discussed.

4.1 Background to capture-recapture

The capture-recapture technique (sometimes referred to as mark-recapture) has its roots in biometrics, in particular the study of wildlife populations (International Working Group for Disease Monitoring and Forecasting 1995b, LaPorte 1994). The first application of the technique to human populations appears to have been Sekar and Deming's attempt to estimate birth and death rates and the extent to which these are registered in official government statistics in 1949 (Sekar, Deming 1949). Since then the technique has been increasingly used in health studies of human populations to generate more accurate rates of disease and disability and estimate the completeness of data sources (LaPorte 1994; Brenner 1995).

The technique involves estimating the number of cases in a defined population using multiple sources of information, assuming that each source alone may under-count the population. This fundamental criticism of traditional surveillance systems has been (in most cases) the driver to explore the benefits of the capture-recapture approach. Data on disease and injury that can be used in the capture-recapture technique have been extracted from a wide range of sources including traditional epidemiological surveillance systems (including fatalities, hospital admission records and disease registers), health surveys and prescription data. The technique appears to have been increasingly used in studies of human epidemiology, and in particular amongst 'hidden' populations.

Capture-recapture methods have been employed to estimate the prevalence of a wide range of medical conditions including diabetes (Ismail, Beeching, Gill et al 2000; Berger, Stenstrom, Chang et al 1998; Rangasami, Greenwood, McSporran et al 1997; Vandewalle, Coeckelberghs, De Leeuw et al 1997; Morris, Boyle, MacAlpine et al 1997; Schober, Tuomilehto, Schneider et al 1995), various cancers (Dockerty, Becroft, Lewis et al 1997; Brenner, Steigmaier, Ziegler 1995; Schouten, Straatman, Kiemeney et al 1994; Robles, Marrett, Clarke et al 1988), HIV(Abeni, Brancato, Perucci 1994; Mastro, Kitayaporn, Weniger et al 1994; Frischer, Leyland, Cormack et al 1993), stroke (Taub, Lemic-Stojcevic, Wolfe 1996), inflammatory bowel disease (Tragnone, Corrao, Miglio et al 1996), meningococcal disease (Ackman, Birkhead, Flynn 1996; Sorensen, Hansen, Ejlersen et al 1995) and tuberous sclerosis (O'Callaghan, Shiell, Osborne et al 1998).

The technique has also become increasingly popular for estimating the prevalence of behaviours in 'hidden populations'. As the prevention of HIV infection became a public health priority, a number of studies employed a capture-recapture technique to estimate the under-reporting of AIDs cases (Bernillon, Lievre, Pillonel et al 2000) and the prevalence of illicit drug use (Brugha, Swan, Hayhurst et al 1998; Knolle 1997; Larson, Bammer 1996; Hay, McKeganey 1996; Domingo-Salvany, Hartnoll, Maguire et al 1995; Korf, Reijneveld, Toet 1994; Simeone, Nottingham, Holland 1993; Frischer, Bloor, Finlay et al 1991). In Northern Italy, capture-recapture was used to estimate the prevalence of alcohol-related disorders in a large community (Corrao, Bagnardi, Vittadini et al 2000). Similarly, capture-recapture methods have been applied to studies of prostitute populations (Watts, Zwi, Wilson et al 1994; McKeganey, Barnard, Leyland et al 1992; Bloor, Leyland, Barnard et al 1991) and the homeless (Fisher, Turner, Pugh et al 1994).

Others have used capture-recapture to assess the optimal sources of data for use in building surveillance systems. In New Caledonia the technique was used to identify the best combination of data sources for a thyroid cancer registry to maximise its completeness (Ballivet, Salmi, Dubourdieu 2000). This approach focuses on assessing data quality in input sources rather than calculating ascertainment-corrected rates of the condition.

4.2 Capture-recapture in injury research

Some studies have adopted the capture-recapture approach in the field of injury research (Table 4.1). The technique has increasingly been used since the inception of the present study in 1997. Sacks and colleagues used the technique to estimate the number of dog bite fatalities in the United States for the period 1979-1986 (Sacks, Sattin, Bonzo 1989). Dog bites were again examined in Chang and colleagues capture-recapture study in Pittsburgh for the year 1993 (Chang, McMahon, Hennon et al 1997). On this occasion, hospital records and animal control agency reports provided input data. Capture-recapture was used to ascertain the completeness of child pedestrian injury reporting in routine public hospital discharge statistics and an active injury surveillance system in New Zealand (Roberts, Scragg 1994). In Pittsburgh, USA, multiple data sources were used in an attempt to ascertain the number of injuries sustained by adolescents in a single school district (LaPorte, Dearwater, Chang 1995). The same researchers advocated capture-recapture as a way of monitoring the incidence of head and spinal injuries in both developed and developing countries (Chiu, Dearwater, McCarty et al 1993).

The technique was also adopted in Colorado in an attempt to establish accurate incidence data for head and spinal cord injuries in the United States (Johnson, Gabella, Gerhart et al 1997). In Iowa, capture-recapture was used to estimate the rates of severe traumatic brain injury using three data sources (Schootman, Harlan, Fuortes 2000). High risk groups were successfully identified using the technique. In Quebec, Rossignol used a two sample capture-recapture to estimate the number of occupational injury fatalities using data from the Workers Compensation Board and death certificates (Rossignol 1994). In Northumbria, a capture-recapture study identified a large pool of serious childhood injuries from TRIs that were not included in the official data sources (Levene, Jarvis, Lowe et al 1998).

To date, the capture-recapture technique has rarely been applied to the study of TRIs. In Karachi, Pakistan capture-recapture was used to estimate deaths and injuries due to TRIs (Razzak, Luby 1998). This study showed that TRIs were a more serious public health problem than was evident from official statistics. Official statistics included only 56% of deaths and 4% of serious injuries. A recent study of children with a serious injury resulting from a motor vehicle accident (applying mark-recapture) concluded that the study violated most of the

requirements of the technique including the requirement for a closed population and equal chance of recapture (Jarvis, Lowe, Avery et al 2000).

Comparisons of police and hospital data (not employing capture-recapture) have also been conducted (Simpson 1996; Morrison, Kjellstrom 1987; Bull, Roberts 1973). Overall, these studies concluded that not all potentially reportable crashes are recorded, and that there were biases in reporting depending upon the type of road user. Crashes involving casualties with less severe injuries, pedestrians, pedal cyclists and motorcyclists were less likely to be recorded.

Table 4.1 Summary of capture-recapture studies in injury research

Lead author	Year	Country	Injury type	No. of sources	Stated purpose
Schootman	2000	USA	Traumatic brain injury	3	AC
Jarvis	2000	UK	Child injuries	2	EI, AC
Razzak	1998	Pakistan	Traffic related injuries	2	EI, AC
Chang	1997	USA	Dog bite injuries	3	EI
Johnson	1997	USA	Spinal cord injuries	3	EI
LaPorte	1995	USA	Adolescent injuries	4	EI
Roberts	1994	New Zealand	Child injuries	2	AC
Rossignol	1994	Canada	Occupational injury fatalities	2	AC
Chiu	1993	USA	Motor vehicle fatalities	2	EI, AC
Sacks	1989	USA	Dog bite fatalities	2	EI

EI – estimate incidence, AC – assess completeness

4.3 Capture-recapture techniques and assumptions

The simplest capture-recapture technique is the two sample model adopted in this study. The technique estimates the number of cases in the total population based upon the number of individuals caught in both lists. The first list provides the individuals for 'marking', and returns them to the population, while the second list provides the opportunity for recapture.

There are a number of underlying assumptions with the capture-recapture technique. Firstly, there is the assumption that individuals can be matched from capture to recapture. Secondly, each individual should have the opportunity to be marked on each list. Thirdly, that the two lists should be independent. Fourthly, that the population is 'closed' during the study period (i.e. that the same population exists at capture and recapture, no individual has joined or left the population).

Some of these assumptions are easily violated in the context of human population studies. For instance, the assumption that an individual has the same probability of appearing on both lists is particularly problematic for capture-recapture in a human health population. An individual may be more likely to appear on one list than another (or indeed neither list) due to their socio-demographics, geography of residence and health service behaviour. Further, the requirement that the population is 'closed' is difficult to adhere to. This may be particularly problematic in studies of young people who are generally more mobile than the population generally (who may also be described as mobile).

Although the minimum number of data sets that can be used is two, multiple sources of data may be available. In the injury field, Schootman (2000), Chang (1997), Johnson (1997) and LaPorte (1995) have employed multiple sources of data for use in their capture-recapture studies. In the LaPorte study, four sources of data on adolescent injuries were employed to ascertain the number of injuries occurring over a four month period in three schools in Pennsylvania. While multiple sources allow more sophisticated statistical analysis (in particular the use of log-linear modelling), the cost-benefits of adding data lists to the technique is questioned by some authors. Chang and colleagues stress the importance of employing the 'optimal' number of sources to ensure the approach is cost-effective (Chang, LaPorte, Aaron et al 1999). In their study of adolescent injury, four input sources produced 91% case ascertainment, however, reasonably accurate estimates of incidence were also achieved using two or three sources.

A sound understanding of the relationship between the input lists (i.e. likely positive or negative dependence) and the data collection and classification methods used are essential for interpreting the results of capture-recapture. Inaccuracy based upon the relationship between datasets is a major concern (Hook, Regal 1992; Brenner 1995). An underlying assumption of

the capture-recapture technique is that the sources are relatively independent. However, both a positive and negative dependency can lead to inaccuracy. Positive dependence can lead to underestimation and negative dependence can lead to overestimation. The relationship between datasets requires careful consideration for each capture-recapture exercise.

In 1995, the International Working Group for Disease Monitoring and Forecasting proposed that capture-recapture (while imperfect) provided a fresh approach, an advance in the ability to monitor disease (International Working Group for Disease Monitoring and Forecasting 1995a). However, the technique has both its avid proponents and its critics. A flurry of papers in the Journal of Clinical Epidemiology in 1999 discussed the application of capture-recapture in a study of measles outbreak (McGilchrist, McDonnell, Jorm et al 1996) and demonstrated the state of the current debate around capture-recapture techniques. A careful reading of the variance and dissent bring the reader to the conclusion that the technique should be used with caution and should always be piloted. The validity of the technique appears to be highly dependent upon the target population, data sources and eventual intended use of the results. It is useful to break down the procedure into two component parts. The first component of the exercise examines the completeness of reporting and the biases inherent in each database. The second calculates ascertainment-corrected rates.

Cormack stresses that there is frequently insufficient information in capture-recapture studies to calculate accurate estimates of population size (Cormack 1999). He argues that epidemiologists using capture-recapture have not fully understood the origins of the technique and questions the relevance and applicability of the technique for use with human populations, in particular the assumptions made about the input data. The aforementioned study of children with a serious injury resulting from a motor vehicle accident (applying capture-recapture) also concluded that their study violated most of the fundamental requirements of the technique (Jarvis et al 2000). These violations included the requirement for equal probability of capture on each input list and the requirement for a 'closed' population. These authors question the technique's ability to accurately estimate the size and characteristics of the unobserved group.

Other authors highlight the benefits of capture-recapture, but note the need for caution in its application. Hook and Regal make 15 explicit recommendations for presenting capture-recapture analyses including assessing the quality and structure of the input data, the use of

ancillary data, commenting on the likely relationship between the input sources and explicitly identifying the final the use of the data (Hook, Regal 1999). Chang and colleagues highlight the importance of source selection and recommended a pilot study before applying the technique widely (Chang et al 1999). They emphasise the importance of understanding the nuances of the data. For example, one of the commonest problems with multiple sources in capture-recapture using human populations is the severity effect. More severe cases are likely to be captured in more than one source.

Formal (but cautious) use of the capture-recapture technique in national and international disease monitoring is advocated to assess the degree of undercount in traditional surveillance systems (International Working Group for Disease Monitoring and Forecasting 1995c). In the injury field, progress towards routinised use of the technique has been made by Chang and colleagues (Chang et al 1999). A county-wide injury monitoring system using the technique is currently being tested. The internet is being employed to transfer monthly data on injury cases for inclusion in the procedure. The authors believe the system provides cost-effective and timely data. Injury incidence rates are available within a month of data transfer. Injury 'hotspots' are identified and preventive action is initiated (Chang et al 1999).

In Scotland (as in other countries) existing routine databases holding information on TRIs are open to criticism of variable ascertainment. Certainly, data generated by traditional epidemiological surveillance systems are frequently criticised as being of poor quality due to under-ascertainment. Under-counting in disease and injury monitoring has long been recognised, but seldom corrected. Capture-recapture may provide a new approach (when used appropriately) that allows for more accurate estimates of prevalence and assessing whether biases in the data exist.

Moreover, there is increasing interest among injury researchers to maximise the use of existing data. This is both cost-effective and eminently sensible, but not always easy or indeed valid if the data sources are of poor quality. The capture-recapture technique could be applied to TRIs in Scotland to examine the completeness of data sources and to calculate ascertainment-corrected rates. Two sources of official data on TRIs described in Chapter 3 appear to satisfy the basic requirements of input data. The use of the capture-recapture procedure in this study is further discussed in Chapter 6.

Key points

- Capture-recapture is increasingly used in studies of human epidemiology to generate more accurate rates of disease and disability and estimate the completeness of data sources.
- A number of injury research studies have employed the technique, including two studies specifically examining TRIs.
- The principal criticisms of the technique (when applied to human epidemiology) are insufficient information to calculate accurate estimates of population size and the violation of many of the fundamental requirements of the technique.
- Proponents of the technique highlight the importance of piloting, quality of input data, use of ancillary data and understanding the structure and underlying associations within the data.
- It is possible to use capture-recapture in Scotland to assess the completeness of official data sets and to estimate the number of TRIs.

Chapter 5 AIM, OBJECTIVES, AND RATIONALE

This chapter sets out the aim of the study and the four key objectives. To address these objectives, ten research questions (and associated null hypotheses) were formulated and presented. The study methods and findings are presented for each of the ten research questions in Chapters 6-9. Finally, the four principal reasons for undertaking the study are outlined.

5.1 Aim

The aim of study was to examine the epidemiology of transport-related injuries (TRIs) among young people (15-24 years) in Scotland between 1986 and 1995 with a view to assessing the utility of official data sources.

5.2 Objectives

There were four key objectives:

- To examine the temporal and socio-demographic trends in TRIs in Scottish young people between 1986 and 1995.
- To compare TRI rates in Scottish young people with their European counterparts over the same study period.
- To establish the location, time and circumstances in which fatal and non-fatal TRIs occur.
- To assess the completeness of data on TRIs in Scottish young people using the capture-recapture technique.

5.3 Key questions and associated null hypotheses

Ten key research questions with associated null hypotheses were formulated:

1. **How common were TRIs as a cause of injury among young people in Scotland between 1986 and 1995?**

   Null hypothesis: TRIs were not a common cause of injury among young people in Scotland between 1986 and 1995.

2. **How did the rates of TRIs among young people in Scotland compare with other European countries?**

   Null hypothesis: Rates of TRIs among young people in Scotland were the same as in other European countries.

3. **What were the trends in fatal and non-fatal TRIs among young people in Scotland by road user type?**

   Null hypotheses: Rates of fatal and non-fatal TRIs among young people in Scotland between 1986-1995 were the same for all road user types.

4. **Were some young people in Scotland at greater relative risk of sustaining a TRI due to their sex and socio-economic status?**

   Null hypothesis: Young people were at equal risk of sustaining a TRI irrespective of their sex or socio-economic status.

5. **What types of injuries were sustained?**

   Null hypothesis: N/A

6. **Where, when and under what circumstances did fatal and non-fatal TRIs occur?**

   Null hypothesis: Fatal and non-fatal TRIs occurred at the same time, in the same location and the same circumstances.

7. What were the characteristics of fatal TRI events compared to non-fatal TRI events?

Null hypothesis: The characteristics of fatal and non-fatal TRIs were the same.

8. Were the observed trends in TRIs associated with changes in exposure to risk?

Null hypothesis: Trends in TRIs were not associated with changes in exposure to risk.

9. To what extent did the two official Scottish data sources on TRIs overlap and what was the associated ascertainment corrected number of TRIs?

Null hypothesis: The two official Scottish data sources on TRIs did not overlap and the associated ascertainment corrected number of TRIs was not possible to calculate..

10. Is capture-recapture a useful technique in TRI epidemiology?

Null hypothesis: Capture-recapture is not a useful technique in injury epidemiology.

5.4 Study Rationale

There were four principal reasons for undertaking this study:

1. TRIs are a common cause of death, disability and lost potential years of life among young people elsewhere in the industrialised world. There is a dearth of epidemiological studies to establish whether this is also the case in Scotland.

2. Valid and reliable data on TRIs are necessary to assess the severity and relative importance of TRIs as a cause of death, hospital admission, disability and economic losses at a national, regional and local level. These data are also potentially useful for prevention and for evaluating the efficacy of preventive initiatives.

3. The injury prevention research community is interested in developing new and effective approaches to data analysis and presentation by linking existing data sources. Co-ordination of injury data across disciplines is currently poor. While in most countries there are available data on TRIs from at least two sources, few studies have attempted systematically to use multiple sources. Exposure data in particular are rarely used to contextualise the results of injury epidemiology.

4. Capture-recapture may provide a cost-effective means of assessing the completeness of data sources and generating more accurate estimates of injury incidence than reliance on a single surveillance system.

Chapter 6 METHODS

This chapter describes the methods that address the ten research questions posed in Chapter 5. As outlined in Chapter 3, data suitable for this study were obtained from a number of sources. The 15-24 year age group was selected for analysis for principally pragmatic reasons. The data were available categorised in this way across all data sources in this study. This age band also allowed a sufficient sample size for analysis by individual year.

6.1 Data obtained

Mortality data and hospital discharge (SMR1) records coded as injuries were obtained from the GRO and ISD for 15-24 year olds between 1986 and 1995. These data are herein collectively referred to as Scottish Health Service (SHS) data. STATS19 data were obtained for the last study year (1995) for all police-reported TRIs occurring in Scotland for casualties aged 15-24 years. WHO mortality data are also used to examine the trends in TRIs Europe-wide for 15-24 year olds between 1986 and 1995.

Further analysis of the IRTAD data on non-fatal TRIs among young people was considered inadvisable due to difficulties with comparison. The small number of valid cases captured in the population-based sample surveys described in Chapter 3 deemed further analysis inappropriate. Data from the NTS (and Scottish subset) were used to conduct a small piece of ecological epidemiology. Scottish Travel Diaries data were limited to one short study period, so were not of further use in examining correlations between exposure data and TRI incidence.

6.2 Data extraction

6.2.1 Mortality data

Mortality data due to all externally caused physical injuries were obtained from the GRO and cleaned. Injury fatalities are those coded as ICD9 E-codes 800-999. This includes both

intentional and unintentional injuries. The data received were anonymised. Nine variables were made available for analysis:

- Age at death
- Sex
- Date of Injury
- Link Number
- Carstairs deprivation category
- Cause of death 1
- Cause of death 2
- Cause of death 3
- Cause of death 4

Data concerning TRI fatalities were then extracted for further analysis. TRI mortality records were included if they met two criteria. Firstly, if they were coded with relevant ICD codes relating to TRIs occurring on public roads. This includes pedestrians, cyclists, motorcyclists (and their passengers) and motor vehicle occupants. The relevant ICD9 E-codes are E8100-8199, E8260-8269 and E8290-8299. Injuries occurring on private roads, and due to water, air and rail accidents were excluded. Secondly, cases were included if the death was not due to suicide. Suicides (due to crashing a motor vehicle) were noted, but were excluded from the data set. The decision to exclude suicides was based on the rationale that suicide prevention requires a very different approach from TRI prevention.

Extraction of TRI mortality records using these inclusion criteria generated 1281 records for further analysis. Several other checks were completed. There were a substantial number of deaths (286; 9%) where intent was 'undetermined'. For the purposes of this study it was important to check whether these were due to a TRI. Further analysis of the ICD9 E-code found no additional cases. It was also important to determine whether any of the 840 deaths due to suicide were due to a TRI. Five deaths (0.6%) were due to crashing a motor vehicle intentionally. None of these deaths occurred in 1995, thus not affecting the capture-recapture procedure. While these have been noted, they were excluded from the analysis. Thus, there were 1281 TRI fatalities on public roads in young people 15-24 years between 1986 and 1995.

To allow comparisons of TRIs among young people in Scotland, with countries elsewhere in the European Union, mortality data from the WHO were obtained. These data were collated for the period 1986 to 1995. Most of the data were available on a CD ROM available from WHO. This was supplemented by data available in the WHO Annuals published up to and including 1998. There may be some differences in classification and coding between the

countries. However, an exploration of the difficulties of comparative analysis suggests that this is less acute for fatal than for non-fatal injuries (EURORISC Working Group 2000).

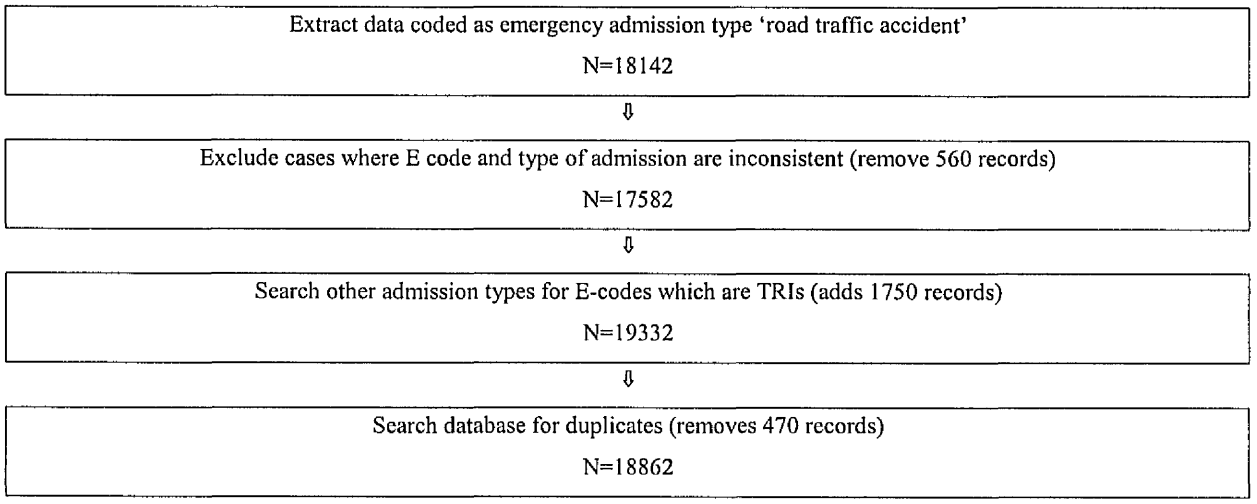
6.2.2 SMR1

All SMR1 hospital discharges due to injury were obtained from the ISD for young people aged 15-24 years between 1986 and 1995. These data were also anonymised. Fourteen variables were made available for analysis:

- Link Number
- Age at admission
- Sex
- Carstairs deprivation category
- Date of admission
- Date of discharge / death
- Type of admission
- Type of discharge (including death)
- Diagnosis 1
- Diagnosis 2
- Diagnosis 3
- Diagnosis 4
- Diagnosis 5
- Diagnosis 6

Data on TRI hospitalisations specifically were then extracted. Three inclusion criteria were applied to these data. Firstly, the record must be coded as an emergency hospital admission (this excludes transfers, booked admissions and repeat admissions). Secondly, the record must be coded with ICD codes relating to TRIs occurring on public roads. This includes pedestrians, cyclists, motorcyclists (and their passengers) and motor vehicle occupants. The relevant ICD9 E-codes are E8100-8199, E8260-8269 and E8290-8299. Injuries occurring on private roads, and due to water, air and rail accidents are excluded. Thirdly (as with mortality data) parasuicides due to crashing a motor vehicle are excluded from the data set. Extraction of the relevant SMR1 records was complex. A flow-chart at Figure 6.1 illustrates the process of data extraction. This process is further discussed below.

Figure 6.1 Data extraction process for SMR1 records



A total of 18,142 SMR1 records coded as type of admission 'road traffic accident' were extracted in the first instance. This procedure identified 17,582 (97%) injuries sustained by pedestrians, cyclists, motorcyclists, motor vehicle drivers and their passengers on public roads. The remaining 560 cases are excluded. These include 360 'non-traffic' accidents (E8200-8259; 2%), and 200 cases where the E-code and type of admission code are inconsistent. A wide range of E-codes were listed, the most frequent being falls (63; 0.3%) and unspecified accidents (28; 0.2%).

Other emergency admission types (not road traffic accidents) were then searched for further relevant E-codes. Cases for inclusion were found in other types of emergency admission. A further 1750 cases with relevant ICD codes were identified for inclusion. The majority of these (85%) were coded as 'other injury (including accidental poisoning other than in the home' (Table 1). At this juncture there were 19332 valid cases of emergency hospital admissions due to TRIs in the data set.

The working dataset was then checked for further inconsistencies. Some were identified. In some cases a readmission or transfer had been coded as an emergency admission on a second SMR1 form, even if the readmission occurred immediately or within 28 days. Two examples are given in Figure 6.2 for illustration. In example 1, the second entry under type of admission should be coded as a transfer (Type of admission = 3). In example 2, the second entry under type of admission should be coded as a readmission (Type of admission 2). A total of 470

(2.4%) double entries were identified. These cases were removed from the working database to avoid double counting of emergency admissions. While theoretically this procedure may result in a number of new injury events occurring within 28 days being excluded, the error margin is likely to be very small. A total of 18862 records remained for analysis.

Figure 6.2 Examples of duplicate cases in SMR1 database

Date of admission	Date of discharge	Type of admission	Type of discharge
Example 1			
12.12.94	13.12.94	5	3
13.12.94	17.12.94	5	1
Example 2			
3.3.89	7.3.89	5	1
9.3.89	10.3.89	5	1

Overall the extracted TRI records represent 12.8% of SMR1 injury records coded as emergency admissions over the study period (Table 6.1). The majority (95%) were correctly coded as 'emergency road traffic accidents' in the first instance. Table 1 illustrates the types of emergency admission with relevant E-codes.

Table 6.1 Types of emergency admission with relevant inclusion E-codes

Type of Emergency Admission	Total cases at first analysis (n=)	No with relevant E-code (n=)	As % of total
Deliberate self injury or poisoning	34083	5	0.01%
Road traffic accident	18142	17279	95.2%
Home accident(including poisoning in the home)	14681	27	0.2%
Other injury (includes accidental poisoning other than in the home)	73141	1489	2.1%
Other (excludes accidental poisoning)	7081	62	0.9%
TOTAL	147128	18862	12.8%

A final task was to match the mortality records with SMR1 records using the unique link number. This exercise revealed that 161 (13%) of fatalities had an associated SMR1 form, suggesting that the majority of deaths (1120; 87%) occurred immediately or within a short time of the injury event. This reflects the findings of a study examining temporal trends in trauma death by the Scottish Trauma Audit Group (STAG) (Wyatt, Beard, Gray et al 1995). They examined 331 deaths following TRI trauma in the Lothian and Borders regions of Scotland. Of these victims, 76% died within one hour of injury and a further 6% died within four hours of injury. The remaining 18% survived more than four hours after the injury event.

6.2.3 STATS19

As explained in Chapter 3, there are three related files of data on the STATS19 system. The variables available for analysis are presented in Figure 6.3. These data are made available by the University of Essex data archive at a charge. Associated literature on data collection and information on variables and coding frames are also supplied with these data.

Figure 6.3 Data available for analysis on STATS19 database

Accident report	Vehicle report	Casualty report
Police force	Police force	Police force
Accident reference	Accident reference	Accident reference
Severity	Vehicle reference	Vehicle reference
Number of vehicle records	Type of vehicle	Casualty reference
Number of casualty records	Towing and articulation	Casualty class
Date	Manoeuvres	Sex
Time	Vehicle location	Age
Road class	Junction location at impactSeverity	
Carriageway type	Skidding and overturning	Pedestrian location
Speed limit	Hit object on carriageway	Pedestrian movement
Junction details	Vehicle leaving carriageway	Pedestrian direction
Pedestrian crossing facilities	Hit object off carriagewaySchool pupil casualty	
Light conditions	First point of contact	Car passenger
Weather	Hit vehicle reference	Bus or coach passenger
Road surface conditions	Parts damaged	
Carriageway hazards	Sex of driver	
Any special conditions at site	Age of driver	
	Breath test	
	Hit and run	

Two inclusion criteria were applied to the analysis of STATS19 records for young people aged 15-24 years in 1995. Firstly, that the TRI had occurred in Scotland (police force codes 90-99). Secondly, that the TRI was coded as 'fatal' or 'serious' (probably resulting in hospital admission). One potential problem is that young people from out-with Scotland could be involved in a TRI in Scotland and thus ascertained by STATS19. It is not possible to examine this phenomenon using the 1995 data. However, postcodes have subsequently been recorded on STATS19 allowing a study of 'tourist' injuries in Scotland that commenced in late 2000. This study is funded by the Scottish Executive and will report in late 2001 (Scottish Executive website 2000).

As discussed in Chapter 3, 'fatal' injuries are defined as cases where death occurs within 30 days of the injury event. 'Serious' injuries are defined as detentions in hospital as an inpatient either immediately after the injury event, or have any of the following injuries: fractures, severe concussion, internal injuries, crushings, severe cuts and lacerations, severe shock requiring medical treatment. Most of these injury types result in hospital admission.

In 1995, there were 5781 police reported casualties as a result of TRIs in Scotland. Of these, 4393 (76%) were minor and are therefore excluded. There were 99 fatalities recorded and 1290 serious injuries (probably resulting in hospital admission). Matching accident reference numbers across the datasets also allowed the number of *injury events* to be identified. Several casualty and vehicle records can potentially match to one accident record. This process yielded 89 fatal TRI *events* that corresponded with the 99 fatalities, and 1121 TRI events that corresponded with the 1290 serious injuries. However, there was some duplication, with 25 TRI *events* corresponding to casualty records both fatal and serious already included in the fatal events. Moreover, there were 10 injury events that did not result in a fatality among the study age group, but did result in at least one fatality. These were also excluded. Thus, there were 1086 injury events with serious casualties (but no fatalities). The total number of TRI events in 1995 was 1175 (Figure 6.4).

6.2.4 Capture-recapture procedure

The capture-recapture technique has been described and discussed in Chapter 4. For the purposes of this study, it was useful to have an indication of under-reporting in both the Scottish Health Service (SHS) and police (STATS19) datasets, and evidence of the types of injuries or socio-demographic characteristics of those not captured by each. The capture-recapture technique was used for this purpose. Data on fatalities and hospitalised (serious) injuries from calendar year 1995 were entered into the procedure. Data extraction for this purpose yielded 97 and 99 fatalities respectively from the SHS and STATS19 databases. Extraction of non-fatal injuries generated 1458 and 1290 cases respectively from the SHS and STATS19 databases. Minor TRI data from STATS19 were not included in this exercise because there is no corresponding source of health data on non-hospitalised TRIs.

6.3 Summary of study data

After obtaining, cleaning and extracting the appropriate records from each database, the following cases were included in the analysis completed for this thesis. (Figure 6.4).

Figure 6.4 Summary of study data

Scottish Health Service Data 1986-1995	
Deaths (died at scene or before SMR1 completion was required)	1120
Deaths (died in hospital, SMR1 completion)	161
Total fatalities	1281
Discharged from hospital alive	18,701
Total SMR1 records completed	18,862
STATS19 Data, 1995	
Deaths	99
Serious injuries	1290
Number of TRIs resulting in a fatality	89
Number of TRIs resulting in serious (but non-fatal) TRIs	1086
Total TRIs	1175
Data entered into capture-recapture procedure, 1995	
SHS deaths	97
STATS19 deaths	99
SHS non-fatal TRIs	1458
STATS19 serious injuries	1290

6.4 Data Analysis

The techniques used to answer the ten research questions using the aforedescribed data are described below. SPSSPC for Windows and Paradox 7.0 for Windows were the software packages principally used for these analyses. The statistical methods applied to answer research questions 1-4 were previously used by the author (and colleagues) during the EURORISC project and were published in peer-reviewed journals (see Appendix 1). The analysis conducted to address the remaining research questions were largely exploratory, involving the combination of data sets and the use of a range of bivariate and multivariate techniques.

1. How common were TRIs as a cause of injury among young people in Scotland between 1986 and 1995?

Data on total fatal and hospitalised injuries (E800-999) were examined over the study period. Frequencies, proportions and average annual age-specific mortality rates (AAAMR) and discharge rates (AAADR) were calculated for all injury causes to assess the specific contribution of fatal and non-fatal TRIs to the injury burden. This is followed by an examination of the trends in the four leading causes of mortality (including TRIs) over the study period. A similar trend analysis is completed for different types of emergency hospitalisations (including TRIs). Linear regression was used to represent the linear component of the mortality profile over the study period. The baseline year adopted for the linear regression was 1986. The following statistics are quoted; the Adjusted R^2, the gradient of the linear model (B) with 95% confidence intervals and the associated p value. The Adjusted R^2 shows the extent to which the two variables are related, and is expressed as a percentage. The regression co-efficient (B) is the per unit change in the age standardised mortality rate and the p value indicates the significance of the relationship. The statistical significance level was set at 5%.

2. How did the rates of TRIs among young people in Scotland compare with other European countries?

Aggregated data on fatal TRIs were obtained from the WHO database for each of the current 15 member states of the EU. Linear regression was used (as described above) to examine the mortality profile for fatal TRIs in each member state between 1986 and 1995. Proportional

changes in the rates are also calculated and presented. The statistical significance level was set at 5%. This allows a comparison of TRIs rates among young people in Scotland with their counterparts elsewhere in the UK and across the EU.

3. What were the trends in fatal and non-fatal TRIs among young people in Scotland by road user type?

Rates of fatal and hospitalised TRIs were examined by road user type. Information on road user type is elicited from the ICD E-codes. The final (fourth) digit of the code indicates whether the injured person was a motor vehicle occupant, motorcyclist (or passenger), cyclist, pedestrian or other road user or unspecified. A variable was computed using the ICD9 codes to distinguish between road user types. The linear regression technique previously described is used again to examine trends in fatal and non-fatal injuries by road user type. The Adjusted R squared, gradient (B) and p value are shown. Again, the significance level was set at 5%.

4. Were some young people in Scotland at greater relative risk of sustaining a TRI due to their sex and socio-economic status?

Age-specific rates and proportions of TRIs were calculated for both sexes and for the seven deprivation categories previously described. Chi-square tests were used to test for differences between groups, and the linear regression technique previously described was used to assess the mortality and morbidity profiles over time by sex and socio-economic status. The measure of socio-economic status is the Carstairs deprivation index based upon the characteristics of post-code sectors (Carstairs 1991). This is a continuous scale from 1-7, where 7 is the most deprived and 1 is the most affluent. Population data from the 1991 census are used to analyse the deprivation category data. Thus, one population denominator is used for each of the ten numerator calculations. While this is not ideal, regular population data by deprivation category are not available because they are based upon census data. The next publication of such data will be approximately one year after the census that was conducted in May 2001. Further, ISD advised that the most appropriate groupings of Carstair's scores are; 1-2, 3-5 and 6-7. Grouping was important to ensure a reasonable sample size for analysis.

5. What types of injuries were sustained?

An injury morbidity matrix developed in Israel as part of the International Collaborative Effort (ICE) on Injury Statistics is used to present data on injury diagnosis. ICE are an international group of injury epidemiologists and statisticians sponsored by the National Center for Health Statistics in Washington who meet annually to develop standardised injury research methodologies with a view to facilitating international comparisons of injury data. The author was a member of this group between 1997 and 1999. The matrix was in its pilot form when it was used as part of the thesis, and results of its use were reported back to the ICE group in 2000. This matrix allows categorisation of injury diagnosis codes by body site and nature of injury. This matrix is used to present SHS data on both fatal and non-fatal TRIs over the study period 1986-1995. Principal diagnosis is examined in the first instance, however the matrix allows inclusion of multiple injuries and this is also illustrated in the results.

6. Where, when and under what circumstances did fatal and non-fatal TRIs occur?

In the first instance, the patterns of fatalities and serious injuries by month and day of the week are examined. The data are then dissagregated by former Scottish council regions to examine geographical differences across Scotland. Population data for 15-24 year olds in these areas were provided by the Local Government Research Branch of the Scottish Executive. This allowed rates to be calculated and for ratio of fatalities to serious injuries to be presented by area. However, these are relatively large geographical boundaries that often encompass both urban and rural areas. This can make interpretation of these findings difficult.

The STATS19 database was then interrogated to examine key indicators in the dataset. These indicators include the time and date of the injury, weather conditions, different road types, and different speed limits. Fatal and non-fatal injuries are included in the analysis. The proportions of fatal and serious non-fatal injuries for each indicator are calculated. Chi-square tests are used to test for differences in the proportions of fatal and non-fatal injuries for each indicator.

7. What were the characteristics of fatal TRI events compared to non-fatal TRI events?

The bivariate analysis described above was followed by a logistic regression analysis to identify any factors that determine the outcome of an injury event as 'fatal'. Fourteen categorical variables were entered into the model. The dependent variable was 'outcome' (fatal / non-fatal). Odds-ratios, associated confidence intervals and significance values (p) are presented for significant variables. The logistic regression was performed using SPSSPC for Windows stepwise regression technique. Most variables were already dichotomous. However, some variables were re-coded into two categories. The author was provided with some statistical advice to complete this exercise.

8. Were the observed trends in TRIs associated with changes in exposure to risk?

Exposure data from sources described in Chapter 3 and fatality and hospitalisation rates were used in a series of bivariate correlations with associated scatterplots. This can be described as 'ecological' epidemiology. This usually refers to the analysis of groups rather than individual subjects. Annual fatality and hospitalisation rates were correlated with annual data on distance travelled (by mode of transport) and the number of journeys (by mode of transport) for 15-24 year olds resident in Scotland. These data were extracted from the DETR National Travel Survey (and Scottish sub-set) and the Travel Diaries study completed for the Scottish Executive described in Chapter 3. Scatterplots with fitted regression lines are presented along with two-tailed significant results.

9. To what extent did the two official Scottish data sources on TRIs overlap and what was the associated ascertainment corrected number of TRIs?

A two sample capture-recapture analysis using SHS data and STATS19 data was performed to estimate the extent of 'undercounting' in the two main data sources for fatal and serious TRIs among young people aged 15-24 years for the calendar year 1995. Individuals were matched using a number of key variables. The standards used to define a match were based upon a concept used by Razzak and Luby in a capture-recapture to estimate deaths and injuries due to TRIs in Karachi, Pakistan (Razzak, Luby 1998). Standard A represents a perfect record match. These are progressively relaxed in Standards B-D. Four variables were used for matching mortality records; age, sex, day of accident, month of accident (Table 6.2).

Relaxing the matching to Standard D was considered defensible given the data collection circumstances. It is possible for a police reported injury to have occurred on the day before the hospital admission is recorded, particularly for injuries occurring in the evening. Moreover, an estimated age is frequently entered at the scene of a motor vehicle accident. Thus it is feasible to include matches where age differs by at least one year. Results for standards A to C are also presented to demonstrate the range of possible results by progressively relaxing the matching criteria. Even Standard D may be regarded as fairly stringent. It does not allow for coding or computerisation errors, or an error in age estimation of greater or less than one year.

Table 6.2 The four matching standards for fatal TRIs.

Standard	Age	Sex	Month	Day
A	Exact	Exact	Exact	Exact
B	Exact	Exact	Exact	STATS19 one day before
C	Within one year	Exact	Exact	Exact
D	Within one year	Exact	Exact	STATS19 one day before

To match records of serious (but non-fatal TRIs) five key variables were used, the same four as for mortality records (age, sex, day of accident, month of accidents) plus a location code (Table 6.3). The police area code (there are nine in Scotland) were matched with the hospital code of the emergency admission. For instance, Glasgow Royal Infirmary and Strathclyde police (the Glasgow area police force) would constitute a match. Circumstances where patients may cross police authority borders for emergency treatment were taken into account. As with mortality records, relaxing the matching criteria to Standard D is considered justifiable given the data collection setting.

Table 6.3 The five matching standards for serious (non-fatal) TRIs.

Standard	Age	Sex	Month	Day	Location
A	Exact	Exact	Exact	Exact	Exact
B	Exact	Exact	Exact	STATS 19 one day before	Exact
C	Within one year	Exact	Exact	Exact	Exact
D	Within one year	Exact	Exact	STATS19 one day before	Exact

Ascertainment corrected numbers of TRIs were calculated for fatal and non-fatal injuries using the formula shown in Figure 6.5. The results from the capture-recapture procedure are calculated using each of the four data matching standards (A-D).

Figure 6.5 Formula for ascertainment corrected number of cases

$$N = \frac{(x+1)\,(y+1)}{(z+1)}$$

where x is the number of cases in database one, y is the number of cases in database two, and z is the number of cases common to both databases

Confidence intervals for the ascertainment corrected rates are also calculated and presented in the results section. The formula for these is shown in Figure 6.6.

Figure 6.6 Formula for Confidence Intervals in capture recapture

$$\text{Standard Error (N)} \quad \sqrt{\frac{X\,Y\,X_1\,X_2}{Z^3}} \qquad N +/- 1.96SE\ (N)$$

where x_1 is the number of cases identified in x, but not y and x_2 is the number of cases identified in y but not x.

Finally, records unmatched in the capture-recapture matching procedure were extracted from the main data sets for further analysis. These cases were examined by age, sex and injury type and chi-quare tests were conducted to test for differences between groups. This was completed for both fatal and non-fatal injuries.

10. Is capture-recapture is a useful technique in TRI epidemiology?

An assessment of the value of the capture-recapture technique in injury epidemiology is presented based on the literature review and the experience of conducting this technique using official data sources in Scotland. A 'SWOT' analysis was completed to illustrate the strengths weaknesses, opportunities and threats associated with the technique. The SWOT approach is a

commonly used management tool used as a means of assessing problems and formulating appropriate recommendations and solutions (Bartol, Martin 1991). The technique involves teasing out the main strengths and weaknesses of an approach and assessing the opportunities that may be presented, and the threats to success an approach may face.

Chapter 7 EPIDEMIOLOGY

This chapter addresses the first four objectives described in Chapter 5. It examines the trends in total fatal and hospitalised TRIs between 1986 and 1995 using data from the Scottish Health Service. Age specific rates of TRIs are then presented to allow comparison of Scottish rates with those of other countries in the EU. The Scottish data are disaggregated further to examine TRI trends by road user type. Finally, patterns in rates by sex and socio-economic status are examined for all TRIs and for motor vehicle occupants and pedestrians specifically.

7.1 Research Question 1

How common were TRIs as a cause of injury among young people in Scotland between 1986 and 1995?

A total of 4974 young people aged 15-24 years died of all causes in Scotland between 1986 and 1995. Of these 3267 (66%) died as a result of an externally caused physical injury (Table 7.1). This includes both unintentional and intentional injuries. In sum, these injuries represent an average annual age-specific mortality rate (AAAMR) of 42.5 / 100,000 and are the leading cause of death in this age group.

TRIs specifically accounted for over one third of all injury deaths (1281; 39%) over the study period (Table 7.1). The AAAMR due to TRIs was 16.7 / 100,000. Suicides accounted for a further quarter (840; 26%) of injury deaths, with an AAAMR of 10.9 / 100,000. Deaths classified as undetermined (286; 9%) are also often included as suicides in studies. The verdict of undetermined death is the most common verdict in the case of a probable suicide (EUROSAVE Newsletter 2000). Arguably then, suicides may in fact account for up to 35% of deaths in this age group.

Assaults were the third leading cause of death, accounting for one in ten injury fatalities over the study period. However, there is a particular feature of note in these data. Fatalities from the Piper Alpha disaster are included (see later). The category 'other transport accidents' (accounting for 2% of all injury deaths) refers to injury events on railways, cable cars, water and air transportation and industrial powered vehicles.

Table 7.1 Injury fatalities in 15-24 year olds in Scotland by cause, 1986-1995. Numbers, % of total injury fatalities and average annual age-specific mortality rate (AAAMR) per 100,000.

Injury cause	ICD9 E-code	No of fatalities (% of total)	AAAMR
TRIs (including pedestrians and cyclists)	8100-8199, 8260-8269, 8290-8299	1281 (39%)	16.7
Suicides	9500-9599	840 (26%)	10.9
Assault	9600-9699	318 (10%)	4.1
Deaths where intent is undetermined	9800-9899	286 (9%)	3.7
Accidental poisoning	8500-8699	123 (4%)	1.6
Falls	8800-8889	91 (3%)	1.2
Other transport accidents*	8000-8079, 8200-8259,8270-8289, 8300-8389,8400-8459,8460-8489	73 (2%)	1.0
Drowning / submersion	9100-9109	58 (2%)	0.8
Fire and flames	8900-8999	55 (2%)	0.7
Ingestions / inhalations and suffocation	9110-9139	39 (1%)	0.5
Machinery	9190-9219	26 (1%)	0.3
Electric current / radiation	9250-9289	23 (1%)	0.3
Other **	8700-8719, 8750-8769, 8780-8799, 9010, 9080,9090, 9160-9189, 9220-9239, 9240-9249, 9290-9299, 9300-9499	54 (2%)	0.7
TOTAL	8000-9999	3267	42.5

** Other includes: excessive cold & other environmental factors, struck by object/ person (accidental), medical misadventure, abnormal reactions, firearms, explosions, hot substance scalds, electrocution, exposure to radiation, late effects.

* Other transport accidents include railway, non-traffic, water, air transport, industrial powered vehicles, cable cars.

Further examination of the trends in the four leading causes of injury death among young people between 1986 and 1995 (excluding deaths where intent is undetermined) showed that TRIs were the leading cause of injury death between 1986 and 1992, and again in 1995 (Figure 7.1). Deaths coded as suicides were the leading cause of injury death in 1993 and 1994. The linear regression analysis revealed a significant linear decrease in fatalities due to TRIs over the study period from 19.3 to 14.3 / 100,000, a (non-significant) non-linear increase in suicide mortality rates from 9.5 to 11.7 / 100,000, a non-linear increase in mortality due to assault from 2.3 to 4.6 / 100,000 and no change in the death rate due to accidental poisoning (Table 7.2). It is worth reiterating that these suicide data do not include deaths coded as 'intent undetermined' and therefore may be an underestimate.

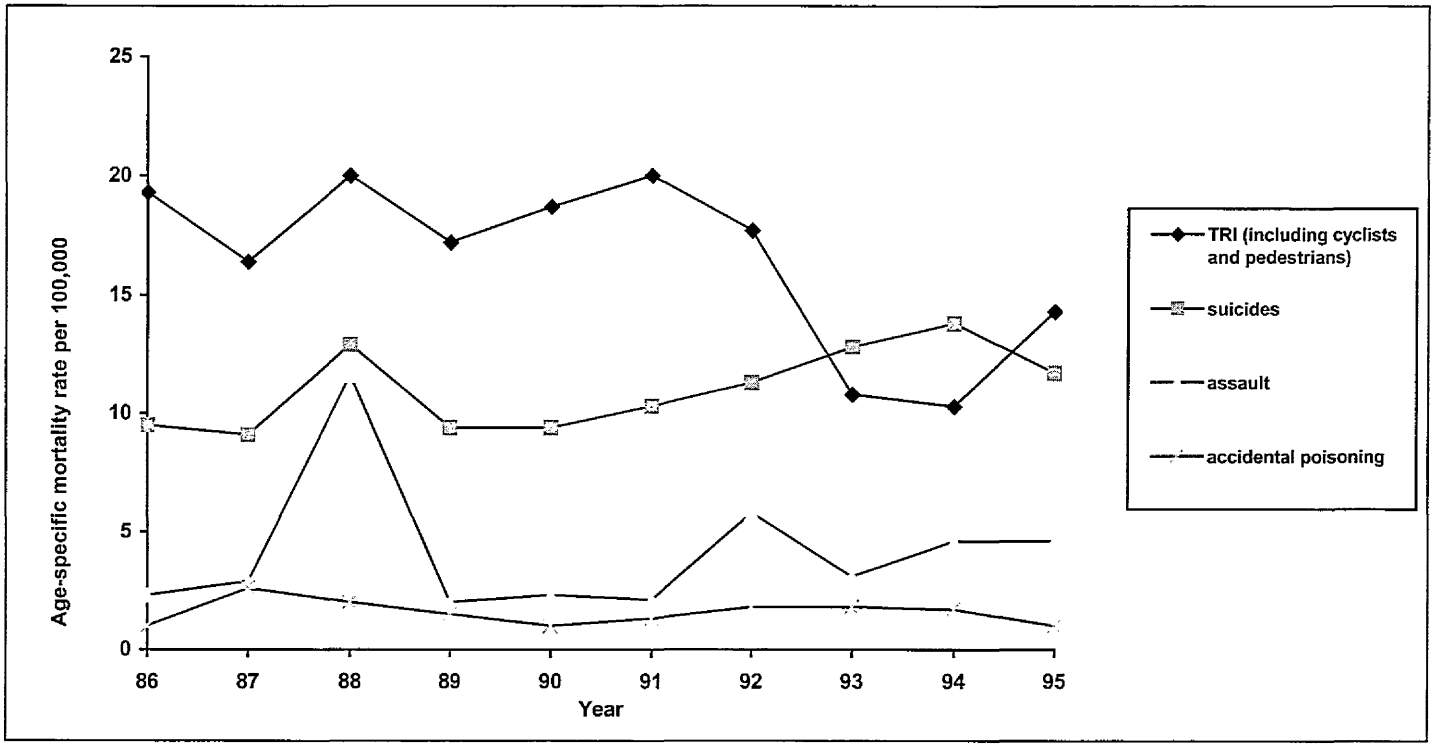
Table 7.2 Trends in injury fatalities in 15-24 year olds in Scotland, 1986-1995. Rates per 100,000, percentage change and linear regression results.

Cause of death	Age-specific mortality rate (1986)	Age-specific mortality rate (1995)	% change in rate (1986-95)	Adjusted R^2	Coefficient B (Confidence intervals 95%)	P value
TRI	19.3	14.3	-26%	38%	-0.8 (-1.5, -0.1)	0.033*
Suicide	9.5	11.7	+23%	32%	0.4 (0, 0.7)	0.053
Assault	2.3	4.6	+100%	1%	0 (-0.8, 0.8)	0.982
Accidental poisoning	1.0	1.0	0%	1%	0(-0.2, 0.1)	0.457

* denotes significant result

Fluctuations in the non-linear trends for suicides, assaults and accidental poisonings are evident in the graphical representation of the data (Figure 7.1). Particularly stark is the increase in assaults in 1988. Further analysis revealed that 86% of these deaths were coded as E9568 'assault by other specified explosive'. The majority of these deaths occurred as a result of the Piper Alpha disaster. After discounting the 1988 data, there remained a general increasing trend in fatalities coded as assaults between 1986 and 1995. While the linear regression analysis from 1986 to 1995 showed that a borderline, non-significant increase in suicide rates occurred, a repeat analysis using the period 1989 -1995 confirmed that a significant linear increase occurred in the later part of the study period. Nonetheless, by 1995 TRIs remained the leading cause of injury death in this age group.

Figure 7.1 Trends in age-specific mortality rates for the four leading causes of fatalities in 15-24 year olds in Scotland, 1986-1995.



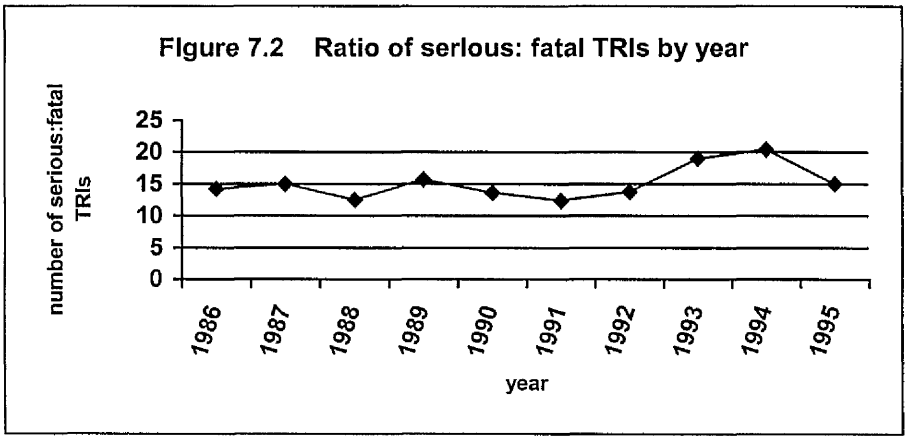
There were 18,862 emergency hospital admissions due to injury over the study period. Over this period, emergency admission rates due to injury increased by 36% from 1648 / 100,000 to 2243 / 100,000. Parasuicides and other injuries (including accidental poisoning other than home) were the most common causes of emergency admission due to injury at both the beginning and end of the study period. Significant linear increases were observed for all emergency admission types, with the exception of TRIs which decreased significantly over the study period, by 21% (Table 7.3). Admissions due to deliberate self harm increased by 77%, home accidents increased by 23% and admissions coded as 'emergency other injury including accidental poisoning other than in the home' increased by 30%. Finally admissions coded as 'emergency - other excluding accidental poisoning' increased by 208%.

Table 7.3 Trends in emergency admission types in 15-24 year olds in Scotland, 1986-1995. Rates per 100,000, percentage change and linear regression results.

Cause of death	Age-specific hospitalisation rate (1986)	Age-specific hospitalisation rate (1995)	% change in rate (1986-95)	Adjusted R^2	Coefficient B (Confidence intervals 95%)	P value
TRIs	276	217	-21%	68%	-6 (-10, -3)	0.003*
Parasuicide	337	596	+77%	59%	30 (25, 35)	<0.001*
Home accidents	160	197	+23%	59%	6 (2, 9)	0.006*
Other injury (includes accidental poisoning other than at home)	823	1073	+30%	81%	23 (15, 31)	<0.001*
Other injury (excludes accidental poisoning)	52	160	+208%	88%	10 (7, 13)	<0.001*

Note: at this stage, all emergency hospital admissions are included irrespective of outcome (fatal / non-fatal)
* denotes significant result

For every fatality over the study period, there were 14 (non-fatal) hospital discharges due to injury. These discharges refer to episodes of care, not patients. An examination of case fatality rates using fatalities and SMR1 records (discharged alive) showed that these had fluctuated over the study period, ranging from a minimum of 12.6 in 1988 to a maximum of 20.5 in 1994 (Figure 7.2). There was no significant linear trend in (hospitalised) case fatality rates over the study period (AdjR2 15%, p=0.15).



7.2 Research Question 2

How did the rates of TRIs among young people in Scotland compare with other European countries?

Analysis of the WHO mortality data showed that over half a million EU citizens died as a result of a TRI between 1986 and 1995. (Morrison et al 2000). Young people aged 15-24 years were disproportionately more likely to sustain a fatal TRI. Over a quarter of fatalities were among this age group. However, most countries experienced a downward trend in TRI fatalities over the study period (Table 7.4). Rates in the EU vary widely, with differentials between the country with the lowest and highest rates widening slightly between 1986 and 1995. In 1986 the highest rates were observed in Belgium (36.9/100,000) and the lowest rates in the Netherlands (16.3/100,000). By 1995, rates varied between 37.1 /100,000 in Portugal and 8.1 / 100,000 in Sweden (Table 7.4).

Linear regression clearly demonstrated that seven countries (including Scotland) experienced significant linear trends in TRI fatalities over the study period. Six of these countries (France, Denmark, Scotland, Sweden, England & Wales and the Netherlands) experienced significant downward trends in TRI mortality. One country (Italy) experienced a significant linear increase in TRI mortality. Interestingly, those countries that experienced the largest declines in rates were not those with the highest rates at the

beginning of the study period. France had the third highest rate in 1986, and were ranked fifth by 1995. Denmark were ranked seventh in 1986 and were tenth by 1995. However, the remaining four countries that experienced significant declines in TRI mortality were firmly at the bottom of the table in 1986 (Sweden, Scotland, England/Wales and the Netherlands) and in 1995. Sweden experienced a remarkable 57% (significant) decrease in TRI rates over the study period from 18.7 to 8.1/100,000. Thus, those countries with the greatest scope for improvement were not those who experienced significant declines in TRI mortality over the study period.

Relative to other European countries, Scotland has a fairly low (and decreasing) rate of TRI fatalities in this age group. However, it is worth noting that rates for England and Wales were slightly lower than for Scotland both in 1986 and 1995. Rates in Northern Ireland were higher than Scotland in 1986, but almost the same (14.2 and 14.3 respectively) by 1995. Thus, the proportional decrease in TRI mortality in Scotland over the study period was slightly lower than for other parts of the UK; 26% decrease in Scotland compared to a 35% decrease in Northern Ireland and a 37% decrease in England and Wales.

Table 7.4 Trends in age specific mortality rates by EU country, 1986-1995 (or latest available year). Proportional differences and linear regression results by country (ranked by 1986 rate).

Country	Mortality Rate 100,000 1986	Mortality Rate / 100,000 1995 (or latest*)	Proportional difference 1986-1995	Adjusted R squared	Regression Co-efficient (95% CI)	Associated p value
Belgium	36.9	30.6*	-17%	64%	-0.9 (-1.5, -0.2)	0.19
Austria	35.6	29.0	-19%	52%	-0.7 (-1.2, -0.2)	0.12
France	34.0	25.7	-24%	59%	-0.8 (-1.3, -0.3)	**0.01***
Portugal	29.8	37.1	+24%	4%	0.4 (-0.7, 1.4)	0.45
Greece	29.6	32.6	+10%	15%	0.5 (-0.2, 1.2)	0.14
Germany	27.2	25.7	-6%	14%	-0.1 (-0.4, 0.4)	0.99
Denmark	25.1	15.5	-38%	80%	-1.1 (-1.6, -0.6)	**0.02***
Spain	23.4	20.4*	-13%	6%	-0.5 (-2.1, 1.2)	0.50
Italy	23.1	25.0*	+8%	46%	0.8 (0.1, 1.5)	**0.04***
N. Ireland	21.9	14.2	-35%	45%	-0.8 (-1.9, 0.2)	0.09
Ireland	20.7	18.5	-11%	12%	-0.3 (-0.9, 0.4)	0.38
Scotland	19.3	14.3	-26%	38%	-0.8 (-1.5, -0.1)	**0.03***
Sweden	18.7	8.1	-57%	90%	-1.3 (-1.6, -1.0)	**<0.001***
England/Wales	18.4	11.5	-37%	78%	-0.8 (-1.4, -0.1)	**0.03***
Finland	18.2	11.7	-36%	30%	-0.9 (-1.8, 0)	0.06
Netherlands	16.3	13.1	-20%	80%	-0.4 (-0.5, -0.3)	**<0.001***

Source: Crude mortality data extracted from World Health Organisation Annuals.
n.b. Luxembourg is excluded due to the small number of cases annually.
*denotes significant result

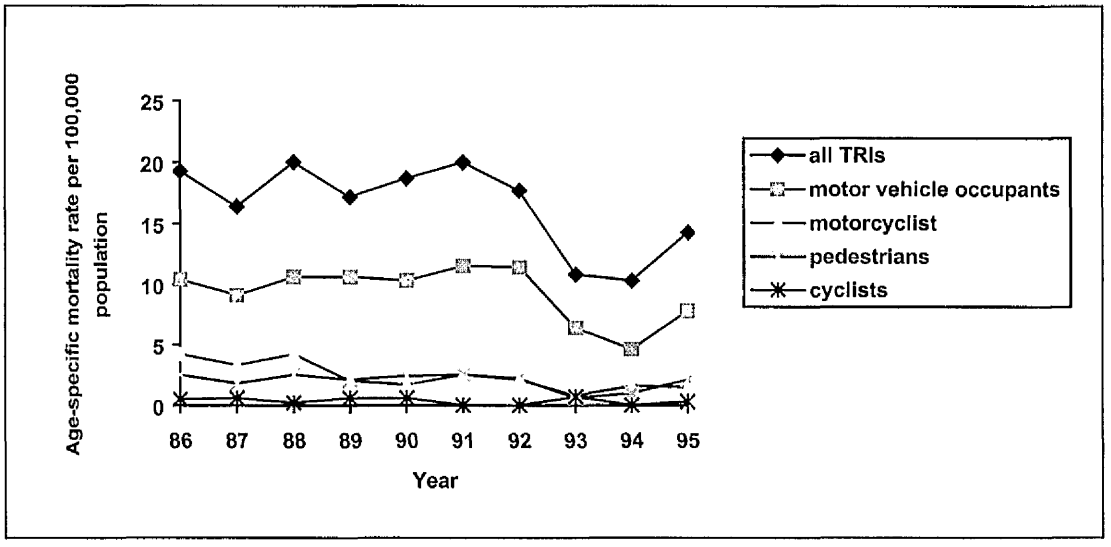
7.3 Research Question 3

What were the trends in fatal and non-fatal TRIs among young people in Scotland by road user type?

According to health service data, motor vehicle occupant (driver or passenger) fatalities accounted for more than half of the 1281 TRI-related fatalities (722; 56%). Motorcyclists (and their passengers) accounted for 190 (15%) fatalities, pedestrian injuries accounted for 154 (12%) fatalities, 28 (2%) of fatalities were pedal cyclists and the remaining 187 (15%) fatalities were sustained by an unspecified road user. A 25% decrease in age-specific mortality rates for motor vehicle occupants was observed over the study period from 10.4 / 100,000 to 7.8 / 100,000 (Figure 7.3).

Age-specific rates of motorcyclist injuries decreased by 64% from 4.2 to 1.5 / 100,000. Rates of pedestrian fatalities decreased by 16% from 2.5 to 2.1 per 100,000 and cyclist fatalities decreased by 40% from 0.5 to 0.3 per 100,000. However, it should be noted that the numbers of fatalities for cyclists in particular are very small annually. The linear regression results are affected by an increase in fatalities in 1995. However, discounting 1995, a significant linear decrease is observed for both motor vehicle occupants and TRIs generally.

Figure 7.3 Trends in age-specific mortality rates by road user type in 15-24 year olds in Scotland, 1986-1995.



nb. 187 fatalities sustained by an unspecified road user type are not included as a separate category in this figure, but are included in the line on all TRIs.

Of the 18701 non-fatal TRI emergency admissions, motor vehicle occupant casualties accounted for 8082 (43%) of non-fatal TRI hospital admissions. A further 3131 (17%) were sustained by motor cyclists and their passengers, 2190 (12%) by pedestrians and 1720 (9%) by cyclists. The remaining 3578 (19%) were unspecified road users. An examination of hospital discharge rates for non-fatal TRIs by road user type showed that rates had declined for most road user groups (Table 7.5). Rates of hospital discharge due to motor vehicle occupants declined, but no significant downward linear trend was observed. However, significant downward linear trends in hospital discharge rates were observed for motorcyclists and pedestrians. In contrast, hospital discharge rates for cyclists rose (non-significantly) by 16%. A significant downward linear trend in admissions coded as 'unspecified' and 'other' was also observed.

Table 7.5 Trends in TRI emergency admissions by road user type in 15-24 year olds in Scotland, 1986-1995. Rates per 100,000, percentage change and linear regression results.

Cause of death	Age-specific hospitalisation rate (1986)	Age-specific hospitalisation rate (1995)	% change in rate (1986-95)	Adjusted R^2	Coefficient B (Confidence intervals 95%)	P value
Motor vehicle occupants	105.4	103.5	-2%	1%	0.2 (-1.6 to 2.0)	0.792
Motor cyclists / passengers	63.5	22.9	-64%	96%	-4.2 (-4.9 to -3.5)	<0.001*
Pedestrians	32.0	26.9	-16%	67%	-0.6 (-1.0 to -0.3)	0.002*
Cyclists	21.9	25.3	+16%	14%	0.4 (-0.2 to 0.9)	0.158
Unspecified and other	52.5	37.8	-28%	51%	-2.3 (-4.1 to -0.7)	0.012*

* denotes significant result

7.4 Research Question 4

Were some young people in Scotland at greater relative risk of sustaining a TRI due to their sex and socio-economic status?

Of the 1281 young people who died due to a TRI between 1986 and 1995, a total of 1004 (78%) were male. A significant male excess was observed for motor occupant, pedestrian and cyclist fatalities (Table 7.6). The male to female ratio for motorcyclist injuries was particularly stark. The STATS19 data yields similar results. In 1995, 72% of fatally injured young people involved in a police-reported traffic accident were male.

Table 7.6 Road user type by gender (fatal injuries). Number, average annual age-specific mortality rate (AAAMR) per 100,000, male to female ratio and chi-square results.

Type	Males		Females		M : F	p value
	No	*AAAMR*	No	*AAAMR*	rate ratio	(Chisq)
motor vehicle occupant	533	*14.2*	189	*4.8*	3: 1	<0.001*
Motorcyclist (or passenger)	179	*4.8*	11	*0.3*	16: 1	<0.001*
Pedestrian	112	*3.0*	42	*1.1*	3: 1	<0.001*
Cyclist	28	*0.7*	0	*0*	na	na**
Unspecified	152	*4.0*	35	*0.9*	4: 1	<0.001*
TOTAL	1004	*26.7*	277	*7.1*	4: 1	<0.001*

* denotes significant result **too few cases for chi-square to run

Of total hospital discharges due to non-fatal TRIs, 13,837 (74%) were among males. As with mortality, a male excess was observed in discharges for all road user types. Once again, the difference was starkest for motorcyclist injuries (Table 7.7). The STATS19 data from 1995 reflect this finding. Approximately 70% of those young people seriously injured in police-reported traffic accident were male.

Table 7.7 Road user type by gender (non-fatal injuries). Number, average annual age-specific discharge rate (AAADR) per 100,000, male:female ratio and chi-squares.

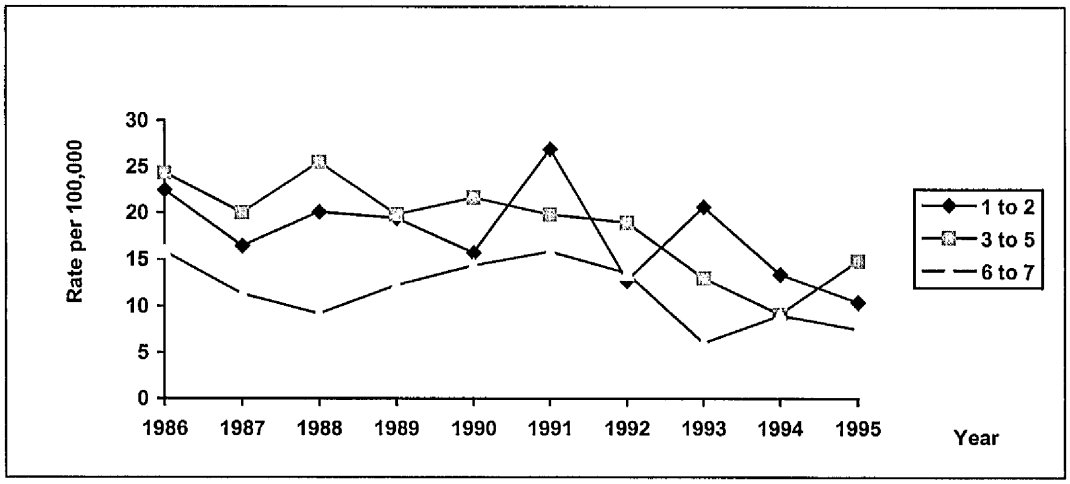
Type	Males		Females		M : F	p value
	No	*AAADR*	No	*AAADR*	rate ratio	(Chisq)
motor vehicle occupant	5527	*141*	2555	*68*	2: 1	<0.001*
motorcyclist (or passenger)	2820	*72*	311	*8*	9: 1	<0.001*
pedestrian	1458	*37*	732	*19*	2: 1	<0.001*
cyclist	1428	*36*	292	*8*	5: 1	<0.001*
injured person unspecified / other	2604	*66*	974	*26*	3: 1	<0.001*
TOTAL	13837	*352*	4864	*129*	3: 1	<0.001*

* denotes significant result

Analysis by socio-economic status requires Carstairs scores to be available. A Carstairs deprivation category was available for analysis in 1191 (93%) fatalities. Analysis of age-specific mortality rates due to TRIs by socio-economic status shows that those in Carstair's deprivation categories 6 and 7 are at least risk of sustaining a fatal TRI (Figure 7.4). In seven of the 10 study years, young people in deprivation categories 3-5 had the highest rate of fatal TRIs, while deprivation categories 1-2 had the highest rates in the remaining three years.

Rates decreased for all deprivation categories over the study period. No significant linear decline in rates was observed for deprivation categories 1-2 or 6-7. However, a significant downward linear trend was observed for deprivation categories 3-5 (Adjusted R^2 = 65%, B= -1.4 (CI95 -2.1 to -0.6); p=0.003).

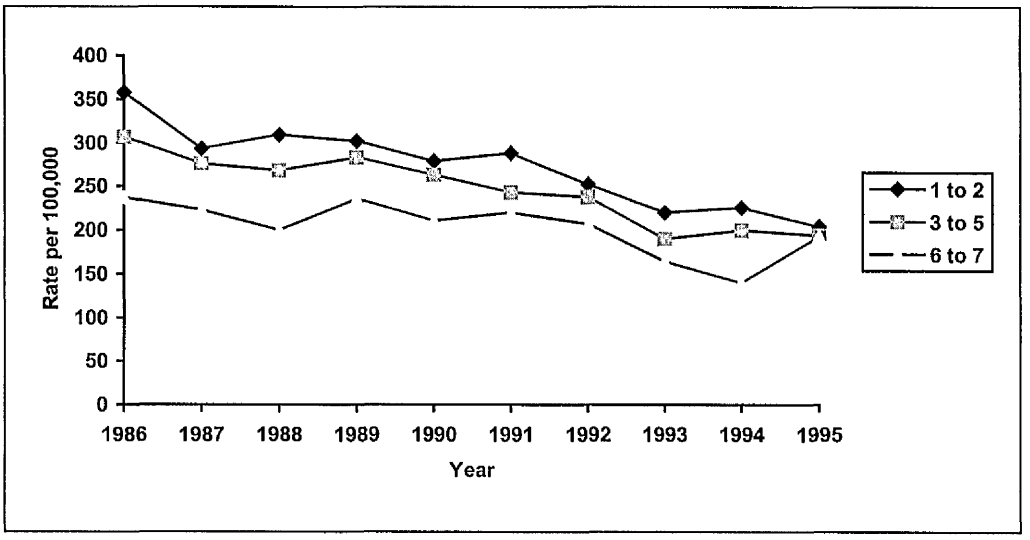
Figure 7.4 Trends in age-specific mortality rates by deprivation category in 15-24 year olds in Scotland, 1986-1995.



The same analysis was conducted for motor vehicle occupant injuries by deprivation category. Similar results were found, with deprivation categories 3-5 experiencing the highest age-specific mortality rates for seven years of the 10 year study period. Deprivation categories 1-2 had the highest rates in 1988, 1991 and 1994. Deprivation categories 6-7 had the lowest rates of motor vehicle occupant injuries throughout the study period. As with the analysis of all TRIs, a significant downward linear trend was experienced only by deprivation categories 3 to 5. Further analysis of mortality data by other road user types was deemed inappropriate because of the small number of cases in each group when analysed by deprivation category.

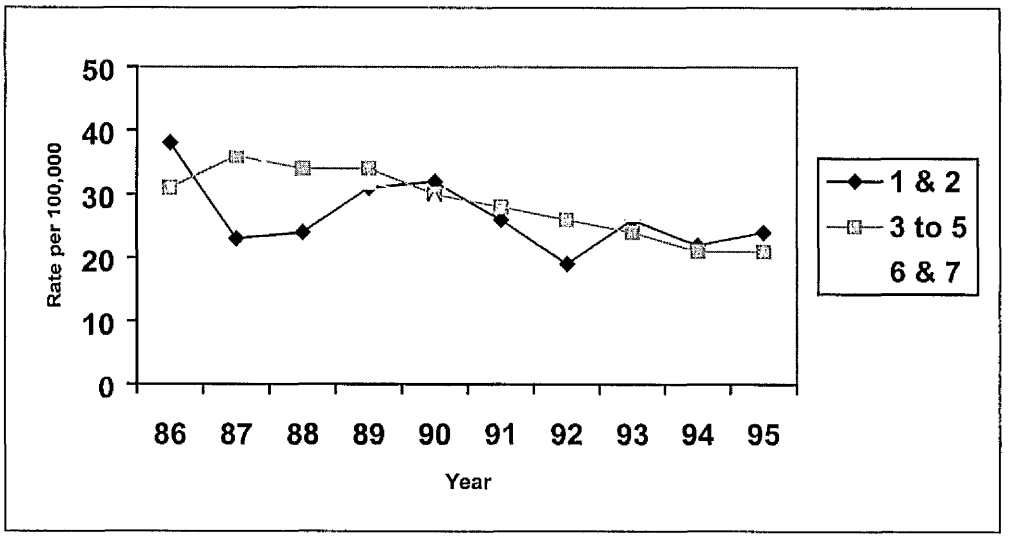
Deprivation category scores were available on 17191 (92%) of non-fatal hospital discharge (SMR1) records. Throughout the study period, young people residing in deprivation categories 1-2 had the highest rate of hospital discharge due to TRIs (Figure 7.5). However, the differentials in rates had narrowed by the end of the study period. Significant linear decreases were observed for all deprivation categories. Rates decreased by 43% (AdjR^2 = 88%, p<0.001) by among those in deprivation cateogories 1-2, by 36% among those residing in categories 3-5 (AdjR^2 = 88%, p<0.001), and by 19% among those in categories 6-7 % (AdjR^2 = 47%, p=0.017).

Figure 7.5 Trends in age-specific hospital discharge rates due to TRIs by deprivation category in 15-24 year olds in Scotland, 1986-1995.



The literature suggests that a higher incidence of pedestrian injuries may be expected amongst those of lower socio-economic status. Data from national travel surveys also demonstrates that the least affluent are least likely to own a motor vehicle. Thus it was deemed important to examine pedestrian injuries specifically when examining socio-economic status. The data show that in seven of the ten study years deprivation categories 6-7 indeed had the highest rate of pedestrian injuries requiring hospitalisation (Figure 7.6). The exceptions were 1988-1990. A higher rate was observed among those in deprivation categories 3-5 in 1988 and 1989 and a higher rate was observed in deprivation categories 1 and 2 and 3-5 in 1990. The gap between categories 6 and 7 and the other two categories appears to have widened towards the end of the study period. A significant downward linear trend was observed in deprivation categories 3-5 (AdjR^2 = 82%; $p<0.001$). No significant downward linear trend was observed for deprivation categories 1-2 or 6-7.

Figure 7.6 Trends in pedestrian injuries requiring hospital admission by deprivation category in 15-24 years olds in Scotland, 1986 to 1995.



Overall, this chapter has demonstrated that the first four null hypotheses set out in Chapter 5 should be rejected. Firstly, TRIs were a common cause of injury in Scottish young people between 1986 and 1995. Secondly, rates of TRIs were not the same in Scottish young people as in other European Union countries. Relative to other countries, Scotland had a low and decreasing rate of TRI fatalities in this age group. Thirdly, rates of TRIs were not the same for all user groups. Fourthly, not all young people were at equal risk of sustaining a TRI. Males, and those residing in areas of relatively greater affluence, were more likely to sustain a TRI.

Key Points

- TRIs accounted for over one third of all injury fatalities and were the leading cause of injury mortality between 1986 and 1992, and 1995.
- Six EU countries (including Scotland) experienced significant linear declines in TRI fatalities over the study period.
- There was a (significant) 21% decline in hospital admissions due to TRIs over the study period.
- Motor vehicle occupants accounted for more than half of TRI fatalities and over 40% of TRI hospital admissions.
- Males, and those residing in areas of relative affluence were generally more likely to be TRI victims. However, those residing in areas of relative deprivation were more likely to be injured as pedestrians.

Chapter 8 WHEN, WHERE AND HOW?

This chapter addresses research questions four to six presented in Chapter 5. It examines the types of injuries sustained by young Scottish TRI victims, and identifies the location, timing and circumstances in which they occur. This is followed by an exploratory analysis to identify the factors that characterise fatal and non-fatal injury events and an examination of the associations between trends in TRIs and transport trends.

8.1 Research Question 5

What types of injuries were sustained?

A primary diagnosis code was recorded for all 18,862 emergency admissions. Diagnosis codes fell within the injury range (8000-9999) for 18696 (99%) cases. Fifty-nine percent of hospital discharge episodes had one diagnosis. The remaining records had multiple diagnoses, ranging from two diagnoses (41%) to six diagnoses (2%). Traumatic brain injury was the leading principal diagnosis among young people who were admitted to hospital (25%) and the leading cause of death after admission to hospital (41% of fatalities) (Figure 8.1). Possible traumatic brain injury was the principal cause in a further 7% of hospital admissions and 23% of fatalities. Injuries to the lower and upper extremities were also common principal causes of hospitalisation (21% and 14% of admissions respectively). Facial injuries (without the eye affected) were the principal diagnosis in 9% of cases. All other principal causes accounted for 3% or less of all hospitalisations.

A total of 161 hospital admissions resulted in a fatality. This represents one percent of hospital discharges over the study period. Of these fatalities, two-thirds (67%) had received multiple injuries (Figure 8.1). Fatalities occurring before hospital admission could take place are excluded because no SMR1 record was available for these cases. Only 13% of total fatalities are logged on the SMR1 database, suggesting that the majority of injuries occur before hospital admission is possible. Traumatic brain injury and possible traumatic brain injury were the most likely injury type to result in a fatality after hospitalisation. Approximately two-thirds of these patients had received multiple injuries (64% of traumatic brain injury patients and 68% of possible traumatic brain injury patients). Although injuries to the upper and lower extremities were common causes of hospitalisation, they were unlikely to result in a fatality. There were a total of 14 fatalities with a primary diagnosis of either an upper or lower extremities injury over the study

period. All but one of the fatalities with extremities injuries (recorded as the primary diagnosis) were multiple injury fatalities.

Figure 8.1 Injury diagnosis by injury type (SMR1 data using Israeli Injury Matrix)

	Primary Diagnosis	n (%) multiple injury	No Died (% of fatalities)	n (%) fatal multiple injury
Head injuries				
Traumatic brain injury	4697 (25%)	342 (7%)	66 (41%)	42 (64%)
Possible traumatic brain injury	1257 (7%)	169 (13%)	38 (23%)	26 (68%)
No traumatic brain injury	415 (2%)	279 (67%)	1 (<1%)	1 (100%)
Neck injuries				
Cervical spine injury - with spinal cord injury	69 (<1%)	9 (13%)	1 (<1%)	1 (100%)
Cervical spine injury - without spinal cord injury	412 (2%)	139 (34%)	4 (2%)	3 (75%)
Other neck injury	371 (2%)	220 (59%)	0	0
Facial injuries				
Injury with eye affected	153 (1%)	143 (93%)	0	0
Other facial injuries	1630 (9%)	1344 (82%)	0	0
Thorax injuries				
Thoracic vertebra with spinal cord injury	14 (<1%)	10 (71%)	0	0
Thoracic vertebra without spinal cord injury	231 (1%) 0	55 (24%)	0	0
Other thoracic injuries	643 (3%)	434 (67%)	7 (4%)	7 (100%)
Abdominal injuries				
Lumbar vertebra with spinal cord injury	11 (<1%)	6 (55%)	0	0
Lumbar vertebra without spinal cord injury	214 (1%)	55 (26%)	2 (1%)	2 (100%)
Other abdominal injuries	312 (2%)	127 (41%)	7 (4%)	6 (86%)
Pelvic injuries				
Sacrum and coccyx without spinal cord injury	8 (<1%)	4 (50%)	0	0
Other pelvic injury	495 (3%)	242 (49%)	3 (2%)	3 (100%)
Upper extremities				
All injuries to upper extremities	2684 (14%)	1746 (65%)	2 (1%)	2 (100%)
Lower extremities				
All injuries to lower extremities	4044 (21%)	1857 (46%)	12 (7%)	11 (92%)
Trunk				
All injuries to trunk	613 (3%)	300 (49%)	0	0
Back				
All injuries to back	62 (<1%)	10 (16%)	0	0
Unspecified				
All injuries with unspecified site	321 (2%)	174 (54%)	15 (9%)	4 (27%)
***Other injuries**				
Other injuries not coded in matrix	40 (<1%)	10 (25%)	0	0
****Other conditions**				
Other conditions (not injuries)	166 (1%)	166 (100%)	3 (2%)	0
TOTAL	18,862	7841 (41%)	161 (1%)	108 (67%)

*Other injuries include late effects, foreign body injuries, post-traumatic shock, other complications of trauma, poisonings, hypothermia, other effects of reduced temperature, drowning and therapeutic complications.

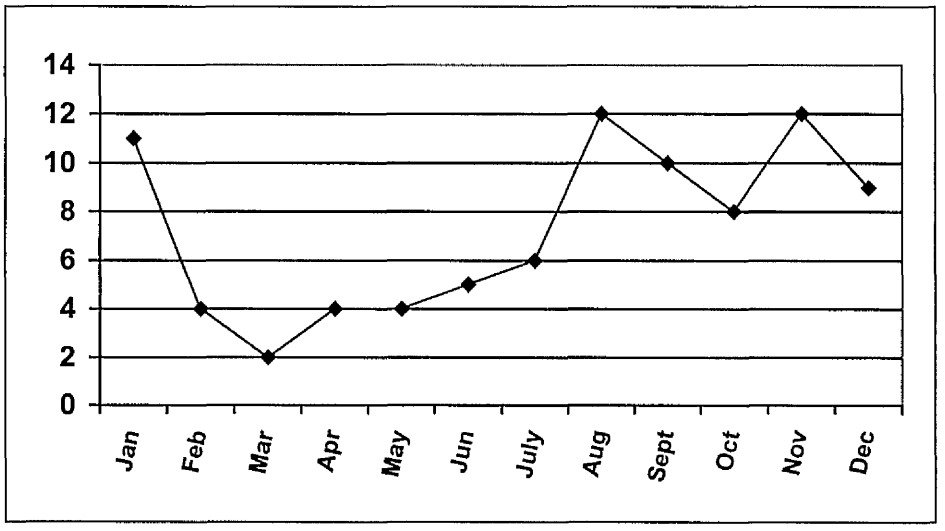
** Other conditions include septacaemia, alcohol dependence, post-concussional syndrome, epilepsy, anoxlic brain damage, heart disease, phlebitis / thrombsis, abrasion of teeth, haematuria, cellulitis / abscess, effusion of joint, displacement of intervertebral disc, backache, cervicalgia, pain in limb, acquired disformities, coma/ stupor, headache, chest pain, abdominal pain, and respiratory failure

8.2 Research Question 6

Where, when and under what circumstances did fatal and non-fatal TRIs occur?

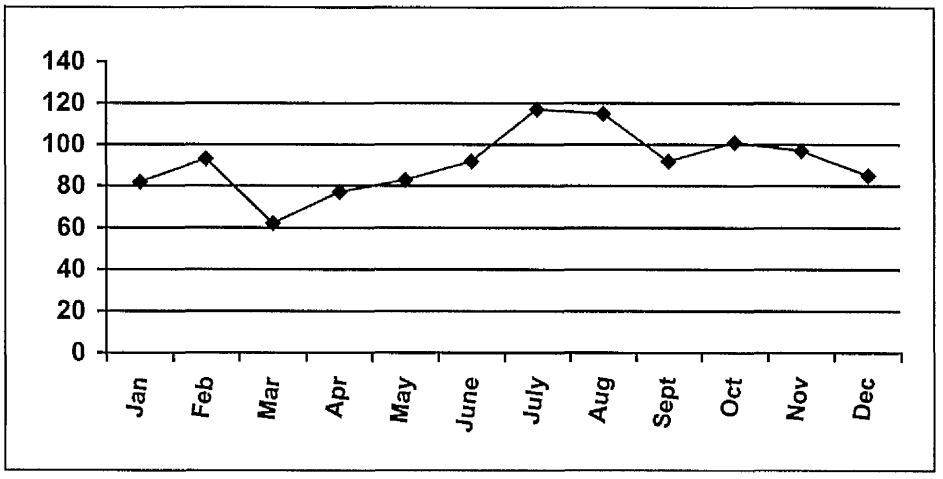
Analysis of the 99 fatalities identified by the STATS19 database in 1995 showed that these fatalities represented 89 TRI events. The highest absolute numbers of fatal events occurred in August and October, with fatalities slightly (but not significantly) higher between October and March, than between April and September (Figure 8.2). The lowest absolute number occurred in March. Fatal events were proportionately more likely to occur at the weekends, but this finding was not significant ($p>0.05$)

Figure 8.2 Number of fatal TRI events by month, STATS19 1995.



There were 1121 TRI events resulting in serious non-fatal injury. Of these, 25 TRIs are already included in the data on fatalities (because at least one person involved in this incident was fatally injured) and a further ten resulted in a fatality of someone outwith the age range for this study. As specified in Chapter 6, these records were removed from the working dataset. The remaining non-fatal TRI events showed a different seasonal pattern from fatal TRIs. The highest absolute number of non-fatal TRIs occurred in July and August (Figure 8.3). The lowest absolute number occurred in March. The pattern for day of the week was similar to fatalities. The highest absolute number of non-fatal TRIs occurred at the weekend; on Fridays (18%), Saturdays (18%) and Sundays (14%). As with fatal events, this finding was not significant ($p>0.05$).

Figure 8.3 Number of non-fatal TRI events by month, STATS19 1995



The research literature suggests there may be differences in fatality rates in young people between urban and rural areas. As discussed in Chapter 6, the availability of data disaggregated by police area in Scotland allowed a comparison of rates of fatal and serious injuries across 8 areas (Table 8.1). These broadly represent the regional authority boundaries that were replaced in the mid-90's by local authority areas. The rates of both fatal injury and serious non-fatal injury were highest in the Highlands and Islands (30 and 307 / 100,000 respectively) and in Dumfries and Galloway (25 and 299 / 100,000 respectively). These are predominantly rural areas of Scotland. The rate in Highlands and Islands is twice the national rate of fatalities (15 / 100,000).

Rates of fatal injury were lowest in Central Region (3 / 100,000). Rates of serious non-fatal injury were lowest in Grampian and Lothian and Borders (146 and 151 / 100,000 respectively). Grampian includes a large rural area, but also encompasses the city of Aberdeen. Similarly, the Borders area of Scotland is largely rural with small to medium sized settlements. However, Lothian encompasses Edinburgh and a number of outlying satellite towns. The ratio of fatal to serious injuries was narrowest in Grampian, where one fatality occurred for every 5 serious TRIs. The ratio was also narrow in the Highlands and Islands with one fatality per 10 serious TRIs. The ratio was widest in Central Scotland with 1 fatality to every 65 serious injuries. This compares to a national ratio of 1:13.

Table 8.1 Rates of fatal and serious TRIs by Scottish council area, 1995

Council area	Fatality rate per 100,000	Serious TRI rate per 100,000	Ratio Fatalities: Serious
Highlands and Islands	30	307	1:10
Grampian	29	146	1:5
Dumfries and Galloway	25	299	1:12
Tayside	18	220	1:12
Strathclyde	10	191	1:19
Fife	9	203	1:23
Lothian and Borders	8	151	1:19
Central	3	194	1:65
All Scotland	15	190	1:13

8.3 Research Question 7

What were the characteristics of fatal TRI events compared to non-fatal TRI events?

The 89 police-reported fatal and 1086 police-reported serious (but non-fatal) events in 1995 were analysed by key indicators available on the STATS19 database. Bivariate analyses showed that fatalities appear to be significantly more likely to occur on A roads, roads with a speed limit of 60mph and when the weather was fine (Fig 8.4). However, there were few fatalities occurring on motorways and 70mph zones. Non-fatal injuries were significantly more likely to occur on roads where the speed limit was 30mph and at junctions. Th result with the variable 'occurrence at a junction' was borderline: 29% of fatal injuries occurred at a junction compared to 39% of non-fatal injuries. No other significant relationships were observed. No association was found between fatal/non-fatal outcome and age, sex, season of the year, time of day, day of the week, light conditions, windy conditions, road conditions and type of impact (front, rear or side impact).

Nonetheless, the proportions themselves paint a useful picture. Males are over-represented for both fatal and non-fatal injuries (73% and 69% respectively). Worthy of note is that more than four out of five injuries (irrespective of outcome) occurred in dry conditions and over 90% occurred in weather conditions not described as windy. Over half of events occurred when the road conditions were dry and the light conditions were 'light'. Front impacts were recorded for approximately two-thirds of events, whereas rear impacts accounted for a small minority of both fatal and non-fatal injury events. The vehicle in question left the road in over one third of cases for both fatal and non-fatal injuries.

Very few fatal and non-fatal TRIs occur on motorways (2% and 3% respectively). However, this is to be expected given that approximately 1-2% of Scotland's road network is classified as motorway (Scottish Executive, personal communication 2000). Over half of fatalities occurred on 'A roads' (and just less then half of non-fatalities). TRIs on these roads appear to be over-represented. Approximately 20% of Scotland's road network is classified as 'A roads'. However, this does not take into account the level of use of these roads. While roads classified as 'B' and 'C' roads account for the largest proportion of the Scottish road network, they do not carry a similar proportion of Scotland's road traffic.

Figure 8.4 Characteristics of fatal and non-fatal TRI events, STATS19 1995

Variable	N (%)	Significance
Age (15-19 years)		
Fatal	37 (42%)	0.14
Non-fatal	541 (50%)	
Sex (Male)		
Fatal	65 (73%)	0.48
Non-fatal	754 (69%)	
Season (summer)		
Fatal	45 (51%)	0.73
Non-fatal	570 (52%)	
Time of day (8am-7pm)		
Fatal	47 (53%)	0.53
Non-fatal	611 (56%)	
Weekday (Mon-Fri)		
Fatal	57 (64%)	0.39
Non-fatal	743 (68%)	
Occurred on motorway		
Fatal	2 (2%)	0.85
Non-fatal	28 (3%)	
Occurred on A road		
Fatal	54 (61%)	0.02*
Non-fatal	519 (48%)	
Light conditions (light)		
Fatal	44 (49%)	0.31
Non-fatal	597 (55%)	
Weather conditions (fine)		
Fatal	78 (88%)	0.01*
Non-fatal	846 (78%)	
Weather conditions (windy)		
Fatal	3 (3%)	0.35
Non-fatal	60 (6%)	
Road conditions (dry)		
Fatal	45 (51%)	0.27
Non-fatal	614 (57%)	
Speed limit 30mph		
Fatal	18 (20%)	<0.001*
Non-fatal	521 (48%)	
Speed limit 60mph		
Fatal	55 (62%)	<0.001*
Non-fatal	425 (39%)	
Speed limit 70mph		
Fatal	11 (12%)	0.08
Non-fatal	67 (6%)	
At junction		
Fatal	26 (29%)	0.04*
Non-fatal	425 (39%)	
Front impact		
Fatal	55 (62%)	0.51
Non-fatal	709 (65%)	
Side impact		
Fatal	30 (34%)	0.24
Non-fatal	303 (28%)	
Rear impact		
Fatal	2 (2%)	0.48
Non-fatal	40 (4%)	
Vehicle left road		
Fatal	34 (38%)	0.79
Non-Fatal	398 (37%)	

There was limited information on BAC tests available in the STATS19 database. Just over one third (38%) of fatality records and 62% of serious injury records had BAC scores recorded. Three (10%) of the 34 BAC tests completed for fatal injuries were positive. There were 59 (9%) positive BAC tests out of 678 tests completed among those seriously (but not fatally) injured. There was no significant difference in BAC positive results between those fatally and non-fatally injured. These data were not entered into the logistic regression because of the unacceptable proportions of missing information.

A logistic regression was performed in an attempt to determine the significant differences in the characteristics of fatal and non-fatal injuries. All the variables listed in the bivariate analysis in Figure 8.4 were entered into this procedure. Four significant variables were identified (Table 8.2). The model shows that fatalities are more likely to occur when the weather conditions are fine, when the road conditions are wet and when the speed limit on the road is 60mph or 70 mph. The remaining variables were not significant after the final iteration.

Table 8.2 Determinants of fatal injuries using logistic regression: variables in the equation.

Variable	Odds Ratio	95% CI for Odds Ratio	Wald	Significance
Weather (fine)	1.8	1.1 to 2.8	5.2	0.02*
Road conditions (dry)	0.4	0.2 to 0.8	6.4	0.01*
Speed limit was 60mph	3.3	2.0 to 5.4	21.2	<0.01*
Speed limit was 70mph	4.8	2.2 to10.3	15.8	<0.01*

* denotes significant result

The model shows that fatalities are most likely to occur both when the weather conditions are fine and when the roads are wet. This appears to be a contradiction in the data. A further check of the raw data reveals that 33 (42%) fatalities occurred when the weather was fine, but the road conditions were wet or icy. This compares to 243 (29%) of non-fatal injuries occurring in these circumstances.

8.4 Research Question 8

Were the observed trends in TRIs associated with changes in exposure to risk?

Fatal and hospitalised (non-fatal) TRIs were correlated with the four indicators of exposure described in Chapter 6 (Table 8.3). Two of these indicators are drawn from the UK-wide

by DETR and two indicators are used from the Scottish sub-set of the National Travel Survey. Correlations were performed for the ten year period 1986-1995.

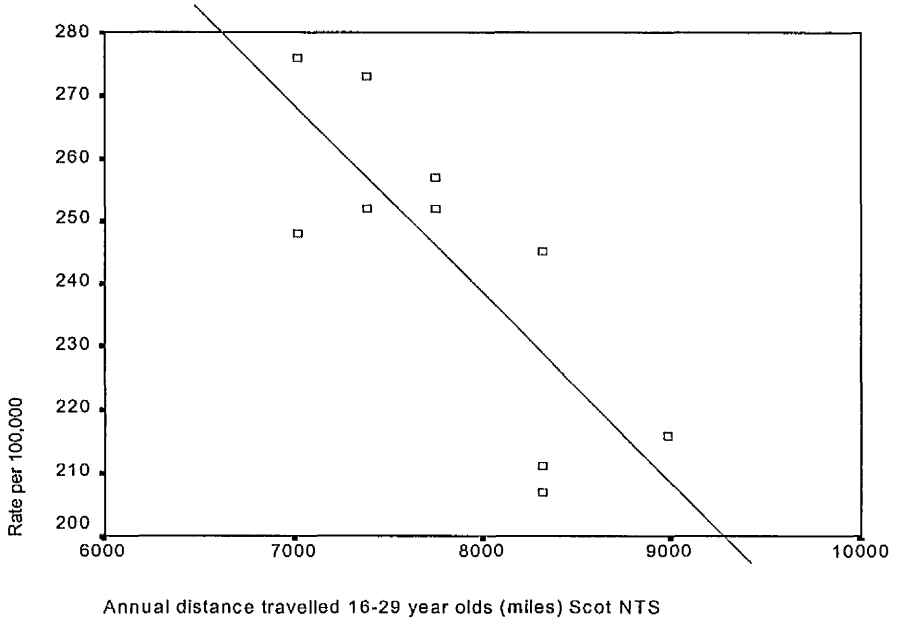
Just one significant correlation was observed. Rate of non-fatal traffic related injuries correlated significantly with distance travelled annually as measured in the Scottish sub-set of the National Travel Survey ($p<0.01$). The scatterplot in Figure 8.5 (with regression line superimposed) clearly demonstrates the association between the declining rates of non-fatal TRI and the increasing distance travelled annually. No other significant correlations were observed between fatal and non-fatal TRI rates and distance travelled by car (UK figures), journeys per year (UK) and annual journeys per year in Scotland.

Table 8.3 Correlations of rates of fatal and non-fatal TRIs and exposure data.

	DETR Distance travelled by car driver	**DETR Journeys per year by car driver**	**Scottish NTS Distance travelled annually**	**Scottish NTS Annual journeys per person**
Fatal TRIs				
Pearson and CI 95	-0.28 *(-0.78 , 0.42)*	-0.82 *(-0.68, 0.58)*	-0.59 *(-0.89, 0.06)*	0.47 *(-0.23, 0.85)*
Sig (2 tailed)	0.421	0.821	0.073	0.170
Non-fatal TRIs				
Pearson and CI95	-0.40 *(-0.82, 0.01)*	-0.16 *(-0.72, 0.52)*	-0.79 *(-0.95, -0.33)*	0.29 *(-0.41, 0.78)*
Sig (2 tailed)	0.252	0.649	**0.006***	0.411

* denotes significant result

Figure 8.5 Scatterplot of non-fatal TRI rates and annual distance travelled



Rates of pedestrian injuries were then correlated with DETR data on annual distance travelled by foot and the number of journeys made on foot per year for 15-24 year olds. There were no significant correlations between these variables and the rate of fatal pedestrian injuries (Table 8.4). However, significant correlations were observed between these variables and the rates of non-fatal pedestrian injury. The relevant scatterplots are shown in Figure 8.6 and 8.7. Figure 8.6 clearly depicts the association between the declining distance travelled by foot (as measured by DETR) and the declining pedestrian injury rate. Similarly Figure 8.7 shows the association between the declining number of journeys made by foot (as measured by DETR) and the declining pedestrian injury rate.

Table 8.4 Correlations of fatal and non-fatal pedestrian injury rates and exposure data

	DETR Distance travelled walking	**DETR Journeys per year walking**
Fatal pedestrian TRIs		
Pearson and CI95	0.46 (-0.24, 0.85)	0.37 (-0.34, 0.81)
Sig (2 tailed)	0.178	0.292
Non-fatal pedestrian TRIs		
Pearson and CI95	0.83 (0.42, 0.96)	0.76 (0.25, 0.94)
Sig (2 tailed)	**0.003***	**0.011***

* denotes significant result

Figure 8.6 Scatterplot of non-fatal pedestrian injury rates and annual distance travelled by foot.

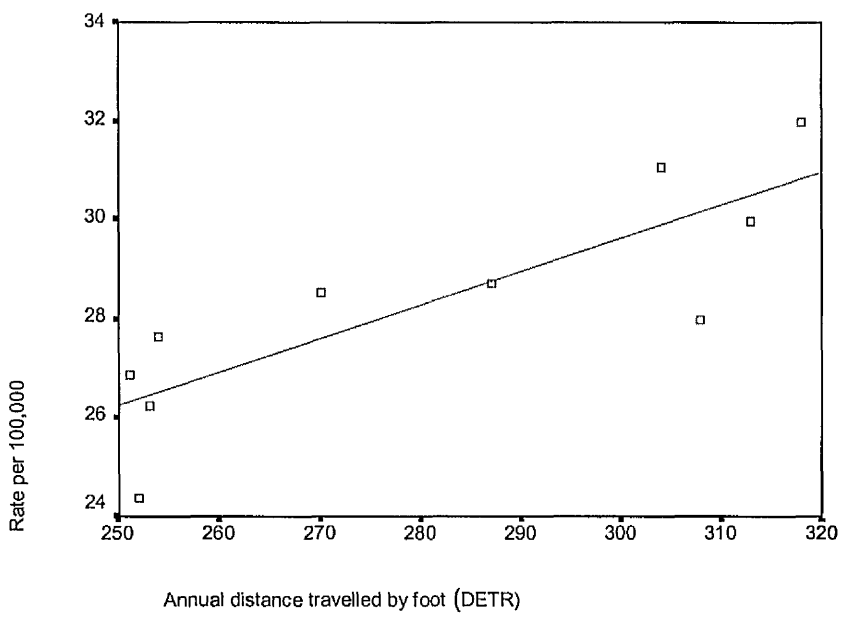
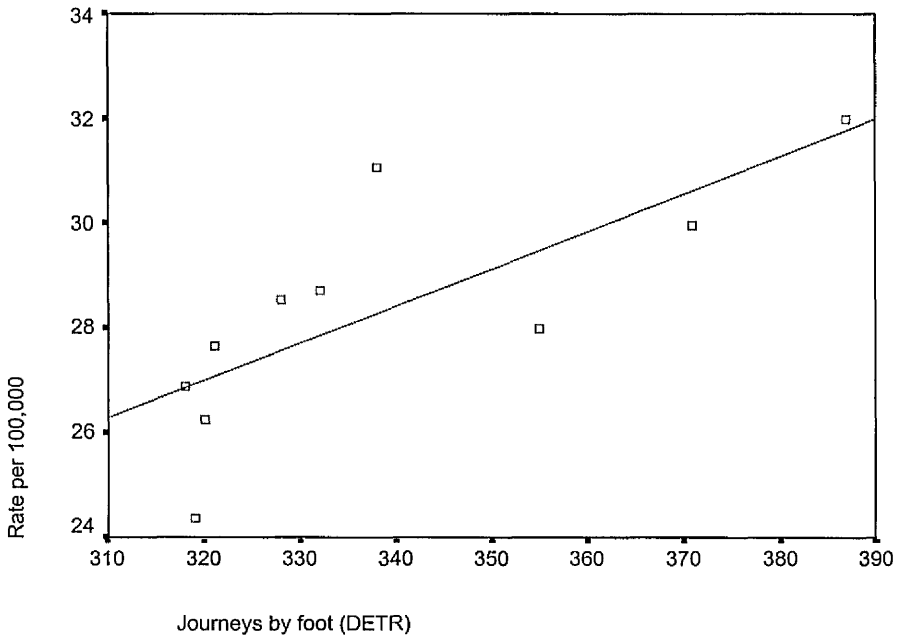


Figure 8.7 Scatterplot of non-fatal pedestrian injury rates and annual number of journeys by foot



Overall this chapter has demonstrated that null hypotheses 6-8 set out in Chapter 5 should be rejected. Fatal and non-fatal TRIs did not occur at the same time, in the same location and under the same circumstances. The characteristics of fatal and non-fatal TRIs were not the same. Lastly, there was some evidence to suggest that TRIs may be associated with changes in exposure to risk, even with the limited data available.

Key Points

- Over 40% of those young people that were hospitalised were suffering from multiple injuries. Of those fatally injured, 67% received multiple injuries.
- Traumatic brain injury was the leading principal diagnosis and the cause of death among those who were admitted to hospital.
- Fatal injury data indicate that rates may be higher in rural areas of Scotland.
- The logistic regression analysis demonstrated that fatal injury events were most likely to occur when the weather conditions are fine, when the road conditions are wet and when the speed limit is 60mph or 70mph.
- Exploratory ecological epidemiology indicates that a significant association exists between decreasing rates of non-fatal TRIs and an increase in distance travelled annually.
- Exploratory ecological epidemiology also indicated that significant correlations exist between declining pedestrian injury rates and the declining number of journeys and distance travelled by foot.

Chapter 9 CAPTURE-RECAPTURE

This chapter describes the capture-recapture exercise. It addresses objectives nine and ten described in Chapter 6. It examines the extent to which the two official data sources on TRIs overlap, calculates ascertainment corrected rates of TRIs and presents a 'SWOT' analysis of the capture-recapture procedure. The results of this component of the thesis were published in 'Injury Prevention' in December 2000 (Appendix 2).

9.1 Research Question 9

To what extent did the two official Scottish data sources on TRIs overlap and what was the associated ascertainment corrected number of TRIs?

Mortality records for the calendar year 1995 were extracted from both working datasets; the SHS data and the STATS19 data. This process yielded a total of 97 fatal TRIs in the SHS data, representing an age-specific mortality rate of 14 / 100,000. An identical search of the STATS19 database identified 99 fatal TRIs. This represents an age-specific mortality rate of 15 / 100,000 for people aged 15-24 years. There were no significant differences in the demographic characteristics of the subjects between the databases for fatal injury. In both databases males accounted for 72% of fatalities. The mean age of those fatally injured was 20.2 years in the SHS dataset and 20.3 years in the STATS19 dataset.

Data were matched using the four matching criteria described in Chapter 5. It was considered defensible to adopt Standard D given the data collection setting. To reiterate, standard D allows age to be estimated within one year and the police record to have been completed the day before the SHS record. It is feasible that the STATS19 record may have been completed the day before (especially if the injury event occurred later in the day) and that age was estimated wrongly because the age is often based on an estimate at the scene of the injury.

Matching fatalities using Standard D generated 92 fatalities common to both data sets (Table 9.1). The estimated completeness of the SHS mortality dataset was 93%. The estimated completeness of the STATS19 dataset for fatalities was 95%. Using the

aforementioned formula described in Chapter 6, the ascertainment corrected number of TRI fatalities was 104 (CI95 103,105). This generated an ascertainment corrected mortality rate of 15 / 100,000 people aged 15-24 years due to TRIs. This is a marginally higher rate than is calculated when using the two sources independently.

As matching criteria were tightened up, the ascertainment corrected number of TRIs increased while the number of cases located in each dataset decreased. Matching Standards A-C generated ascertainment corrected numbers of TRIs ranging from 108 (CI95 106,110) to 139 (CI95 129,149). Population-based rates calculated using the ascertainment corrected numbers varied between 15 / 100,000 for Standard D and 21 / 100,000 for Standard A (this constitutes a perfect match on all variables). Using the strictest matching Standard (A), the ascertainment corrected rate is 139 (CI95 129,149). This results in an age-specific TRI mortality rate 40% higher than using SHS data alone and 50% higher than using the STATS19 data alone. However, this standard requires a perfect match on all variables and is very unlikely to be achieved in practice.

Table 9.1 Capture recapture results for fatal TRIs, 15-24 year olds in Scotland, 1995

Standard	No cases in SHS (Rate per 100,000)	No cases in STATS19 (Rate per 100,000)	No of cases in both databases	Ascertainment corrected no.	CI95%	Rate per 100,000 population
A	97 (14)	99 (15)	69	139	129, 149	21
B	97 (14)	99 (15)	84	114	111, 117	17
C	97 (14)	99 (15)	89	108	106, 110	16
D	97 (14)	99 (15)	92	104	103, 105	15

A statistical comparison of the unmatched and matched cases of fatal injury was deemed inappropriate because of the small numbers involved. There were five unmatched cases in SHS and the seven unmatched cases in STATS19. All the unmatched SHS cases were male, and six out of seven unmatched STAT19 cases were male. Drivers accounted for two of the five unmatched SHS cases and all but one of the STAT19 cases. Two of the cases in the SHS unmatched data had a road user type coded as 'unspecified'. As discussed in Chapter 6, this information is extracted from the fourth digit on the ICD Version 9 E-code provided on the hospital discharge record.

A search for non-fatal, hospitalised injuries identified 1458 cases in the SHS dataset, representing an age-specific hospital discharge rate of 215 / 100,000 people aged 15-24

years (Table 4). A total of 1290 records of 'serious' (i.e. injuries requiring hospitalisation) TRI casualties were located in the STATS19 database. This represents an age-specific rate of 190 / 100,000 people aged 15-24 years. In both datasets approximately 70% of casualties were male (69% and 72% respectively), and the mean age of those hospitalised was 19.5 years. There were no significant differences in age or sex between the two working databases.

Cases were matched using the matching standards described in Chapter 5. As with the fatal TRIs, it was deemed justifiable to relax the matching to Standard D given the data collection setting. The additional variable used in matching records of non-fatal injuries was the location code. It is possible for a TRI to occur in one area, but hospitalisation to take place in an adjoining area. As specified in Chapter 6, this was allowed for in Standard D.

Matching cases using Standard D produces an ascertainment corrected number of TRI-related injuries of 1969 (CI95 1932, 2006) (Table 9.2). Thus, according to the capture-recapture procedure, the estimated completeness of the SMR1 and STATS19 databases was 74% and 66% respectively. This generated an ascertainment corrected serious TRI rate of 291 / 100,000 for young people aged 15-24 years using Standard D. This represents a 35% increase in the rate of non-fatal TRIs than when using the SHS data solely and a 53% increase than when using the STATS19 data only.

Stricter matching criteria (Standards A-C) generated ascertainment corrected numbers of TRIs ranging from 2140 (CI95 2090, 2190) to 3053 (CI95 2921, 3125) (Table 9.2). The resulting population rates for the four standards also varied widely between 291 / 100,000 (Standard D) and 451 / 100,000 (Standard A). The strictest standard A (constituting a perfect match on all variables) generates a rate of non-fatal TRIs 110% higher than using SHS data solely, and 137% higher than using STATS19 data only. However, as with mortality records, this level of accuracy is unlikely to be achievable in practice.

Table 9.2 Capture recapture results for serious (non-fatal) TRIs, 15-24 year olds in Scotland, 1995.

Standard	No cases in SHS (Rate per 100,000)	No cases in STATS19 (Rate per 100,000)	No of cases in both databases	Ascertainment corrected no	CI95%	Rate / 100,000 population
A	1458 (215)	1290 (190)	616	3053	2921, 3125	451
B	1458 (215)	1290 (190)	781	2408	2336, 2480	356
C	1458 (215)	1290 (190)	879	2140	2090, 2190	316
D	1458 (215)	1290 (190)	955	1969	1932, 2006	291

There were no significant differences in the age of cases matched and unmatched in either database based on results adopting Standard D (Table 9.3). The mean age differed by 0.2 years between matched and unmatched cases in SHS and 0.1 year between matched and unmatched cases in STATS19. While there was no significant difference in the proportion of males and females in matched and unmatched cases in the SMR1 data, females were under-represented in the unmatched STATS19 cases ($p<0.05$).

Table 9.3 Key characteristics of matched and unmatched records, 1995

	Matched SHS records n=955	Unmatched SHS records n=503	Matched STATS19 records n=955	Unmatched STATS19 records N=335
Mean age (yrs)	19.5	19.3	19.5	19.6
Sex (n;% male)	666 (70%)	340 (68%)	741 (78%)	188 (56%)
Road User Type				
Car occupants	457 (48%)	244 (49%)	610 (64%)	242 (72%)
Pedestrians	128 (13%)	54 (11%)	164 (17%)	53 (16%)
Cyclists	97 (10%)	61 (12%)	80 (8%)	15 (4%)
Other / unspecified	273 (29%)	144 (29%)	101 (11%)	25 (7%)

Approximately half the unmatched cases in the SHS data were car occupants. This corresponds almost exactly to the proportion of drivers include in the matched cases. This compares to 72% of unmatched cases in STATS19 and 64% of matched cases in SHS coded as car occupants. In both cases this represents a significantly higher proportion of drivers matched and unmatched in STATS19 ($p<0.05$). In the SHS data, 11% of unmatched cases were pedestrians compared to 16% of unmatched cases in STATS19. In

the SHS 12% of unmatched cases were cyclists. This compares to 4% in STATS19. In 1995, cyclists represented 3% of all TRIs in the total SHS dataset. Thus cyclists are over-represented in the unmatched SHS data ($p<0.05$).

A total of 29% of unmatched cases in SHS were coded as 'other /unspecified', this compares to just 7% in the STATS19 data. The STATS19 data allowed a specific coding of road user type in almost every instance. If road user type had been better coded in the SHS data, this may have been a potentially useful matching variable. In fact, a retrospective check illustrated that in over 65% of matched cases a match was also achieved on road user type. However, there were a substantial number of SHS records classified as 'unspecified' that matched with STATS19 records that were coded as car occupants.

9.2 Research Question 10

Is capture-recapture a useful technique in TRI epidemiology?

Strengths

- Capture-recapture provides a method of assessing the completeness of datasets and highlights the biases inherent in each. This was useful in interpreting the results of this study and should prove valuable when designing studies of TRIs among young people. For example, a study of cyclist injuries among young people in Scotland using STATS19 data solely would be inappropriate.

- The data available in Scotland were largely complete (there was little missing data) and in general provided variables with sufficient discriminatory power to match cases. The existence of a location code in both SHS and STATS19 allowed matching of cases where an ambiguity would have existed if these data were unavailable.

Weaknesses

- It is difficult to comply with the requirement for a 'closed population' in this study (as described in Chapter 4). This may be particularly difficult to achieve amongst 15-24 year olds in the Scottish population because there is a tendency for this age group to be

transient. The ascertainment-corrected number generated in this study may be an overestimate because the population may not be 'closed'.

- It is possible that over-estimation occurred in this capture-recapture exercise because their was no direct link between the two datasets. The two information sources adopted in this study do not directly refer individuals to the other. However, this does not discount completely some association. The police record is completed at the scene of the injury event, often when medical services are present. It is worth noting that a direct relationship between datasets can also be problematic, leading to under-estimation.

- Misclassification of TRIs as 'other injuries' in the SMR1 data may excluded valid cases from a capture-recapture analysis. While these data have been included in the data-set for this study, this required a significant amount of further cleaning and checking (as described in Chapter 6). It would be important for researchers to complete this cleaning exercise before conducting the capture-recapture exercise. This is a time-consuming and arduous process.

- The definition of 'serious' in STATS19 may not have corresponded exactly to the hospitalisation requirement in the SHS data. 'Serious' injuries in the STATS19 database are those defined as detentions in hospital as an inpatient or with the following injuries; fractures, severe concussion, internal injuries, crushings, severe cuts and lacerations and severe shock requiring medical treatment. While it is likely that these injuries would result in hospital admission, it may not be the case in every instance. Thus, the ability of the SMR1 database to successfully identify non-fatal TRIs may be underestimated because injuries classified as 'serious' in the STATS19 database may not have resulted in hospital admission.

- Matched and unmatched cases in the datasets were not homogenous. Thus the requirement for equal probability of capture may not have been met. For example, females and cyclists appear to be under-represented in the unmatched STATS19 cases. This is a requirement for the capture-recapture procedure, yet must be difficult to achieve in most studies of human epidemiology due to demographics and factors associated with attendance at health services (including help-seeking behaviour, travel patterns and accessibility of health and other social care facilities).

Opportunities

- Capture-recapture may provide a cost-effective means of assessing completeness of data sources and more accurate estimates of TRI incidence amongst young people in Scotland (though these should be viewed with caution). The procedure is relatively east to run using a software package such as Paradox once the data for inclusion have been extracted and cleaned.

- The technique is relatively novel in injury research and should be viewed as a methodological approach to be piloted. It can potentially maximise the use of existing data. Injury researchers generally advocate the use of multiple data sources to improve and supplement existing information.

- A new population based survey in Scotland (the Scottish Household Survey) may be a useful source of ancillary information in future analysis, particularly if the study does not focus on one age group. These survey data may be used to validate the findings of capture-recapture exercises, particularly if they are not limited to one age grouping.

Threats

- Ascertainment-corrected rates of TRIs calculated in this study should be viewed with extreme caution because the study does not achieve all the requirements of the capture-recapture technique. In this study it is more likely that the calculated rates are an overestimate (rather than an underestimate) because the two input lists are relatively independent.

- This procedure should be piloted (as in this study) to establish whether it is an appropriate methodology before applying it more widely. Specific attention should be paid to the quality of the input data, the data collection setting and the relationship between datasets.

- The technique can be time-consuming (and therefore expensive), especially if more than two data sources are used. In this study a substantial amount of data cleaning and manipulation were required to ensure high quality input data. The capture-recapture method would be made much simpler if non-anonymised data were available. However, this is not available to external researchers. Even within the public sector currently, the

police and the health service do not routinely share such data. There are issues of confidentiality to consider.

- The resulting ascertainment corrected rates can vary widely (depending upon the matching standards applied). This is particularly the case for non-fatal injuries. Thus, the importance of understanding the data collection setting and the assessing the accuracy of coding in advance cannot be overestimated.

Overall this chapter has demonstrated that null hypotheses 9 and 10 set out in Chapter 5 should be rejected. The two official data sources did overlap and ascertainment-corrected numbers of TRIs were possible to calculate. Further, capture-recapture may be a useful technique in injury epidemiology to examine the completeness of data sources, although the ascertainment-corrected rates should be used with caution.

Key Points

- The ascertainment corrected rate of fatal TRIs in Scottish young people in 1995 was 104 (using matching standard D).
- The ascertainment corrected rate of non-fatal (hospitalised) TRIs in Scottish young people in 1995 was 1969 (using matching standard D).
- Both sources of data on fatalities were almost complete (93% and 95%). The two sources of data on non-fatal TRIs were less complete (74% and 66%).
- The capture-recapture technique (as used in this study) does not comply with all the requirements of the technique. Caution should be used when using the ascertainment corrected rates.

Chapter 10 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

This chapter discusses the strengths and weaknesses of the study design overall, and the capture-recapture exercise specifically. The main results of the study are then discussed in the context of the wider research literature. The chapter ends with eight key recommendations.

10.1 Study Design and Data Quality

Overall, this study has provided a comprehensive overview of the trends and patterns of TRIs in young people in Scotland between 1986 and 1995 using multiple, population-based data sources. The study by no means exhausted the potential uses of these data, there are many more analytical exercises that could be undertaken. Indeed, one of the difficulties with this study was defining the scope of analysis and formulating the research questions. But, is this type of epidemiological study a useful exercise?

While epidemiological analysis plays an important role in monitoring trends and identifying risk groups, the major challenge for injury prevention professionals is to plan, implement and evaluate interventions designed to reduce incidence of TRIs. The research evidence on effectiveness of preventive measures suggests that this would require a multi-disciplinary approach with a well-designed evaluation as an integral part of the development process (Munro et al 1995, Towner et al 2001). The data used in the course of this study could play an important role in evaluating new interventions. However, as a detached and one-off exercise the value of this type of epidemiological study is limited.

Routine injury surveillance and injury epidemiology have proven particularly useful if they are designed as an integral a part of a community safety approach that includes regular needs assessment and regular reviews of prevention activities. This approach has been used widely in Sweden and by the WHO Safe Communities programme (Lindqvist et al 1996). One controlled evaluation showed that an injury prevention programme based on local action can significantly reduce injuries requiring health care in a community (Timpka, Lindqvist, Schelp et al 1999). The authors stress that local prevention can provide a complement to national level campaigns and help make progress towards national targets.

The data used in this study could form the basis of a national injury surveillance system for TRIs in Scotland, and in the case of the SMR1 data, for injuries more generally. But, there would be limitations to this approach. Firstly, these data lack a good measure of injury severity. While the injury morbidity matrix used in this study does allow some differentiation between injuries, this is probably not sufficient for surveillance purposes. Further, the data used in this study represent only the 'tip of the iceberg' of injuries. Data on less severe injuries are not currently available in the health field and are of dubious quality from police records. It is questionable whether the development of a national injury surveillance system for TRIs would be cost-effective given the inherent difficulties. There may, however, be scope to develop community based surveillance using these data if they were available disaggregated to a smaller area level.

This study has shown that the input data from the Scottish Health Service and the STATS19 data for fatalities are of high quality. Either source of data on fatalities could be used with confidence. The capture-recapture exercise highlighted some problems and biases inherent in the non-fatal injury data. However, these too should be viewed with caution. In particular, the ability of the SMR1 database to successfully identify non-fatal TRIs may be underestimated because injuries classified as 'serious' in the STATS19 database may not have resulted in hospital admission. A more definitive indicator of whether hospitalisation occurred would be a useful addition to the STATS19 database.

Overall, the quality of the data could probably be described as 'reasonable', particularly with knowledge of data limitations. This can help in the interpretation and subsequent use of research results. The best approach is to use data from both sources when examining TRIs. The two sources can complement each other. The STATS19 data adds considerable depth to the information on injury classification available in the SMR1 data. These data also provide important information on the circumstances around the injury event.

The process undertaken to extract the SMR1 data required for this study from the Scottish Health Service dataset clearly demonstrated that without cleaning, 95% of SMR1 records with an E-code corresponding to a TRI were correctly coded as 'road traffic accidents'. In the SMR1 data there were a large number of records coded as 'other / unspecified' road user types which limits the accuracy of the analysis possible with this dataset. An improvement in the coding of the road user type variable in the SMR1 dataset would be valuable. A previous study of the accuracy of SMR1 data in stroke patients pointed to

inadequate data provided by clinicians on the form as an important source of error (Davenport, Dennis, Warlow 1996). Overall, this study suggested that the SMR1 data were reasonably accurate, though generalisability across hospitals may be problematic due to differences in coding. This may also be the case with TRI data.

The STATS19 data are less likely to capture data on cyclist injuries, probably because many injured cyclists do not report the incident to the police, but may present for treatment at a hospital. Thus, a study of cycling injuries in Scotland should not rely upon STATS19 as its principal source of data. The principal advantage of the STATS19 data is the wealth of information it provides on the circumstances, location and vehicles involved in an injury event. So, even if these data are only available for a small number of injuries, the data may be worth examining further. It would be important to assess how representative these data were. Data on minor injuries recorded by STATS19 were not used in this study, but the literature suggests that these data are less reliable than the data on fatalities and serious injuries (Adams 1988). The degree of under-reporting increases greatly as the severity of injury decreases. Further, there were no corresponding health service data on minor injuries, so a capture-recapture exercise for minor injuries was not possible.

The exposure data used in this study are particularly limited. As mentioned in Chapter 3, the National Travel Survey (NTS) is not designed to produce annual figures for Scotland. The Scottish figures are often presented as three yearly data because of the small sample size, and are probably subject to sampling variability. However, better quality data for Scotland are available now and will be available in the future. The Scottish Household Survey launched in 1999 is designed to collect information on travel patterns for a large, representative sample of the Scottish population. This continuous survey includes a whole module of questions on travel behaviour and travel choice. These data will allow more reliable ecological epidemiology to be performed.

The national routine data sources used in this study do provide a useful, and probably under-utilised, source of data that is population-based and reasonably accurate. The advantages of using routine data for research and evaluation have previously been highlighted (Bain, Chalmers, Brewster 1997). These include: the relative low costs of secondary analysis compared to conducting primary research, the population coverage, the time period data have been collected (allowing trends to be examined) and the size of the databases (that helps to reduce sampling error). The hardest part of the process for a researcher can be finding out who holds the data, what data are available, the level of data

completeness and data accuracy and which individual data items are available to external researchers. At the outset of this study, early negotiation of data requirements was crucial to ensure the data required was extracted from the central database. If agencies responsible for collecting routine data are interested in extending the use of these for research, it may be useful to establish some means of eliciting researchers' data requirements. This could be achieved electronically or by establishing user groups.

In the course of this study, other potential uses of the data have become apparent. In this study the data have been used for epidemiological analyses across European Union countries. International comparisons of fatality rates are facilitated by the World Health Organisation Mortality Data thanks to the International Classification of Diseases system. Data on non-fatal injuries were not (at the time of writing) deemed comparable enough across countries to allow further analysis. Work is on-going in this area including further development of morbidity matrices through the International Collaborative Effort (ICE) on Injury Statistics and the calculation of correction factors by the IRTAD working group for the IRTAD data.

The SMR1 data may also be used for cohort studies. It should be possible to follow individuals through the SMR1 system using the unique link number. While not conducted in the course of this study, the data should allow a follow-up of those admitted for a TRI (say in a given calendar year) to examine whether a repeat admission was recorded in the months and years to come, either for a repeat TRI or injury generally. Finally, the data may be useful for needs assessment and to guide the planning of interventions, both by providing information on existing circumstances and forecasting future change.

To reiterate, both the SHS and STATS19 data could be used to evaluate the impact of interventions to prevent TRIs at population level, either nationally across Scotland or in particular geographical areas. However, the boundaries for health data and police authorities are not co-terminous and this requires consideration in advance of evaluation. It would be very useful if the data were available at unit postcode level to allow researchers' to build area-based data sets. Work is on-going in Scotland to develop small area statistics in the health, education, employment and social work fields with the recent push towards community planning in Scotland (Scottish Executive website, 2000).

10.2 Capture-recapture

Capture-recapture showed that mortality data from either the SHS or STATS19 appear to represent a reasonably complete dataset. Most fatal TRI injuries were recorded by both official sources. A number of problems were highlighted by the capture-recapture procedure. The police failed to record a small number of fatal TRI injuries in STATS19. A retrospective review of the police records revealed that one of these deaths was classified as a 'serious' rather than a 'fatal' injury. This case was identified in the SMR1 hospital discharge database and had a hospital stay of greater than 30 days. Missing information in the SHS data may be due to misclassification of the injury cause.

The capture-recapture procedure showed that a lower proportion of completeness was observed in both official data sources for non-fatal injury. This resulted in an ascertainment corrected number of non-fatal TRIs over a quarter higher than the number available for analysis in each individual database. This is a similar rate of completeness to the routine hospital discharge statistics revealed in a survey of injuries in New Zealand (Roberts, Scragg 1994). Non-fatal TRIs recorded by the SHS (but not STATS19) may have been classified as 'other' injuries. A number of injuries with relevant ICD codes are coded as 'emergency-other' in the database (5% of all hospital discharges in this age group). The police may classify an injury as serious enough for hospital admission at the time of the accident, but the casualty may not be admitted to hospital. Conversely, some injuries recorded as 'slight' by the police may have resulted in hospital admission. A capture-recapture analysis including non-hospitalised TRIs was not possible because there is no matchable source of population-based health data.

Some TRI incidents resulting in non-fatal injuries had not been attended by the police. The STATS19 documentation suggests that an appreciable number of non-fatal TRIs are not reported to the police (University of Essex Data Archive 1996). Several explanations have been offered for such under-reporting. Casualties may not report an accident because they do not consider it serious enough or because insurance cover is inadequate (Simpson 1996). Another explanation (perhaps particularly pertinent to young drivers) may be that casualties, or their fellow passengers, are unlikely to call for police assistance if the driver has consumed alcohol or drugs. Reasons cited for the disproportionate number of young people injured in TRIs include their propensity to drive under the influence of alcohol and/or drugs (Farrow 1987b).

There are a number of drawbacks with the use of the capture-recapture in human populations. A recent study of children with a serious injury resulting from a motor vehicle accident (applying mark-recapture) concluded that the study violated most of the requirements of the technique (Jarvis al 2000). These requirements have also been violated in the present study. This suggests that any deductions about the size and characteristics of the unobserved group in the capture-recapture analysis should be treated with extreme caution.

The ascertainment corrected number generated in this study may be an overestimate because the population may not be 'closed'. An underlying assumption of the technique is that it is applied to a 'closed population'. The population of 15-24 year olds in Scotland is likely to be transient (probably more transient than the population as a whole). There should also be equal probability of capture. But, the cases matched in each database are not homogenous to those unmatched. For example, cyclist injuries are undercounted in the STATS19 database. Under-representation of pedestrian and cyclist injuries has been reported elsewhere. Further, (although not specifically addressed in this study) a severity effect has been observed in other studies (Simpson 1996, Jarvis et al 2000). The more serious the injury, the more likely it is that it will appear in a database.

A further drawback is inaccuracy based upon the relationship between datasets (Hook, Regal 1992, Brenner 1995). An underlying assumption of capture-recapture is that the two sources are relatively independent of each other. Both a positive and negative dependency can lead to inaccuracy. Positive dependence can lead to underestimation, and negative dependence can lead to overestimation. Since the two information sources in the present study are not directly related, the ascertainment corrected number of non-fatal injuries may be an overestimate. One system does not refer individuals to the other. However, this does not discount completely some association. The police record is completed at the scene of the injury, often with the health services present. The hospital record is completed on discharge or transfer to another hospital.

The quality of the input data is also crucial to the application of capture-recapture (Chang, et al 1999). The relatively high quality of the input data and the discriminatory nature of available variables were fundamental to the capture-recapture technique in this study. Optimal data sources with high rates of variable completion were used in the study. The existence of a location code in both data sets was essential for matching cases of serious (but non-fatal) injury. Without this variable there were a number of cases that could have

been matched to more than one corresponding record. Consideration must also be given to the data collection setting before deciding upon matching standards. As set out in Chapter 6, it was deemed justifiable to relax the matching criteria given the context of data collection in this study.

In conclusion, the capture-recapture technique has been extensively used in other research areas, but remains an under-exploited tool in injury prevention research. This study has shown that capture-recapture method may be a useful tool for demonstrating the completeness of the data sources in Scotland and indicating where biases in capture exist within sources. The use of capture-recapture to identify biases has been highlighted by others (Schootman et al 2000). This is vital contextual information in the analysis, interpretation and reporting of the data. For instance, the study demonstrates that any analysis of cyclist injuries should not rely on police-reported data. Accurate estimates of injury rates are also vital for effective prevention and evaluation of preventive interventions. However, the capture-recapture technique in this human study of TRI injury did not achieve all the requirements of the approach. In fact, it violated most of these. While this does not render the results invaluable, the ascertainment-corrected rates should be viewed with extreme caution.

With devolution of health and education to the new Scottish Parliament, a number of new surveys have been launched that may provide potentially useful data for researchers in road safety and transport. The Scottish Health Survey and the Scottish Household Survey contain questions on road traffic accidents, travel patterns and a wealth of socio-demographic information. While these may still be limited for analysis of phenomena in specific age groups or household types, these should provide important ancillary information, particularly in relation to the capture-recapture analysis.

10.3 Trends and Patterns

This study has clearly demonstrated that injuries were the leading cause of mortality in young people in Scotland between 1986 and 1995, causing over two-thirds of mortality. Almost two in five injury deaths were due to TRIs specifically. This generally reflects findings from other industrialised countries (Langley, Smeijers 1997; Fingerhut et al 1996; Wayne Sells, Blum 1996; Elmen 1994). The USA, Canada and the European Union as a whole appear to have a higher proportion of total mortality due to injuries than Scotland.

In these areas, between 80 and 90% of total deaths annually attributed to injury (Morrison et al 2000; US Department of Health and Human Services 1997).

The Scottish age-specific rates are similar to other industrialised countries. In all countries where epidemiological data has been published (including Scotland), TRIs are the most common cause of injury mortality in young people. However, a significant linear decrease in TRI mortality has been observed in young people in Scotland and in other countries in the EU. This study found that six EU member states (including Scotland) have experienced significant linear declines in TRI mortality. The research literature cites changes in travel patterns, decreases in risk behaviour, improved road infrastructure and improved vehicle design as the key factors contributing to the decrease in fatalities due to TRIs in industrialised countries (Vulcan 1995, Barrs et al 1998). However, the reasons for the differentials in rates between member states remains unclear.

More than half of young people who were killed as a result of a TRI were motor vehicle occupants or their passengers. This pattern has been apparent in studies from other industrialised countries (Langley, Smeijers 1997; Singh, Yu 1996; Fingerhut et al 1996). For example, in New Zealand (between 1984 and 1993) 62% of deaths in 15-19 year olds were due to TRIs, with over 60% recorded as vehicle occupants (Langley, Smeijers 1997). While rates of TRIs were lower in the United States than for New Zealand over this period, the proportion of young people killed as vehicle occupants is higher at just over 85% (Fingerhut et al 1996). This may be due to differences in exposure to risk between these countries.

In Scotland, approximately one in eight young people involved in a fatal TRI event were motorcyclists (or their passengers), one in five were pedestrians and a further 2% were cyclists. There has been a decrease in mortality for all road user types in Scotland over the study period, by a quarter for motor vehicle occupants, two-third for motor-cyclists and an eighth for pedestrians. Data collected post-1995 has confirmed that this pattern has largely continued up to and including 1999 (Scottish Executive website 2000). This reflects the findings from a study conducted for England and Wales between 1985-1995 (DiGuiseppi, et al 1998). This study demonstrated a 32% decline in mortality in 15-19 year olds largely due to a reduction in deaths of vulnerable road users (motorcyclists, cyclists and pedestrians), corresponding to large decreases in motorcycling, cycling and walking.

These associations were also evident in this study. Transport trends show that travel by foot has decreased substantially and this study suggests that there is a significant correlation between TRI mortality in pedestrians and the declining trends in travel by foot over the ten study years. Pedestrian TRI mortality is also more prevalent amongst those in Scotland least likely to have access to a motor vehicle. In general, car ownership has increased substantially among the population. However, this does not appear to have resulted in an increase in TRIs. This study demonstrated an association between declining rates of TRIs and an increase in the distance travelled annually.

TRIs continue to be an important cause of morbidity in young people in Scotland. By 1995, the age specific rate of hospital discharge was 217/100,000 and capture-recapture estimates suggest this rate may be closer to 291/100,000. If the number of non-fatal injuries resulting in permanent impairment is (as estimated by Barrs and colleagues) approximately equal to the number of fatalities, then approximately 100 young people in Scotland are permanently impaired each year. In contrast to other injury causes, hospitalised injuries due to TRIs decreased by 21% between 1986 and 1995. However, TRIs continue to result in over 1500 hospital admissions annually in Scotland and as such are a significant burden on the health service. In agreement with the data on mortality, young people were more likely to be injured as a motor vehicle occupant than as any other road user type. Hospital discharges fell only slightly for motor vehicle occupants, but reduced significantly for motorcyclists and pedestrians.

A substantial majority of hospitalisations that resulted in fatalities were the result of traumatic or possible traumatic head injury. These tended to be multiple injury events. This represents only 13% of total fatalities. This means that 87% of deaths occurred before occurred before admission to hospital was achieved. A study that examined the temporal trends in trauma deaths in the Lothian and Borders area of Scotland confirms this finding. This study showed that over three-quarters of TRI trauma cases died within one hour of the injury event (Wyatt et al 1995). These cases will, therefore, probably not appear on the SMR1 database. This stresses the importance of primary prevention of TRIs. The vast majority of young people admitted to hospital were not fatally injured (99%). Head injuries and injuries to the upper and lower extremities were common amongst this group.

Patterns of TRIs based on sex and socio-economic status are evident. Young men, and those of higher socio-economic status appear to be at increased risk of a TRI fatality. The disproportionate number of young men sustaining fatal TRIs has been observed elsewhere

in the research literature (see Chapter 2). Explanations for this male excess include both increased risk exposure and risk behaviour compared to their female counterparts. In contrast to most research findings that observe an association between increased injury incidence and low socio-economic status, young people killed as motor vehicle occupants in this study were more likely to reside in areas of greater affluence in Scotland. Further, young people fatally injured as pedestrians are significantly more likely to reside in areas of relatively greater deprivation. This may (at least in part) be due to levels of exposure. A number of authors have pointed to the effect of car ownership on TRI incidence and socio-economic status (Potter 1997, Abdalla et al 1997).

So, TRIs remain the leading cause of injury mortality and a significant contributory to injury morbidity in young people generally. Yet these injury events appear to be more socially acceptable in comparison to other causes of death and ill health in young people. While not the specific subject of study in this study, media coverage of other causes of mortality such as drug-related deaths and assaults appear to be more frequent and extensive in comparison to TRIs. However, mortality rates for these causes fall far behind rates of TRIs. For example, 2.3/100,000 fatalities were the result of an assault between 1986 and 1995 compared to 19.3/100,000 fatalities due to TRIs. There appears to be at least an acceptance, but probably a 'normalisation' of TRI injuries in the young in Scottish society.

However, it should be noted that the analysis of all-cause injury mortality conducted in this study suggests that suicide represents the greatest public health challenge in Scottish young people. If we assume that deaths classified as undetermined are likely to be suicides, then suicide represents a further third of injury mortality in this age group, and was the leading cause of injury mortality in 1994 and 1995. Parasuicide also appears to be increasing in young people in Scotland. Age-specific rates increased by a staggering 77% over the study period. In contrast to fatal TRIs (which appear to be decreasing significantly), suicides have shown an increasing trend generally and a significant increase since 1989. This pattern has been observed in young people elsewhere in the UK, in particular young males. In England and Wales between 1970 and 1998 there was a substantial increase in the suicide rates of young males aged 15-19 years (McClure 2001). This study also noted a slight decrease in the suicide rates for young women, however, 'undetermined' deaths increased. A recent review of risk factors for suicidal behaviour among young people cites social and educational disadvantage, childhood and family diversity, exposure to stressful life events and mental health problems as the key factors (Beautrais 2000).

The number of drug-related deaths in young people in Scotland (some of which are recorded as poisonings) is also a cause for concern. While there are difficulties with classification, there appears to have been an increase in total drug-related deaths since the early 1990's (Information and Statistics Division, personal communication 1998). The data in this study also suggest that 'other injury' (including cases of accidental poisoning other than in the home) is a further concern for the future, with hospitalisations increasing by 30% over the study period. These cases include admissions due to drug overdose.

10.4 Prevention

There are sound economic reasons for investing in TRI prevention. The total value of avoiding one single road accident death is estimated at £900,000 (Braddick 1995). Assuming that the capture-recapture estimate is relatively accurate for young people fatally injured in Scotland in 1995, the total cost for that year would be £93.6 million. It is an interesting exercise to compare this figure with the average costs of local safety schemes. RoSPA estimate the cost of a local safety scheme at less than £100,000 (RoSPA personal communication, 1999). RoSPA further note that the level of funding earmarked for such projects in the UK is less than 1% of the total cost to the economy of TRIs.

However, it is the social costs that are particularly concerning. Research suggests that between one quarter and one third of TRI survivors suffer some form of psychological distress after the event. While such distress appears to be most acute immediately after sustaining an injury, a minority of victims continue to suffer from psychological distress several weeks later. Assuming the capture-recapture estimate is relatively accurate for non-fatal injuries in young people in 1995, approximately 500-600 victims will have suffered from psychological distress as a result of a serious TRI in Scotland. This estimate does not include young people who were not injured in the TRI events or had minor injuries (not resulting in hospital admission). This too has important consequences for health and social services and the economy generally.

It may be that preventive measures are beginning to impact on the TRI rates, and exposure to risk is decreasing. However, investing in prevention is an easier step if there is some evidence upon which to base decisions about appropriate and effective interventions. Overall, the reviews published to date generally concur that the evidence for prevention of TRIs in young people (and more generally) is fair or weak. A number of published reviews have pooled the available evidence on the effectiveness of TRI prevention

measures. These were described in Chapters 1 and 2. The weight of evidence to date suggests that a 3-pronged approach including environmental, educational and enforcement initiatives are the most effective. This approach addresses both risk exposure and risk behaviour.

The reviews of evidence suggest that without a safe road infrastructure, there is likely to be no significant reduction in TRI fatalities. Few free-standing educational interventions have been shown to be effective. Certainly, safer road design and roadside environments do appear to result in fewer injuries. There still appears to be scope in Scotland to address this further as a means of prevention. The logistic regression in this study illustrated that fatalities are still more likely to occur on roads with 60mph speed limits. In Scotland, these are predominantly roads with two-way traffic, rarely with space for stopping by the roadside. These road types are also most commonly relied upon in remote rural areas. The examination of TRI events in 1995 by former council areas showed that the areas with the highest mortality and hospitalisations rates were predominantly in rural areas of Scotland.

Other environmental measures are also advocated. The prevention literature suggests that permanently switched on lights in cars can reduce TRIs occurring during hours of daylight. The regression analysis conducted for this study did not suggest that significantly more fatalities occurred when it was light. Almost half (49%) of fatalities in this study did occur during daylight. A meta-analysis of 17 observational studies demonstrated that there were 10-15% less multi-party crashes in cars with their lights switched on (Elvrik 1996). It should be noted that these types of study run the risk of confounding and do not represent very strong evidence. A similar meta-analysis concluded that roadside guards will reduce injury severity (Elvrik 1995). It is also estimated that this intervention will reduce the chance of sustaining a personal injury by approximately a half.

Improved survival may be a contributory factor in the decrease in mortality rates. An analysis of the contribution of hospital care on trauma outcome (using injury severity scores) showed a substantial decline in the probability of death among children and young people admitted for severe injury (Roberts Campbell, Hollis et al 1996). The authors suggest that hospital care of seriously injured children and young people may be making an important contribution to reducing injury rates. The ratios of fatalities to hospitalisations in this Scottish study did not change significantly over the study period. This ratio compared all fatalities to all non-fatal hospital admissions, not hospitalised fatalities to non-fatal hospitalisations.

It is also possible to hypothesise that by changing travel patterns, the TRI rate can be reduced. For example, a move towards increased use of public transport may be positive both in terms of safety and environmental considerations. However, this is not clear-cut. The ecological epidemiology conducted using the TRI rates and information extracted from the National Travel Survey (UK-wide and Scottish subset) provides only a very broad indication of associations between these variables. It is particularly important to note that the data for Scotland are based on a small sample size. Significant correlations were observed between rates of pedestrian injury and walking frequency and distance travelled by foot, and between non-fatal TRIs and the increased distance travelled annually. There appears to be an association between reduced exposure and reduced pedestrian injuries. However, despite an increase in the annual distance travelled by motor vehicle, there was still a significant reduction in non-fatal TRIs. Transport statistics suggest that young people are moving away from public transport and from walking and cycling. It is perhaps also difficult to advocate cycling in the current climate. This may increase the number of cyclist injuries if a safe environment for cyclists is not provided.

Risk behaviour is also an important factor. The research literature suggests that young men are more likely to indulge in a host of risk behaviours than their female counterparts (Womens Unit 2000). Research also suggests that adolescents can have unrealistic beliefs about their skills relative to others and may deliberately choose to take risks (Farrow 1987b). Young male drivers in particular overestimate their driving skills and engage in high risk-taking behaviour. It is then important to consider multi-dimensional means of changing risk related attitudes and behaviour and risk assessment skills. Driving can be as much a social activity as it is a skills based one. An appreciation that these aspects of prevention are as important as a physical change in the environment.

There may have been a decrease in risk behaviour in recent years which also partly explains the reduction in TRI fatalities and hospitalisations. Certainly there has been a substantial reduction in drink driving in the past decade (Department of the Environment, Transport and the Regions 1997). There is good evidence to suggest that avoiding alcohol before driving prevents TRIs and reduces severity (Raffle 1989; Mayou, Bryant 1995). In this study, a total of 10% of fatalities and 9% of hospitalisations recorded by the police in 1995 had a positive BAC score. There may be problems with this particular information (due to incompleteness). Research data from elsewhere support the claim that drink driving is less socially acceptable and has reduced since the 1980s.

'Drugged' driving has been highlighted as a particular problem amongst young people in Scotland. While the prevalence of drug use appears to be increasing among young people, this does not necessarily support the hypothesis that more TRIs are a result of driving under the influence of drugs. A recent study shows that fewer than one in twenty young people had driven under the influence of any drug in the previous 12 months (Scottish Executive 2001). Overall, the limited evidence currently available on driving under the influence of drugs suggests that while drugs pose a threat, it is a secondary threat when compared with alcohol.

Overall, it is very likely that the factors described above combine to result in a reduction in incidence and severity of TRIs. In most industrialised countries there have been concurrent changes: improvements in road infratructure, decreases in risk behaviour, changes in travel patterns and improvements in health technologies. This adds weight to the need for a co-ordinated, multi-disciplinary approach to the prevention of TRIs which continue to represent a leading cause of death and hospitalisation among Scottish young people.

10.5 Recommendations

1. **The prevention of TRIs should continue to be a high priority by health and education professionals, local authorities, the police and road planners.**

   TRIs are the leading cause of death and a significant contributor to morbidity in young people in Scotland, yet they are potentially preventable. Where targeting is appropriate (as opposed to a population-wide approach), prevention programmes should target young drivers, in particular young men. Those with access to a car at an early age (generally young people residing in areas of relative affluence) are also at particular risk and should be targeted.

2. **Epidemiological analyses should be routinely updated to monitor trends in TRIs and to identify risk groups.**

   This study has shown that such monitoring is achievable using official data sources, but researchers should be aware of the limitations of the data. Use of multiple data sources should be encouraged to help build a comprehensive picture of TRIs in Scotland. Routine data sources provide a cost-effective and reasonable accurate source of TRI data that are population-based. The Scottish Health Survey and the

Scottish Household Survey should provide additional information not available in the lifetime of this study. However, it will be important to balance the resources required to conduct this type of analysis with the funding required to design, implement and evaluate appropriate interventions (see recommendation 3).

3. **A well-designed intervention to reduce TRIs in young people (with an equally well designed evaluation) should be piloted in Scotland.**

   The evidence available to date suggests that this should be a multi-disciplinary and three pronged approach that tackles education, environment and enforcement concurrently. This intervention (as with all interventions) should be have clear and measurable aims and objectives, a definitive statement on the target group or population and clear and measurable inputs, outputs and outcomes. If funding allowed, this approach could be piloted in one urban and one rural area in Scotland. Routine data used in this study could be usefully employed in such an evaluation, bearing in mind the weaknesses identified in this study. This would require co-operation between a number of agencies including local authorities, health boards, police authorities and the voluntary sector. Such partnerships in Scotland have been developing in recent years and begun delivering a more co-ordinated effort at tackling local issues, including injury prevention. However, there has yet to be rigorous evaluations of these initiatives.

4. **Economic evaluation should be built into evaluations of TRI prevention measures.**

   The literature appears to suggest that the most effective environmental approaches are also the most cost-effective. Limited resources are available to tackle TRIs in Scotland and the input resources should be used to gain the maximum benefits, in this case a reduction in mortality and morbidity due to TRIs. Often in economic evaluation the cost of an existing intervention is compared with a new intervention to establish which is more cost effective. Piloting of a three-pronged approach to TRI prevention in Scotland should include an economic evaluation within the study design.

5. **Capture-recapture can provide a potentially useful technique for assessing the completeness of data sources but the resulting ascertainment corrected rates should be viewed with extreme caution.**

   This technique has increasingly been adopted in public health research. However, the technique violates a number of requirements when used with human populations, including the requirements for a closed population, equal probability of capture and

the relationship between the input datasets. Researchers must consider in each case the effects of non-achievement of these requirements.

6. **Research should be conducted to examine the factors contributing to declines in TRI mortality and morbidity across the EU.**

   This study showed that those countries that experienced the largest declines in rates were not those with the highest rates at the beginning of the study period. This suggests there is scope for improvement for all, even those countries experiencing relatively low rates of TRIs. Of particular note was the significant 57% decrease in TRI rates in Sweden over the study period, despite the relatively low rates in 1986. Research which further explores the factors contributing to these trends would be valuable. Such a project could examine each country's approach to prevention, the resources committed to TRI prevention and assess the contributions of risk exposure and risk behaviour.

7. **A pilot project should be undertaken to assess the feasibility of establishing community based injury surveillance and prevention projects in Scotland.**

   With the move towards community planning in Scotland, data on a range of health and social indicators are becoming available at small area level (usually postcode sectors). The data used in this study should be potentially useful for such a system. It may be sensible to include all injuries in such a system (as with the WHO Safe Communities projects) rather than to limit the scope to TRIs. There are already areas in Scotland where a local approach to injury prevention is advocated and practiced. A useful pilot would be to establish an injury surveillance and prevention project in a local area to assess its feasiblity and value.

8. **The prevention of suicide in Scottish young people should remain a priority.**

   While not the specific focus of this study, the analysis suggests that further attention should be given to the increasing public health burden of suicide and parasuicide in young people in Scotland. While fatal TRIs appear to be decreasing significantly in young people, suicides have generally increased and have increased significantly since 1989. Review work on the epidemiology of suicide and the key factors influencing suicidal behaviour has been conducted elsewhere in the world. The focus for policy makers and practitioners should be piloting interventions to reduce suicidal behaviour in young people, in particular young men. A national framework for suicide prevention in Scotland has been circulated for consultation and will be finalised in 2002.

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