INJURIES AMONG THE ELDERLY

Study of fatal and non-fatal injury events

Harmmeet Sjögren

Departments of Surgery and Forensic Medicine
Umeå University Umeå 1994
Cover

Water colour by author illustrating our complex environment with intersections, road signs, traffic lights, pedestrian zebra crossings, stairs, environmental hazards, and the consequences with falls, bicycle crashes, femur fractures, and rib fractures. We are expected to adapt to this complex environment even in the autumn of our lives. Only in the ideal world when there is a balance between demands and the human ability to cope, can the key fit the key hole!
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Akademisk avhandling

som med vederbörligt tillstånd av Rektorsämbetet vid Umeå Universitet för avläggande av doktorsexamen i medicinsk vetenskap kommer att offentligen försvaras på engelska språket i Tandläkarhögskolans föreläsningssal B, 9tr, Norrlands Universitetssjukhus fredagen den 30 september 1994, kl 09.00

av

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Umeå 1994
ABSTRACT

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In view of the expected increase in the proportion of elderly in the population in most western countries, we studied injuries among the elderly (≥60 years) by investigating hospital-treated injuries in inpatients and outpatients, and fatal injuries.

One-year Hospital Injury Data - Even though the elderly made up only 15% of the injured in one year, they accounted for 42% of the total cost of trauma medical care, showing that injuries among the elderly place a disproportional burden on the health care system. The mean medical care cost increased significantly from the age of 60 years. Serious injuries (MAIS≥3) in the elderly cost almost 2.5 times more than those in the younger group (<60 years).

Study of 1,313 injury events in 1,268 elderly showed annual injury, fracture, and mortality rates per 1,000 elderly population of 57, 31, and 0.6, respectively. Almost half were injured in the home environment, and 23% in the traffic environment. Most of the severe and critical injuries (MAIS≥4) occurred in the traffic environment. Injury rate, severity of injuries, fractures, and the duration of hospitalization increased with age. Almost half of the injuries were fractures; most common were wrist and hip fractures. Women had a higher injury rate, more severe injuries, and longer duration in hospitalization than men had.

Study of 621 injury events in 600 elderly injured in the home environment, showed annual injury and fracture rates of 30 and 15 per 1,000 elderly home population, respectively. Injuries were grouped into fall injuries (76%) and non-fall injuries (24%). The fall injury incidence was higher in women than in men. Most falls occurred indoors. Environmental factors played a role in half of the fall injuries, and intrinsic factors in at least one fifth. Intrinsic factors in falls became increasingly important with advancing age. Non-fall injuries were mostly sustained in woodworking. Fall injuries were of a greater severity and accounted for 80% of the cost of medical care of elderly in the home environment.

Study of 298 injury events in 297 elderly injured in the traffic environment, showed that pedestrian falls accounted for 52% of the injuries, and vehicle-related events for 44%. The main groups in the vehicle-related injury category were bicyclists (48%), car occupants (34%), and pedestrians (4%). Two thirds of the pedestrian falls involved slipping on ice/snow. Ice/snow-related injuries (all categories) accounted for 37% of the total cost of all injuries in the elderly in the traffic environment. Vehicle-related crashes resulted in the most severe and critical injuries and the most fatalities, and cost (total and mean) more than pedestrian falls.

Fatal Injury Data from Northern Sweden - Study of 379 elderly injured in the traffic environment in a ten-year period, showed that the car occupants (43%) made up the largest category followed by pedestrians (28%), bicyclists (15%), and two-wheel-motor-vehicle riders (8%), but the risk of fatal injury per unit distance travelled was highest for pedestrians and bicyclists. Males had double the death rate as females. Most car occupants were killed in multivehicle crashes, mostly in the daylight, and at intersections. Ice/snow was the major (31%) precrash factor. One quarter of pedestrians were injured at pedestrian crossings, and half of them during darkness. One in six pedestrians was under the influence of alcohol. All pedestrians and bicyclists were injured in collisions with motor vehicles and most were injured at intersections. Pedestrians and bicyclists had more serious head injuries than chest injuries.

Study of 514 car drivers (≥18 years) injured in a 13-year-period, showed that fatalities per unit distance, and per licensed driver were highest for the ≥70-year-old and 18-19-year-old drivers. Elderly (>60 year old) and <25 year old drivers had similar fatality frequencies. The older drivers (>60 years) initiated the crash more often than younger (≤60 years) ones.Fatal head injuries decreased whilst chest injuries increased with age. The older drivers were more likely to die from post-trauma complications than younger ones.

In a study of role of disease in 480 fatally injured drivers (≥18 years) who died within three days of the crash, a grading system was developed to assess the probability of contribution of medical intrinsic factors (MIF) to the crash. Almost one quarter of the drivers were found to have MIF. Drivers with MIF were more often at fault than those without. Medical intrinsic factors were probably an underlying cause in 1 of 17 fatal crashes in all ages, and 1 of 5 fatal crashes in the elderly; in 4% of the elderly the probability was strong.

A "passive automatic" approach which does not require any action on the part of the elderly, is to be recommended when improving safety in the home and in the traffic environments. The elderly drivers can be regarded as the "miner's canary" to indicate which passive safety improvements are needed in the traffic environment. In view of the expected population trends, it is important that authorities and public health workers accept the challenge to continue and intensify the injury preventive work for the elderly.

Key words: elderly, injury, prevention, traffic, home, fall, crash, disease, bicyclist, pedestrian, cost, vehicle
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Harmeet Sjögren

Departments of Surgery and Forensic Medicine
Umeå University 1994
Umeå University Medical Dissertation

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ISBN 91-7174-929-2
New Series No 410 - ISSN 0346-6612

Printed in Sweden by
Larsson & Cos Tryckeri AB
Umeå
Now with the wisdom of years, I try to reason things out
And the only people I fear are those who never have doubts
Save us all from arrogant men, and all the causes they're for
I won't be righteous again
I'm not that sure anymore

Shades of grey wherever I go
The more I find out the less that I know
Ain't no rainbows shining on me
Shades of grey are the colours I see

Billy Joel 1992
Shades of Grey
River of Dreams
ABSTRACT

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In view of the expected increase in the proportion of elderly in the population in most western countries, we studied injuries among the elderly (≥60 years) by investigating hospital-treated injuries in inpatients and outpatients, and fatal injuries.

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A "passive automatic" approach which does not require any action on the part of the elderly, is to be recommended when improving safety in the home and in the traffic environments. The elderly drivers can be regarded as the "miner's canary" to indicate which passive safety improvements are needed in the traffic environment. In view of the expected population trends, it is important that authorities and public health workers accept the challenge to continue and intensify the injury preventive work for the elderly.

Key words: elderly, injury, prevention, traffic, home, fall, crash, disease, bicyclist, pedestrian, cost, vehicle
This thesis is based on the following publications, which will be referred to by their Roman numerals:

I. Sjögren H & Björnstig U.  
Trauma in the elderly; the impact on the health care system  

II. Sjögren H & Björnstig U.  
Unintentional injuries among elderly people: incidence, causes, severity and costs  

III. Sjögren H & Björnstig U.  
Injuries among the elderly in the home environment. Detailed analysis of mechanisms and consequences  

IV. Sjögren H & Björnstig U.  
Injuries to the elderly in the traffic environment.  
Accident Analysis & Prevention. 1991;23:77-86.

V. Sjögren H, Björnstig U, Eriksson A, Sonntag-Öström E & Öström M.  
Elderly in the traffic environment: analysis of fatal crashes in Northern Sweden  
Accident Analysis & Prevention. 1993;25:177-188.

VI. Sjögren H, Björnstig U, Eriksson A & Öström M.  
Differences between older and younger drivers; characteristics of fatal car crashes and driver injuries  

VII. Sjögren H, Eriksson A & Öström M.  
Role of disease in traumatic deaths of motor vehicle drivers  
Submitted for publication
DEFINITIONS & ACRONYMS

Accident
An unpremeditated event resulting in recognizable damage. The term “accident” is avoided in this thesis since it is regarded as an unscientific term, instead the term “injury event” is used.

AIS
Abbreviated Injury Scale is a consensus derived, anatomically based system that classifies individual injuries by body region on a 6-point ordinal scale ranging from AIS 1 (minor) to AIS 6 (currently untreatable).

BAC
Blood alcohol concentration; alcohol denotes ethanol.

Elderly
Persons aged 60 years and over were regarded as elderly in this thesis.

Hip fracture
Both trochanteric and collum fractures are referred to as hip fractures.

Home environment
Residential building and its immediate surrounding; injuries occurring beyond the garden boundaries and those in institutional settings were taken not to occur in the home environment.

Hospital-treated injuries
Treatment of inpatients and outpatients at a hospital; these include both fatal and non-fatal injuries.

Injury
Unintentional or intentional damage to the body, resulting from acute exposure to thermal, mechanical, electrical, or chemical energy. The terms “injury” and “trauma” are used interchangeably.

Injury rate
The number of injuries expected to occur in a defined number of people within a defined time period

Injury risk
Injuries per unit distance travelled.

Intervention
A specific prevention measure or activity designed to reduce injuries.

ISS
Injury Severity Score is the sum of the squares of the highest AIS code in each of the three most severely injured body regions: head or neck, face, chest, abdominal or pelvic contents, extremities or pelvic girdle, and external (lacerations, contusions, abrasions, and burns, independent of their location on the body surface). ISS scores range from 1 to 75.

MAIS
Maximum AIS, which is the highest single AIS code in a person with multiple injuries, describes overall severity.

MIF
Medical intrinsic factors, for example, myocardial infarction, atherosclerosis, epilepsy (for details see page 50).

Passive protection
Measures which protect the individual automatically, without any action on the individual’s part.

Traffic environment
All public and private roads including bikeways and parking lots.
INTRODUCTION

I. INJURIES

Injury and Disease

Injury and disease were considered by primitive peoples to be the visitation of outraged spirits or the effect of human misbehaviour directed through some evil eye. Hippocrates provided alternatives through his systematic account of the effect of environment on health (Hogue 1980).

Injuries have always been a serious public health problem, but in the 19th century, injuries were overshadowed by infectious diseases such as tuberculosis, influenza/pneumonia and gastroenteritis in the western world. In the 20th century, improvement in the sanitary conditions and other public health measures aimed at controlling infectious diseases left injuries as the foremost cause of death and ill health in the western world (Baker et al. 1992).

For much of this century, injuries were regarded as "accidental happenings" without any rational or observable explanation. The unscientific term "accident" is still used by the layman and has the connotation of bad luck, carelessness, fate, and other moralistic terms which tend to exclude scientific approaches to this problem (Langley 1988). Definition of accidents refer to random or chance events, yet existing data indicate that accidents, like diseases, are nonrandom events (Langley 1988).

There are no basic scientific distinctions between injury and disease (Haddon & Baker 1981). In some cases the etiologic agents are identical, for example, mechanical forces produce "injury" to the spine when applied in large doses; in smaller doses over long periods they produce lumbar disc "disease" (Hrubec & Nashold 1975). The rational approach used to control infectious and other diseases where the etiologies are more widely understood can also be applied to injuries (Haddon & Baker 1981).

The Magnitude of the Injury Problem

In Sweden, it is estimated that every day at least ten people are fatally injured, six people are injured so seriously in traffic that they are permanently disabled, and 600 people are admitted to hospital due to injuries (Spri report 1988). About 4% of all deaths in Sweden are due to injuries (Official Statistics of Sweden 1990).

Today injury is the single greatest killer between the ages of one and 44 years. Above the age of 45, injuries account for fewer deaths than other health problems, such as cardiovascular disease, cancer and stroke. Despite this decrease in the proportion of deaths due to injury, the
injury death rate (number of fatal injuries per unit population) is in fact higher among the elderly than among younger people (Baker et al 1992). In Sweden, more than half (57%) of the people who die due to injuries, and 51% of all inpatients treated for injuries, are aged ≥65 years (Åberg 1994).

II. POPULATION TRENDS

In the western world the proportion of older persons is increasing in the population. Older persons are more healthy and vigorous and live longer today. In Sweden, the average life expectancy for men is 74 years, and for women 80 years (Statistical Yearbook of Sweden 1992). Demographers refer to these changes in the age structure of the population as the "squaring of the pyramid" (Committee for TRB special report 1988). The population was once pyramidal: there were many young people at the base and few very old people at the pinnacle. The "Baby Boom and then Bust" cycle and the increase in average life expectancy changed the shape of this structure. It is fast becoming a square with an almost equivalent number of people in each age group.

Today in Sweden, 23% of the population is aged 60 years and over (Statistical Yearbook of Sweden, 1992). This share is expected to increase to 26% by the year 2025, when 2.5 million people shall be aged 60 years and over. It is the "very old" people over the age of 80 years that are expected to relatively increase the most: this group is expected to triple in size between 1985 and 2025 (Statistical Yearbook of Sweden 1992).

Fresh figures (July 1994) from the Swedish Road Safety Office show that there is a higher proportion of elderly driving license holders than younger ones: 15% are aged 65 years and over and 10% are aged 18-24 years (personal communication). The elderly driving license holders over 65 years of age are expected to increase by about 30,000 per year in Sweden (Schelin 1991). The proportion of elderly drivers with access to a car is also expected to increase and reach equivalent proportions to younger drivers by the turn of the century (see Figure 1) (Vilhelmson 1989).

With the growing elderly population, there is growing concern about the safety of transportation for this sector. Although automobiles and highways have improved dramatically during this century, many of the design assumptions used today are based on the performance characteristics of a younger population (Committee for TAB special report 1988, PF Waller...
1991). As pointed out by Yanik (1986), the problem of the elderly in the traffic environment has received little attention, in contrast to other age groups (e.g. Haddon et al 1961, Evans 1988, Williams & Carsten 1989, Baker et al 1992).

An increase in number of older persons in the population is bound to have impact on different spheres of society including the care of the elderly, health care, and transportation needs of the elderly. Thus, measures need to be taken today to cater for the growing elderly population.

![Chart showing expected trend in the proportion of licensed drivers with access to a car in the household (Vilhelmson 1989)](image)

**Fig 1. Expected trend in the proportion of licensed drivers with access to a car in the household (Vilhelmson 1989)**

### III. INJURY PREVENTION

The Swedish Government aims to implement the WHO strategies "Health for All by the Year 2000" in different areas, one of which is injury prevention (Svanström et al 1989). Since the elderly are over-represented in fatal and non-fatal injuries, and due to the expected increase in the older population, this group deserves serious attention and should be given priority by public health professions as far as injury prevention, medical care of injuries (DeMaria 1993) and rehabilitation (Cifu 1993) are concerned.
History of Injury Prevention

The first of many landmarks came from Hugh De Haven, a World War I pilot who studied cases in which individuals had plunged, in free fall without sustaining serious injuries and found that it was not the force per se that produced injury but the environment that controlled deceleration of the force and its distribution over the body (De Haven 1942). Support for this concept, came a decade later, when Colonel John Stapp (1955) of the US Air Force subjected himself to deceleration forces in sledge tests (see below). The next landmark came when Gordon (1949) suggested that injuries behaved like classical infectious diseases and could be studied by the same techniques. Gibson's concept that injuries can be produced only by energy interchange (Gibson 1961) was extended by Haddon (1980) which led to the development of systematic analyses of preventive approaches presented in the form of Haddon's "phase-factor matrix" (see Table 1).

In Haddon's matrix the host, vehicle/equipment, and environment are seen as factors that interact over time to cause injury. The preinjury phase includes everything that determines whether an injury event will take place. The injury phase includes everything that determines...
whether an injury results from the injury event. The postinjury phase includes everything that determines the consequences of the injury. This approach to injury control was designed around traffic injuries but it can even be applied to non-vehicle injuries such as falls in the elderly.

Table 1. The Haddon matrix with examples

<table>
<thead>
<tr>
<th>Phases</th>
<th>Human</th>
<th>Vehicle/equipment</th>
<th>Physical and Socioeconomic environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preinjury</td>
<td>Alcohol</td>
<td>Braking capacity of motor vehicles</td>
<td>Visibility of hazards</td>
</tr>
<tr>
<td></td>
<td>Vision</td>
<td></td>
<td>Ice/snow</td>
</tr>
<tr>
<td></td>
<td>Dizziness/balance</td>
<td></td>
<td>Door threshold</td>
</tr>
<tr>
<td>Injury</td>
<td>Osteoporosis</td>
<td>Safety belts</td>
<td>Guard rails</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External hip protectors</td>
<td>Energy-absorbing floors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Airbags</td>
<td></td>
</tr>
<tr>
<td>Postinjury</td>
<td>Age</td>
<td>Fuel system integrity</td>
<td>Emergency medical response</td>
</tr>
</tbody>
</table>

Injuries can be controlled with a variety of strategies (Committee on Trauma Research 1985). Three general strategies which can be applied to all types of injuries in the elderly are:

* Persuade persons at risk of injury to alter their behaviour for increased self-protection, for example, to use safety belts, to use special footwear in icy conditions, and not to drive if they are medically impaired

* Require individuals to change behaviour by law or administrative rule, for example, by laws requiring safety belt use, and by medical examination at a certain age

* Provide automatic protection by product and environment design, for example, by automatic safety belts, by airbags, by an external hip protector to prevent hip fractures, and by prevention of osteoporosis

Each of these general strategies has a role in a comprehensive injury control program. The first strategy is usually referred to as "active intervention" while the third strategy as "passive intervention", and the second strategy comes between these extremes (Haddon 1974). It is the general consensus in research that the second strategy requiring change in behaviour will
generally be more effective than the first, and that the third one providing automatic protection will be the most effective (Committee on Trauma Research 1985).

Active countermeasures involve education and behaviour change. It is usually more difficult, more expensive, and less effective or even impossible to modify the individual (Waller 1985). Passive countermeasures require little individual action on the part of the those being protected. The automobile air bag is a classic example. Even though passive intervention is the most desirable, truly passive interventions are not always possible. In many cases a mixed strategy addressed to each of the three phases of the injury sequence is more feasible (Committee for Injury Prevention & Control 1989). One such example is the prevention of fractures in the elderly. The mixed strategy approach in this case includes decreasing the risk of falls (Waterston 1991), increasing the level of exercise (Aloia et al 1978), using an external hip protector (Lauritzen et al 1993), preventing osteoporosis by hormone replacement therapy (Lindsay 1988), and reducing post injury complications (Gustafson et al 1991).

IV. IMPORTANCE OF INVESTIGATING INJURIES IN THE ELDERLY

Elderly have a high death rate from injuries and a high rate of hospitalization for injuries at short-stay hospitals (Baker et al 1992). In view of this and the expected demographic changes, with the proportion of elderly in the population increasing in most western countries, studies on injuries in the elderly are important. It is also important to keep in mind that due to cohort differences, for example, changing driving experiences and other trends in drug use, the elderly today may not necessarily reflect the characteristics of older persons in the future (PF Waller 1991).

To reduce the frequency and severity of injuries, approaches based on science rather than guesswork need to be applied (Haddon & Baker 1981). Thus, by collecting and analysing data about injuries in the elderly - where, when, and how they occur, it can be possible to understand patterns of occurrence and thereby use the information as a basis for designing preventive measures.

In the present thesis, the magnitude and nature of the problem of injuries in the elderly is illustrated by our findings on cost of injuries (paper I) and the study on an overview of injuries treated at the hospital (paper II). Since we found that most injuries occurred in the home environment (paper III) and the traffic environment (paper IV, V, VI), we carried out detailed studies of injuries in these environments. Since fatal injury patterns usually differ from non-fatal
ones, fatal injuries in the traffic environment (*paper V, VI*) were also investigated. When carrying out the study on fatal injuries in the traffic environment, the issue of role of disease in elderly drivers became apparent. In view of this and since the subject of health status and traffic safety is still controversial and needs further research (JA Waller 1991), we investigated this difficult issue of medical impairment in fatally-injured car drivers (*paper VII*).
GENERAL AIMS

The main aim of the thesis was to study some aspects of fatal and non-fatal injuries in the elderly:

- Overview of different categories of injuries

- The economic impact of trauma in the elderly on the health care system

- Causes, circumstances and consequences of injuries in the home and in the traffic environment

- Characteristics of elderly injured car drivers

- The role of medical impairment in fatal crashes
MATERIALS AND METHODS

I. HOSPITAL DATA

The results in Papers I, II, III, and IV were based on hospital injury data (inpatients and outpatients) collected at University Hospital of Northern Sweden in Umeå. This is the only hospital serving a well-defined area of about 60 km around Umeå (see Figure 2). Overlap with the neighbouring health districts served by other hospitals is negligible due to a sparse rural population. Cases, mostly minor injuries, which are treated at local medical centres in the area are not included in our hospital data; these are estimated to be about 10% of the trauma cases (Björnstig et al 1992).

1. Health district of University Hospital of Northern Sweden in Umeå
   Population: 115,000 inhabitants
   ≥ 60 years: 20,750 inhabitants
   Area: 9,348 km²

2. District of Institute of Forensic Medicine in Umeå
   Population: 907,200 (Jan 1985)
   ≥ 60 years: 202,050
   Area: 225,438 km²

Fig 2. Map of Sweden showing the districts of the University Hospital of Northern Sweden and the State Institute of Forensic Medicine
The injured persons were interviewed, when possible, when they were receiving their primary treatment at the hospital. Further data were obtained from the hospital patient medical records and sickness benefit records. Police reports were also examined when relevant. The calculation of the cost of medical care, which included both inpatient and outpatient treatment, was based on the mean operational costs for different departments. Data only up to one year after the injury event were used. Data from long-term care and rehabilitation after the acute care were not included. For details of the method see Paper III.

**Paper I:** 8,872 persons (≥0 years) injured in one year (April 1985 through March 1986) were analyzed.

**Paper II:** 1,268 persons (≥60 years) injured in 1,313 injury events during one year (April 1985 through March 1986) were analyzed.

**Paper III:** 600 persons (≥60 years) injured in 621 injury events in the home environment during one year (April 1985 through March 1986) were analyzed.

**Paper IV:** 297 persons (≥60 years) injured in 298 injury events in the traffic environment during one year (April 1985 through March 1986) were analyzed.

**II. FATAL INJURY DATA**

The results in Papers V, VI and VII were based on victims who were fatally injured in the traffic environment. All victims were autopsied at the State Institute of Forensic Medicine in Umeå, which is responsible for all medicolegal autopsies in the northern half of Sweden (Figure 2).

Autopsy reports which in most cases included toxicological analyses, police records, and hospital records when relevant, were examined. The blood alcohol concentration (BAC) was taken into consideration in only those victims who died on the site or were dead on arrival at the hospital.

Based on the information in the police reports, a judgement as to who initiated the crash was made (for details of the criteria used, see paper V).

**Paper V:** 379 autopsied victims (≥60 years) who were fatally injured in the traffic environment over a period of 10 years (1977-1986) were analyzed.
Paper VI: 514 car drivers (≥18 years) who were fatally injured in the traffic environment over a period of 13 years (1977-1989) were analyzed.

Paper VII: 480 car drivers aged ≥18 years who were fatally injured and died within three days of the vehicle crash in the traffic environment over a period of 13 years (1977-1989) were analyzed.

In paper VII, based on medical intrinsic factors (MIF) from autopsy findings and the medical history, a risk that the driver was suddenly unable to cope (sudden incapacitation) was subjectively graded on a scale from 0 to IV by a forensic pathologist (for details refer to paper VII). For example, recent myocardial infarction was judged to entail a high risk of sudden incapacitation and thereby classified as a grade III incapacitation risk. Cases without MIF were victims who may still have some minor atherosclerosis but this was considered not to constitute a risk for sudden incapacitation (grade 0).

The probability of contribution of disease to the crash was graded using a scoring system from 1 to 9 which took into account both the different grades of incapacitation and other causal factors (e.g. environment, intoxication, behaviour, vehicle mechanical fault) involved (for details see paper VII). Thus with both a low risk of incapacitation and involvement of extrinsic causal factors, the probability of contribution of MIF to the crash was considered to be low. On the other hand, when the risk of sudden incapacitation was high with no evidence of extrinsic causal factors involved, the probability of contribution of MIF was considered to be high.

III. GENERAL METHODS

In both the hospital and the fatal injury studies, injury rates per unit distance were calculated using data from a Swedish investigation on travel patterns in 1984 (Swedish Official Statistics 1987). This investigation was based on personal interviews and the distance travelled for each crash category determined.

The severity of injuries was graded according to the Abbreviated Injury Scale (AIS); where MAIS designated maximum injury (Committee on Injury Scaling, 1985) (see Table 2). The AIS score and the fatal injury were related to the six major body regions according to the AIS scale. Injury severity scores (ISS) were worked out according to Baker et al (1974).
Table 2. The Abbreviated Injury Scale (1985) with some examples

<table>
<thead>
<tr>
<th>Code</th>
<th>Descriptor</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Injury</td>
<td>Superficial abrasion or laceration of skin; finger fracture; toe fracture; one rib fracture; wrist or ankle sprain/contusion</td>
</tr>
<tr>
<td>1</td>
<td>Minor</td>
<td>Major laceration of skin; fracture of 2-3 ribs; clavicle fracture; radius/ulna fracture; humerus fracture; tibia fracture; finger or toe crush/amputation</td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Contusion of cerebrum; skull base fracture; fracture of ≥4 ribs with stable chest; cord contusion; femur fracture</td>
</tr>
<tr>
<td>3</td>
<td>Serious</td>
<td>Cerebrum laceration; fracture of ≥4 ribs with hemo/pneumothorax</td>
</tr>
<tr>
<td>4</td>
<td>Severe</td>
<td>Major penetrating head injury; brain stem contusion; myocardial perforation</td>
</tr>
<tr>
<td>5</td>
<td>Critical</td>
<td>Massive destruction of both cranium and brain; decapitation; transection of torso</td>
</tr>
<tr>
<td>6</td>
<td>Maximum</td>
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RESULTS

Only a summary of the most important results is presented here; for details refer to the individual papers.

I. COST OF INJURIES (Paper I)

Even though the elderly made up only one sixth of the total number of persons injured during a one year period, they accounted for 42% of the total cost of the medical care of injuries. The total medical care cost in females peaked after 70 years of age, while in males it peaked between 10 and 29 years. The mean cost of medical care per person increased significantly at 60 years of age and rose thereafter in both sexes (see Figure 3); the mean cost was four times higher in the older group (≥60 years) than the younger (<60 years) one. In the older group, the mean medical care cost of serious and severe injuries (MAIS≥3) was more than twice as high as that in the younger group.

II. OVERVIEW OF HOSPITAL-TREATED INJURIES AMONG THE ELDERLY (Paper II)

Of a total of 1,313 injured, 58% were females and 42% were males. Almost half of the injured were aged between 60 and 69 years. The annual injury, fracture, and mortality rate per 1,000 persons ≥60 years were 57, 31, and 0.6, respectively. The injury and fracture rate increased with advancing age.

Fig. 3. Mean medical care cost of injuries per patient by age
Almost half of the elderly were injured in the home environment (see Figure 4). Nearly one quarter were injured in the traffic environment. One in eight older persons was injured in institutions (long term medical care institutions not included); old-people's homes were the most common places.

![Bar chart showing causes of injuries at different locations](image)

Fig 4. Causes of injuries at different locations

Falls was the most common (70%) cause of injury. Fall injuries were more common in women than in men. With advancing age the frequency of falls increased; falls was the cause of injury in 85% of over 80 year olds. Ten per cent were injured in vehicle crashes.

More than half of the elderly had major injuries (MAIS≥2). Women on the whole received more serious injuries than men. With increasing age, the severity of injuries increased. Although the majority of the elderly were injured in the home environment, all the severe and critical injuries (MAIS≥4) occurred in the traffic environment. Another interesting observation was that 40% of those injured in institutions received serious (MAIS≥3) injuries.

Half of the injuries were fractures; upper extremities was the most common location followed by the lower extremities. Hip fractures (22% of fractures) and radius fractures (21%) were the most common followed by fractures of the rib/sternum, humerus, malleolei and vertebral column. In falls, 60% of the injuries were fractures and dislocations.

One third of the injured were hospitalized for an average duration of 13 days. With increasing age, the total number of days in hospital increased and reached a peak at about 70 years of age. The mean number of days in hospital also increased with advancing age.
A total of 13 persons were fatally injured: six in vehicle crashes, six in falls, and one choked on his food. Nine of these died in hospital. The other four died outside the hospital and were thus taken directly to the State Institute of Forensic Medicine.

III. HOSPITAL-TREATED INJURIES AMONG THE ELDERLY IN THE HOME ENVIRONMENT (Paper III)

The annual injury rate and the fracture rate were 30 and 15 per 1,000 elderly living at home, respectively. The 621 injury events were grouped into two main categories: fall injuries (76%) and "other" injuries (referred to as non-fall injuries). Fall injuries were more common in women than in men.

Most falls (71%) occurred indoors. The most common causes of falls were slipping (25%) and tripping (18%). The mechanism was unspecified in 13% of the falls; this group included cases who had no memory of the circumstances of the fall event. One in five persons who fell reported that intrinsic or health factors were the cause of the fall. In this group, sudden dizziness, blackout, fainting and weakness was reported by 11%, balance difficulties associated with disability or a medical condition - for instance, stroke or Parkinsonism - was reported by 5%, and five men were under the influence of alcohol. Other intrinsic factors, such as defective vision were also reported. Both falls due to intrinsic factors and those where the mechanism was unknown increased with advancing age. The majority of non-fall injuries occurred in woodworking, home maintenance or building work.

Environmental factors were stated by the patient to play a role in inducing half of the falls. Snow/ice was the main causative factor in 13% of falls, and throw rugs in 8% of falls. Stairs was given to the cause in 5% of falls.

Fifty-eight percent of falls resulted in fractures; hip fractures were the most common (24%). Fall injuries were of a greater severity than non-fall injuries, and 43% of falls required hospitalization for an average of 15 days. Falls accounted for 92% of the injury-related costs; falls where an environmental factor was implicated accounted for almost 43% of the total cost of fall injuries.

The medical cost of injuries for the elderly injured in the home environment exceeded the cost of traffic and occupational injuries in all ages in the same geographic area.
IV. HOSPITAL-TREATED INJURIES AMONG THE ELDERLY IN THE TRAFFIC ENVIRONMENT (Paper IV)

The annual injury rate was 15 per 1,000 persons ≥ 60 years. The 298 (60% females, 40% males) injury events were grouped into three main categories: falls (52%), vehicle crashes (44%) and "other" injury events. The main groups in the vehicle-crash category were bicyclists (21%), car occupants (15%), and other vehicle occupants (6%), for example, kick sledge, motorcycle/moped, and pedestrians (2%).

In females, falls were a more common cause of injury than vehicle events, whilst in males there was a tendency for a converse relationship. There was clearly a higher number of falls in the winter. Injuries associated with bicycle events occurred in the early spring, in the summer and in the autumn.

Almost two thirds of the falls involved slipping on ice/snow; tripping was the underlying mechanism in 15%. Dizziness was mentioned in one case and at least two cases were under the influence of alcohol.

In almost one quarter of the bicyclist crashes, a four-wheel vehicle was involved. In the motor-vehicle group, 65% were drivers. Just over half of the motor-vehicle crashes involved collision with another vehicle, 37% involved only one vehicle, and 4% were animal-vehicle crashes. Three of the five pedestrians were knocked down by a four-wheel vehicle.

Sixteen per cent of the injured received serious injuries (MAIS≥3). It was only victims of vehicle events that received severe and critical (MAIS≥4) injuries. Almost half of the injuries were fractures. Fractures were more common in falls than in vehicle events. The location of fractures differed between the different injury categories; in fall and pedalcycle groups, the most common fracture site was the radius and/or ulna; and in the car group, it was the rib cage. Intracranial injuries (concussion, cerebral contusion, intracranial hemorrhage) occurred almost exclusively in vehicle injury events.

About one third of the injured were hospitalized for a mean of 11 days. Almost half of the vehicle events and one quarter of falls resulted in inpatient treatment. Both the total and the mean costs of vehicle-associated injuries were higher than that of falls. Injuries due to ice/snow took up 37% of the cost of all injuries in the traffic environment; these injuries accounted for 76% of the cost of fall injuries and 11% of the cost of vehicle events.
When frequency and cost were taken into consideration, the fall group was larger than the pedalcycle group and that in turn larger than the car occupant group (see Figure 5).

Six of the injured died while in hospital: three bicyclists, one car driver, one pedestrian who was knocked down by a car, and one person who fell.

![Frequency and Cost Diagrams]

Fig. 5. Frequency and the total cost (medical care and social security) of injuries in the traffic environment

V. FATAL INJURIES AMONG THE ELDERLY IN THE TRAFFIC ENVIRONMENT

(Paper V)

The annual fatal-injury rate was 19 per 100,000 ≥60 year population; for males it was more than double that for females. The fatal-injury rate for elderly male car drivers was ten times greater than that for the female car drivers. The fatal-injury risk (deaths per unit distance) was highest for bicyclists and pedestrians.

Of the 379 fatally-injured elderly persons, 68% were males and 32% females. The car-occupant group (43%) was the largest followed by the pedestrians (25%), bicyclists (15%), and two-wheel-motor vehicles (TWMV) (8%). Most car drivers (89%) were male but the majority of car passengers (74%) were female.

Car occupants were injured mostly in the winter, and bicyclists mostly in the summer. Only 15% of car drivers were injured during darkness. Almost equal proportions of pedestrians were injured during darkness and daylight.
About the same number of car occupants were injured at intersections as on straight roads. One quarter of the pedestrian fatalities occurred at pedestrian crossings, and more than half of the bicyclists and most of the TWMV rider fatalities occurred at intersections.

Most car occupants (85%) were fatally injured in multivehicle crashes and 15% in single-vehicle crashes. Environmental factors probably played a role in the precrash phase in 44% of the car-occupant crashes. Slippery conditions due to ice/snow probably played a role in 31% of the vehicle crashes.

In 63% of the fatalities in single-vehicle crashes, the car crashed into a road-side obstacle: 42% into a natural object (e.g. a tree), and 21% into an artificial object (e.g. an utility post).

In multivehicle crashes, 85% of the elderly car drivers were assessed to initiate the crash: 36% crossed over to the wrong side of the road and crashed into an oncoming vehicle; 21% failed to yield the right of way; 13% misjudged the traffic situation, for example, overtaking; and 14% misjudged a left turn.

Thirty-five per cent of elderly car occupants were fatally injured in frontal impacts, 29% in side impacts, 26% in multiple impacts, and 2% in rear impacts. Among front-seat occupants, serious injuries (AIS≥3) were more common in side impacts than in frontal impacts; the most common injuries in both frontal and side impacts were chest injuries. However, severe head injuries (AIS≥4) appeared to be more common in side impacts than in frontal impacts. In frontal impacts, fatal chest injuries were just as common in the drivers as in the front-seat passengers.

All pedestrians and bicyclists, and most TWMV riders were injured in collisions with motor vehicles. Seventy-eight per cent of the bicyclists and 54% of the pedestrians were judged to be at least partly responsible for initiating the crash. Assessment of this responsibility was not clear cut in 16% of pedestrian-vehicle crashes.

Only 4% of the car drivers had detectable blood alcohol levels and all of them were below the legal alcohol limit in Sweden (which at this time was 0.5 o/oo). However, 15% of the pedestrians had a BAC ≥0.5 o/oo.

Car occupants had a higher proportion of serious (AIS≥3) chest injuries than head injuries, while in pedestrians and bicyclists, serious (AIS≥3) head injuries were more common than chest injuries.

For car occupants, the most common cause of death was chest injuries followed by head injuries. Fatal head injuries were more common in car occupants than in the other crash
categories. Seventeen per cent died due to conditions arising after the crash, for example, myocardial infarction, pulmonary thromboembolism, and pneumonia.

Fifty-eight per cent were dead on arrival at the hospital: 67% of car occupants, 50% of pedestrians, 46% of bicyclists, 63% of TWMV riders. There was no significant correlation between delayed death and advancing age within the elderly group. Seventeen per cent died between one month and 5.5 months after the injury event.

VI. DIFFERENCES IN FATAL INJURIES BETWEEN OLDER AND YOUNGER DRIVERS (Paper VI)

Fatalities per unit distance of driving by age showed a skewed U-shaped curve: they were highest for the ≥70-year-old group and the 18-19-year-old group and the lowest for the 30-39-year-old drivers. Fatalities per 10,000 licensed drivers showed an U-shaped curve with the highest rates in the ≥70-year-old group and the ≤25 year-old group. The older (≥60 years) drivers contributed just as substantially to the total fatality frequency as the ≤25-year-old drivers.

Older (≥60 years) drivers were more often injured in the winter, in the day-time, and at weekends than younger (<60 years) drivers. With increasing age there was a clear increase in fatalities occurring at road intersections.

With increasing age there was an increase in proportion of drivers who initiated the multivehicle crash. There was a decrease in single crashes and a converse increase in multivehicle crashes with advancing age. Multivehicle crashes involving a failure to yield the right of way and misjudgement of a left turn were three times more common in the older group than the younger group. Older drivers were also more likely to cross over to the wrong side of the road and crash with an oncoming vehicle than younger drivers.

The older the driver, the greater the likelihood of crashes with "clear" side impacts or frontal impacts, whilst multiple impact crashes decreased with age.

Extrinsic precrash factors played the least role in crashes involving the youngest (18-24 years) and the oldest drivers (≥70 years). Ice/snow was the most common factor; this played the greatest role in crashes of 50-59-year-old drivers. Involvement of road side hazards decreased with increasing age of driver.

The proportion of drivers with detectable levels of alcohol in the blood decreased with age; only 6% of older drivers were inebriated. Blood alcohol levels of above 2 o/oo were found in
only 1% of the older drivers. Liver steatosis was more commonly found in drivers above the age of 25 years than those below this age.

Fatal head injuries decreased whilst chest injuries increased with age. Chest injuries started to increase at the age of 50 years. The older drivers received a higher proportion of moderate and serious injuries (MAIS 2-3) than the younger ones. A significantly higher proportion of older than younger drivers had lower ISS (<1-15).

Safety belt usage clearly increased with age. Fatal chest injuries were more common in the non-belted than the belted drivers. Fatal head injuries were, however, more common in the belted than in the non-belted group, particularly among the younger drivers.

For older drivers, fatal head injuries were common in side impacts than in frontal impacts, whilst the proportion of chest injuries in the two impact types was similar.

In older drivers the most common cause of death was chest injuries, whilst in the younger it was head injuries. A larger proportion of older drivers died from various complications such as pneumonia and pulmonary embolism than younger drivers. The ones dying from complications had a lower ISS than those without.

A higher proportion of younger drivers than older drivers were dead on arrival at the hospital. Of those who survived more than two days, the older drivers were twice as likely to die from post-trauma complications than the younger drivers.

VII. ROLE OF DISEASE IN FATAL CRASHES (Paper VII)

Twenty-two per cent of the car drivers had medical intrinsic factors (MIF) that were judged to constitute a risk of sudden incapacitation. Medical intrinsic factors were more common in males than in females, particularly in the elderly (>60 years) drivers.

The mean age of the victims with MIF was 65.5 years; MIF became more common with advancing age. Extrinsic precrash factors, for example, ice/snow, played a smaller role in crashes where the drivers had MIF than in those without MIF. It was more common for drivers with MIF to be involved in crashes where the vehicle crossed over to the wrong side of the road and collided with an oncoming vehicle than those without MIF. A higher proportion of drivers with MIF initiated the crash than those without MIF.

In 6% of the drivers, MIF probably contributed to the crash; the mean age of these drivers was 67 years. Twenty-five (85%) of these drivers suffered from coronary heart disease, two
drivers suffered from epilepsy, one driver had diabetes mellitus, and one had a craniopharyngioma with recent hemorrhage. In 1.3% (n=6) of the drivers, the probability was strong (grade 2). For a brief description of these six cases refer to Paper VII. In all these cases, the vehicle crossed over to the wrong side of the road and crashed into an oncoming vehicle or a tree. Five of these victims were aged over 60 years.

In 20% of the ≥60-year-old drivers, MIF probably contributed to the crash; the probability was strong in 4% of the cases. We, however, did not find any case where the incapacitation definitely contributed to the crash.

In 68% of the drivers, the incapacitation did not seem to play a role in the crash; in these cases extrinsic factors and/or alcohol played a role in the crash. In another 13% of the drivers, no conclusion could be reached either due to lack of information or as there was no extrinsic factor or alcohol involved in cases with no risk of sudden incapacitation.
DISCUSSION

I. DEFINITION OF ELDERLY

It was found in paper I that the mean cost of medical care of injuries increased significantly at the age of 60 years and rose thereafter in both sexes. This suggests that at about the age of 60 years, the consequences of injuries start to become worse. This is probably because there is a reduction in toleration of trauma with age since similar injuries in the young and old have a poorer prognosis in the older patients (Baker et al 1974, Smith et al 1990). Thus on the basis of this, all persons above the age of 60 years were defined as being elderly in the present thesis, particularly as the main interest in the present work was to investigate the problem of injuries from the medical care point of view. The basis of this definition is biological rather than chronological; in Sweden people over the age of 65 years are entitled to old-age pension and thereby "administratively" regarded as "old". Some studies in the literature regard persons 60 years and over as elderly (eg Schlag 1993) while others define elderly as those who are 65 years and over (eg Champion et al 1989).

II. MORTALITY AND MORBIDITY DATA

In the present thesis both mortality and morbidity data are used to investigate the injury problem in the elderly. Injury mortality data are easier to obtain and more complete than morbidity data. However, mortality data alone do not always reflect the extent or severity of a particular injury problem since most people who are injured do not die of their injuries (Committee for Injury Prevention & Control 1989). Studies have shown that the leading causes of non-fatal and fatal injuries are clearly different, and that the mortality data are not a good guide to either overall injury incidence or the medical consequences of injuries (Barancik et al 1985). In view of this, a thorough examination of an injury problem should consider both mortality and morbidity data. The relationship between mortality and morbidity can be seen in the "injury pyramid" (see Figure 6).

Hospital Data (Inpatients & Outpatients)

From an epidemiological point of view, it is important that all trauma cases are included in the injury surveillance data from a certain geographic area (Robertson 1992). The basic principle in calculating population rates in the trauma cases in the numerator should only come from the
population in the denominator. This is a major problem in hospital trauma registries where the population from which the injuries come is often difficult or impossible to define (JA Waller 1988).

![Injury Pyramid](image)

**Fig 6.** The injury pyramid (modified from Committee for Injury Prevention & Control 1989)

In the present work, since the University Hospital of Northern Sweden in Umeå is the only hospital serving a well-defined area with negligible overlap with the neighbouring health district, it provided a unique opportunity to study nearly all the injured who seek emergency medical attention from a particular area. Since our material includes both outpatients (ambulatory) and inpatients (nonambulatory), it is a representative sample that reflects the trauma problem in the area investigated. Bias is inherent in studies from hospitals that do not also examine persons receiving only ambulatory care, since there are substantial differences between hospitalized and ambulatory patients in type of activity at time of injury, and in anatomic location and injury type (Payne & Waller 1989).

Even though we used a population-based study design, caution should be used in interpreting our results. Our rate estimates reflect the number of injury events coming to acute medical attention in our study area. All "accidents" do not necessarily result in injury and all injuries do not necessarily come to acute medical attention: Nevitt et al (1991) found that 60% of falls did not result in injury and only 6% of falls resulted in major injury (fracture, laceration treated with sutures); and Cwikel (1992) showed that 37% of elderly fallers visited the
emergency room. Also our surveillance system would not have identified those persons with injury events resulting in minor injuries treated at local medical centres. We estimate that our material included 90% of all trauma cases in the area, and at least all those with an injury severity of MAIS≥2 (Björnstig et al 1992). A cross check against the obligatory coding of the external cause of injury (E code) (World Health Organisation 1977) by Björnstig et al (1992) showed that for injury events resulting in inpatient treatment, our identification is virtually complete. On the basis of this, our results should be considered as conservative estimates of the overall problem of injury events among the elderly.

Hospital injury data has a number of advantages compared to official data: for instance they include all types of pedestrian injuries, including falls, which seldom come to the knowledge of official authorities, as well as bicyclist injuries, of which only 10% get reported in official statistics (Björnstig & Näslund 1984, Stutts et al 1990).

**Fatal Injury Data**

Since a national decree strongly recommends that police authorities request postmortem examination of all fatally injured victims of vehicle crashes, it is estimated that only a negligible number of cases were not autopsied at the State Institute of Forensic Medicine and thereby not included in our mortality data on vehicle-related injuries. Moreover, injured cases who may have been hospitalized for a long period of time would not be reported to the police and thereby not be autopsied. However, these cases are too few to have a significant effect on the results. The other advantage with our data was that it came from a well-defined population since the State Institute of Forensic Medicine is the only centre in Northern Sweden, serving more than half of the nation.

The advantage with our data compared to official Swedish traffic data is that we included all fatalities regardless of period of survival, intention or traffic classification. In official traffic data, only injuries in road traffic are reported; excluded are victims who survive more than 30 days, intentional injuries, and off-road injuries (cf Statistics Sweden 1992).

**Alcohol** - To get a reliable estimation of the blood alcohol level at the time of the crash, only those who were dead on arrival at the hospital were assessed. Since intoxicated victims are more likely to suffer immediate death than to be admitted for treatment (Dischinger et al 1988, Fell & Hertz 1990), it is reasonable to assume that only a negligible number of drivers with blood alcohol were not included in the present dead-on-arrival material. It is possible that some of the
drivers in this selected sample may have been given intravenous infusions on the way to the hospital, but this would have only a negligible effect on the blood alcohol concentration (Jones 1991).

The content of alcohol in blood in this thesis was expressed as weight (g) per weight (kg) whole blood. If other units, for example, weight per volume are used, an error of a few percent at the most (cf Evans & Frick 1993) will be present, which is insignificant for practical purposes.

**Cause of Death** - Criteria used to judge the primary cause of death can cause bias in fatal injury data. In the present work, to minimize inter-individual differences in judgements, the judgement of cause of death was made by one forensic pathologist (Prof Anders Eriksson) using the WHO rules (1977) for classification of cause of death. This method might favour skull injuries when several causes of death are present.

**III. IMPACT OF INJURIES AMONG THE ELDERLY ON THE HEALTH CARE SYSTEM (Paper I)**

The impact of injury on society is enormous in terms of the economic cost, the public and private burden of the cost, and the devastating effect on the lives of injured persons and their families (Rice et al 1989).

The cost of injuries, as estimated in the present work, is a valuable indicator of the short-term consequences of injuries since it takes into account a number of aspects: inpatient and outpatient treatment, and sickness benefit. The importance of this indicator does not lie in the absolute monetary value, but in the relative cost for different age groups or injury categories. This makes it possible to highlight areas that need to be given priority in intervention programmes and research. To reduce the burden on society it may well be more valuable to prevent injuries that have worse consequences rather than a high frequency.

Even though the elderly were 15% of the total number of persons injured, this group accounted for 42% of the total cost of medical care. Thus, even if the number of elderly injured is relatively low, this age group has a disproportional consumption of the health care resources expended on trauma care.

Since most of the elderly in Sweden are not in employment after the age of 65 years, the financial burden on society in the form of sickness benefit was negligible. However, even when this was taken into account, the mean cost of injuries in the elderly group (≥60 years) was nearly
three times greater than in the younger group (<60 years). Thus, the elderly group, particularly women above the age of 70 years, need to be given priority in injury intervention programmes.

Serious and more severe injuries (MAIS≥3) in the elderly had a higher cost, which is an indication of worse consequences, than in the younger group. In line with this, older patients have been shown to have a higher case fatality, higher complication rates, and longer stays in hospitals (Weingarten et al 1988, Finelli et al 1989, McCoy et al 1989).

Rehabilitation - The estimate of cost of injuries in paper I is a minimum cost, since the cost of rehabilitation in long-term care units, home help, and other types of care is not included. According to Oreskovich et al (1984), 92% of elderly hospitalized for severe injuries did not return to their previous level of independence, and 72% required full-time nursing one year after the injury. This problem of consequences of injuries in the elderly was also illustrated by Covington et al (1993) who reported that 26% of the injured elderly required rehabilitation, nursing home or other care, compared with 4% of adults and children. This shows the scale of help that the elderly need after an injury, putting a heavy financial burden on society.

Comparison with Other Injury Groups - In the University Hospital health district, medical care of trauma in the elderly cost two times more than vehicle-associated injuries (all ages), four times more than occupational injuries (all ages), and 2.8 times more than pediatric trauma. Despite this, research has focused relatively little attention on trauma in the elderly compared with other well-known trauma groups (Harlan et al 1990). Thus, there is disparity between trauma cost and investment in injury research and prevention programmes. In view of this, prevention of and more efficient management of injuries in the elderly can have considerable economic and health impact especially in the future.

IV. OVERVIEW OF INJURIES AMONG THE ELDERLY (Paper II)

Rate of Injury - It was found that in one year, 57 per 1,000 elderly ≥ 60 years were treated at the hospital for injuries; 19 per 1,000 elderly were hospitalized. The annual mortality rate in the area was 0.6 per 1,000 elderly. Since one tenth, mostly minor injuries, were missed, and nearly all patients with fractures are treated at the hospital, the fracture rate, which was 31 per 1,000 elderly, is a more reliable figure. The present injury rate is comparable with findings in an elderly inner-city population in the United States of 48 injured per 1,000 elderly ≥ 65 years (Grisso et al 1990), and in a community based study of hospital admissions in France which reported that
17 per 1,000 elderly ≥65 years were hospitalized (Tiret et al 1989). In the Northeastern Ohio trauma study, fractures rates of 18 per 1,000 persons 60 years old rising to 30 per 1,000 persons 80 years old were reported (Fife 1985).

The injury rate increased with advancing age after 75 years. Others have also found a similar trend in falls in the elderly (eg Lucht 1971, Grisso et al 1990). In line with findings on elderly in institutions (Gryfe et al 1977), in the home (Lucht 1971), and in the community (Tiret et al 1989, Grisso et al 1990), we also found that women had a higher injury rate than men.

**Location and Causes of Injury Events** - Almost half of the elderly were injured at home. This finding, consistent with previous research on falls (Waller 1978, Schelp & Svanström 1987, DeVito et al 1988, Grisso et al 1990), may be because elderly people spend more time at home, because they are less careful around the home, or because the home is an unsafe environment. Nearly one quarter were injured in the traffic environment, and at least 13% in institutions. Although a high proportion of elderly were injured in the home environment, all the severe and critical injuires occurred in the traffic environment, suggesting that further investigation of injuries among the elderly in both these environments is merited. A high proportion of injuries occurring in institutions were serious, indicating the frailty of this group of elderly.

Falls was the most common cause of injury in the elderly, comprising 70% of all injuries; vehicle crashes accounted for 10%. This can be compared with a French study which found that 77% of injuries in old people ≥65 years resulting in hospital admissions were caused by falls (Tiret et al 1989). Figures from the United States are lower: a study from Philadelphia showed a fall rate of 26 per 1,000 population ≥65 years compared to the corresponding rate in our study (39 per 1,000 population ≥60 years) (Grisso et al 1990).

**Severity and Consequences of Injuries** - One third of the elderly were hospitalized. The severity of injuries, the proportion of injuries that were fractures, and the duration of hospitalization was found to increase with advancing age in the elderly group. An increase in injury severity with age in the elderly group has also been reported by Margulec et al (1970) and Gryfe et al (1977). These findings suggest that the elderly population is a heterogeneous group and it is possible that different injury control measures are needed for the "young old" and the "old old" groups.

Women were found to have more severe injuries and a longer stay in hospital than men. However, as regards the severity of injuries, the contrast between the sexes was more distinct.
between 60 to 79 years of age. Above this age, men were just as likely as women to be severely injured. Grisso et al (1990) also found a similar trend in fall injury rates. Thus injury prevention strategies directed to the elderly need to consider these differences between the sexes with advancing age; much research till now has focused on the problem of fractures in women, particularly hip fractures (e.g. Meunier 1993). This is not to say that hip fractures in women is not a problem but injuries in men also need attention (Seeman 1993). We also found, as expected (Melton & Riggs 1985), that the frequency of hip fractures, which was also the most common fracture type, increased with age. It was interesting that this type of fracture was more common among women up to the age of 85, above this age it was just as common among men.

V. INJURIES IN THE HOME ENVIRONMENT (Paper III)

All causes of injury in the elderly in the home were investigated. Even though three of four injuries were falls, non-fall injuries in the elderly also deserve attention. The annual home injury and fracture rates were 30 and 15 per 1,000 elderly >60 years, respectively. Consistent with previous research (Sattin et al 1990), the fall injury rate and the fall fracture rate was higher in women than in men. Biological factors, such as osteoporosis, probably play a role in the occurrence of fractures in women. Elderly women also seem to have less sensitive visual motion detection mechanisms than males which increase their risk of falling (Owen 1985).

FALL INJURIES

Preventive strategies could be directed toward the host (the elderly person), the agent (the mechanical energy) or the environment. The present findings are discussed using this model.

Modification of Intrinsic Factors in the Host

Preinjury Event Phase - Nineteen per cent of the persons injured in falls reported that intrinsic or health factors were the cause of the fall, and 13% of the victims could give no reason for the fall. With advancing age, fall injuries where intrinsic and unspecified factors were implicated became more common, as has been found by others (Morfitt 1983, Overstall et al 1977). Many reports have emphasized the importance of intrinsic factors in falls (e.g. Prudham & Evans 1981, Cohn & Lasley 1985).

There is considerable uncertainty about which intrinsic factors best predict fall injuries in the elderly. The role of drugs such as benzodiazepines in falls has been extensively discussed
(Granek et al 1987, Ray et al 1987, Ryynänen et al 1993, Yip et al 1994). Other predisposing factors for falls are cognitive impairment, disability of the lower extremities, decreased lower extremity strength, and abnormalities of balance and gait (Tinetti et al 1987, 1988, Tinetti & Ginter 1988; Whipple et al 1987, Grisso et al 1991). A recent prospective study suggested that measure of spontaneous postural sway can be used as a preliminary screening tool for risk of falling (Maki et al 1994). Impaired vision can also be an important risk factor in the elderly (Felson et al 1989). However, these factors may actually predict falling rather than predict who will fracture when they fall.

**Injury Event Phase** - The association between osteoporosis and fractures, particularly hip fractures, has been extensively discussed (Cummings et al 1985, Devogelaer 1993). The dramatic increase in hip fractures with age is widely believed to result primarily from age-related osteoporosis (Riggs & Melton 1986). Prevention of osteoporosis by hormone replacement therapy (Lindsay 1988) has been shown to reduce the incidence of hip fractures by 50% after five years or more of therapy (Paganini-Hill et al 1981). Calcitonin (MacIntyre et al 1988) and biphosphonate (Reginster et al 1989) also prevent bone mineral loss. Sodium fluoride with calcium supplements increase bone mass but their effect on fractures still remains debatable (Riggs et al 1990, Mamelle et al 1990).

While several studies have found that low bone mass and increasing age are associated with an increased risk of hip fractures (Ross et al 1990, Cummings et al 1990), virtually all investigators have also found a considerable overlap in bone density values between hip fracture patients and age- and gender-matched controls (Cummings 1985, Melton et al 1990). Cummings & Nevitt (1989) put forward a hypothesis in which they proposed that in addition to osteoporosis and falling, hip fractures are a result of several age-related changes in neuromuscular function that increase the likelihood that a fall will lead to a hip fracture. Recently, Greenspan et al (1994) concluded that among elderly fallers, in most of whom the hip bone mineral density is already less than the fracture threshold, fall characteristics and body habitus are important risk factors for hip fractures. Thus the nature of the fall determines the type of fracture, while bone density and factors that increase or attenuate the force of impact of the fall determine whether a fracture will occur when the faller lands on a particular bone (Nevitt & Cummings 1993).
**Reduction in Mechanical Energy (Injury Event Phase)**

Hip fractures among the elderly represent a significant and rapidly growing public health problem (Cummings et al 1985a). We found that one in every four fractures was a hip fracture. As discussed above, there is considerable controversy as to whether a fracture of the hip among the elderly should be regarded as a disease (related to the excess loss of bone associated with osteoporosis) or as an injury event (related to increased frequency or severity of trauma), or as a combination of the two (Melton & Riggs 1986).

Recently, investigators have begun to focus on the etiologic role of fall severity in hip fracture risk. It has been postulated that the direction of the fall, the use of protective responses, such as breaking the fall with the outstretched arm, and the energy-absorbing capacity of soft tissues over the hip may be more important determinants of hip fracture than femoral bone mass (Cummings & Nevitt 1989, Melton & Riggs 1985). It has been shown that the impact site and the body mass index, an indicator of trochanteric soft tissue thickness, are stronger predictors of hip fracture risk than femoral bone mineral density; the increased soft tissue thickness reduces impact forces delivered to the hip in a fall (Hayes et al 1991, Hipp et al 1991, Maitland et al 1993). In line with this concept, several authors (Myers et al 1989, Cummings & Nevitt 1989, Greenspan et al 1994) suggested that an external cushioning of the hip area can be one way of decreasing the impact forces of a fall. Recently, a Danish study on elderly in a nursing home showed that external hip protectors reduced the risk of hip fracture by 53% (Lauritzen et al 1993).

There is current research being carried out in the United States on the development of air bags for hips and knees (Zylke 1990). "Active air bags" have sensors that detect the onset of a fall leading to ejection of gas into the air bag. Since air bags are claimed to absorb twice as much shock for the same thickness as the best foams on the market, including that used on the space shuttle (Zylke 1990), they may prove to be even more effective than external foam hip protectors as the ones used by Lauritzen et al (1993). The greatest advantage of external protectors is that they reduce the risk of injury regardless of the circumstances of the fall or the environment or even the degree of osteoporosis. On the other hand, compliance is a problem.

**Modification of Environment**

**Preinjury Event Phase** - In the present work, an attempt was made to determine the proportion of falls where an environmental causative factor could be identified. This was not always clear cut, particularly in the "older" elderly, where there was often overlap between intrinsic and
environmental factors. Others have also discussed this issue (Morfitt 1983; Nelson & Amin 1990) and according to Droller (1955), the "liability to fall" is always bound up with the "opportunity to fall".

We found that environmental factors played an important role in causing about half of the falls. These findings are comparable with other reports: Lucht (1971) 39%, Waller (1978) 45%, and Morfitt (1983) 45%. Clark (1968) found that an environmental component could be ascribed in 22% of the hip fractures. Thus, at least theoretically, it could be possible to influence half of the falls by environmental modification. Moreover, we also found that fall injuries where an environmental factor was implicated, accounted for almost 43% of the total cost of fall injuries, showing the burden of environmental-related injuries on the health care system.

Falls on stairs are common in elderly persons (Svanström 1971). We found that almost one in six fall injuries occurred on stairs, and stairs were implicated to be the underlying precipitating cause in almost one third of the injuries on stairs. As pointed out by Sheldon (1960), we also found that missing the last step on descent of a flight of stairs, was a common mechanism. Improvement of lighting on stairs and installation of spotlights placed on both the sides of the last step can make this step more distinct. Other stair design considerations include detection of tread edge, lighting (glare), and handrails (Archea 1985; Pauls 1989). Degraded visual acuity in the elderly also seems to be an important factor in foot placement and foot clearance in stair descent (Simoneau et al 1991)

**Injury Event Phase** - Most falls occurred on the same level, and almost three of four events occurred indoors, as has been found by others (Haga et al 1986; Grisso et al 1990). The finding that women were more likely than men to fall indoors is consistent with Campbell et al (1990). In addition, the fall injuries occurring indoors were of greater severity than those occurring outdoors. This may be because frail people have a tendency both to sustain severe injuries and to stay indoors (Wild et al 1981). The floor indoors may also influence the severity of injury. Better energy-absorbing floor materials, for example, similar to those used in boxing rings (Hogue 1982) can have an injury preventive value. However, making the floor more energy absorbing by using throw rugs is not suitable because these will probably increase the opportunity to fall by tripping and slipping as was found in the present work. Thus materials covering the whole floor area are to be recommended. The degree of slip resistance of floor surfaces may be
another aspect that needs to be considered (Redfern & Bloswick 1987). Floor slipperiness was, however, found to be only a minor hazard in the present work.

In line with Haddon's (1974) ideas, the elderly, even more so the ones who due to underlying intrinsic factors run an increased risk of falling and receiving severe injuries, need an environment that is less hazardous, more negotiable, and that accommodates for their increased vulnerability.

**Mixed Injury Prevention Strategy**

Due to the multifactorial etiology of most falls, a "mixed strategy", as recommended by Haddon et al (1981), could be the most effective fall injury prevention strategy in the elderly. This strategy combines environmental modification with other injury countermeasures such as estrogen therapy, improvement of orientation and protective responses in the faller, and enhancement of local shock absorption,

A prospective study in Denmark on prevention of fall injuries among the elderly (70-80 years old) in the home, which used a multidisciplinary approach including making environmental changes showed a tendency of decline in fractures but no statistical significant decrease in the overall incidence of injuries (Poulstrup 1989; 1992). However, a Swedish study carried out in Falköping where the population was informed, the staff educated, and the environment improved, showed a decrease in the number of injuries in the elderly (Schelp & Svanström 1987).

**NON-FALL INJURIES**

One in every four injuries in the home were non-fall injuries; the incidence was higher in men than in women. Common activities associated with non-fall injuries were woodworking, home maintenance and building work, and household chores. One third of non-fall injuries were sustained in woodworking; an electric saw was the most common injury causing object. Waller (1989) also pointed out that 17% of carpenters receiving medical attention were injured when using an electric saw. In a report on woodworking injuries, Justis et al (1987) found that the table saw was the most dangerous machine and the failure to use properly installed guards was the most common causal factor of woodworking injuries. As old people often have poor eyesight and have other age-related changes that make them more prone to injury, safety systems in power tools should be adapted to their needs.
VI. INJURIES IN THE TRAFFIC ENVIRONMENT (Papers IV, V, VI)

HOSPITAL-TREATED INJURIES (Paper IV)

Injury Rate
We found that 1-2 persons per 100 elderly >60 years were injured in the traffic environment in our district in one year.

Overview of Injuries
More than half of the injuries in the traffic environment were pedestrian fall injuries; 21% were bicyclist injuries, 15% were car occupant injuries, and only 2% were pedestrian-vehicle injuries. This shows that pedestrian falls were found to be just as important as vehicles in causing injury in the elderly in the traffic environment. It is important to highlight this issue, as little attention has so far been paid to the pedestrian who is not injured in a vehicle crash. In the district studied, elderly (≥60 years) were found to account for 46% of pedestrian falls in all ages in the traffic environment; the corresponding figure for vehicle-associated injuries is 13% (unpublished data). Thus, since only 20% of the population in this district is ≥60 years, pedestrian falls are clearly over-represented in the elderly.

Females were found to have a higher rate of falls than males. Men were more frequently injured in vehicle crashes than in pedestrian falls, especially with increasing age. Men are known to drive more than females, particularly in the elderly group (Planek & Fowler 1971).

Fractures were more common in pedestrian falls than in vehicle crashes. The pattern of fractures differed between the different injury categories: the most common fracture site in the pedestrian fall group and bicyclist group was the wrist followed by the hip, and in the car occupant group it was the thoracic cage. One quarter of the hip fractures occurred in vehicle crashes. Hedlund et al (1987) also pointed out the importance of hip fractures in traffic crashes. Vehicle-related crashes caused the most severe and critical (MAIS≥4) injuries and the most fatalities, and cost (total and mean) more than pedestrian falls. Thus from the injury cost point of view, it is most important to prevent vehicle-related injuries, but when total injury frequencies are considered, pedestrian falls deserve just as much priority in injury prevention programs as vehicle-related injuries to make the traffic environment safer for the elderly.
**Pedestrian fall-related Injuries**

Almost 40% of the total cost (medical care and sickness benefit) of injuries in the traffic environment went to pedestrian fall injuries. Two thirds of the pedestrian falls were initiated by ice/snow. Also in other countries - Denmark (Merrild & Bak 1983), England (Ralis et al 1988), and the United States (Waller 1978, Lewis & Lasater 1994) - ice/snow has been documented to be a hazard for pedestrians. Ice/snow-related pedestrian fall injuries took up 30% of the cost of all injuries in the traffic environment. Thus, we identified one of the most costly hazards causing injuries in this environment. According to Haddon & Baker (1981), emphasis and priority should be given to countermeasures directed at the hazard that would most effectively reduce injury losses. In view of this, special schemes aimed at removing ice/snow, reducing slipperiness by spreading sand and salt, and heating of pavements are definitely needed. Special anti-slip devices that can be attached to shoes, provided to this vulnerable group can have a preventive value. The devices available on the market at present need to be adapted so they can be easier for old people to use.

Tripping was another common mechanism in pedestrian falls, particularly over kerbstones. It is questionable whether kerbstones have to be so high and whether they are needed at all at pedestrian crossings. A more distinct marking of the edges of the kerb can make this more conspicuous, particularly as old people have age-related visual impairments (Cohn & Lasley 1985). This measure would also make it easier to distinguish the pavement from the road and thereby have an additional beneficial effect on the incidence of vehicle-pedestrian crashes; improved delineation has been found to reduce crash rates (Deacon 1988). Injuries caused by tripping over uneven paving stones is another problem that needs to be pointed out (David & Freedman 1990).

**Vehicle-related Injuries**

The problem of the elderly bicyclist was highlighted in the hospital-treated injuries: almost half of the cases in the vehicle category were bicyclists compared with car occupants who represented only one third of the vehicle category. Furthermore, the vulnerability of the elderly bicyclist was reflected by the finding that of the seven who died in the traffic environment, three were bicyclists. Moreover, the total cost of bicyclist injuries was greater than that of car occupants. Permanent disability also seems to more common in elderly bicyclists than in younger ones.
(Olkkonen et al 1993). Wong (1987) also pointed out that a high proportion of bicyclists injured in traffic are elderly.

Car occupants took up 40% of the cost of all vehicle-related injuries. Findings have shown that there is a trend among the elderly to rely more on the car as a mode of transportation than in the past (Rosenbloom 1988, Vilhemsson 1989). In view of this and other risk factors (Evans 1988, Brorsson 1989) taken together with the expected population trends, it is important to prevent car crashes in the elderly.

A total of six pedestrians were injured in collisions with vehicles, and two died as a result of their injuries. Increased pedestrian mortality among the elderly has also been found by Sklar et al (1989). The mean cost and the fatality rate of pedestrian injuries was high compared to the other injury categories. Elderly pedestrians do run a much higher risk of being injured and of suffering more serious injuries than younger people (Haddon et al 1961, Wong 1987, Teanby & Gorman 1993).

FATAL INJURIES (Papers V, VI)

Injury Rate
The annual fatal injury rate for the elderly in the traffic environment was 19 per 100,000 ≥60 year-old population; it was highest for the car drivers and pedestrians.

Male elderly drivers had a higher fatal injury rate but a lower fatal injury risk (per unit distance) than females. Evans (1991) found that in the United States, elderly male drivers had a higher fatal injury rate, but there was, however, no difference in the fatal injury risk between the sexes. Our finding of a higher fatal injury risk in females compared to males may be because females are less experienced as drivers than males (Hakamies-Blomqvist 1994). It is interesting that the crash characteristics of younger female drivers are similar to the ones found in older drivers (Hakamies-Blomqvist 1994).

The elderly were over-represented in fatal traffic crashes as reflected by the fatal injury rate by age. Higher crash rates due to age-related impairment of, for example, sight (Burg 1971, Kline et al 1992), or perception (Scialfa et al 1987) may account for this. Elderly also have a lower injury tolerance and have a higher risk of fatal outcome from the same impact than younger persons (Evans 1988, 1991).
Injury Risk

The number of car driver fatalities per unit distance driven showed a U-shaped pattern with age; this is in line with others (Cerelli 1989, Williams & Carsten 1989, Evans 1991). It has been the general consensus in reports from the United States that even though the injury risk in older drivers is as high as that for the young drivers, the major contribution to traffic fatalities comes from young drivers (Williams & Carsten 1989, Evans 1991). In the United States, 30% of fatally-injured passenger car drivers are aged 18-24 years and 11% are aged ≥ 65 years (FARS 1986). However, we found that the 18-24-year-old drivers (21%) and ≥65-year-old drivers (20%) contribute about equally to the total number of fatalities. This discrepancy may be partly due to differences in the proportions of young (18-24 years) licensed drivers between Sweden (13%) and the United States (17%); the proportions of older drivers do not differ much between these countries (11% and 12%, respectively) (FARS 1985, Swedish Road Safety Office 1985). Differences in the traffic environment between these two countries may also partly explain the discrepancy.

Thus, the present results suggest that since older drivers make a substantial contribution to traffic deaths in Northern Sweden, they must have at least equal claim as young drivers on resources available for intervention.

Overview of Injuries

The largest category, which accounted for 43% of the fatalities, was the car occupant group, followed by pedestrians and bicyclists. However, the pedestrians and the bicyclists had the highest number of fatalities per unit distance travelled. Thus, the unprotected road users also need to be given their fair share of attention in road safety as has also been pointed out by Mohan (1990). This fatal injury pattern differed from the non-fatal one in the elderly in the traffic environment (see above and paper IV) where pedestrian fall-related injuries were the most common followed by bicyclist, car occupant and the pedestrian-vehicle categories. Unintentional fatal fall injuries have been found to be less likely to be investigated by a medical examiner than transportation fatalities and thereby under-reported in medical examiner data (Dijkhuis et al 1994). This could also be a limitation in our fatal injury data. We found in our hospital study on the traffic environment that one of the six who died in hospital was injured in a fall.

The profile of crash categories with age was different from that found in other countries. We found, for example, that 58% of all fatally injured pedestrians and 51% of bicyclists were
aged 60 years and over. The corresponding figures for the United States for the over-65-year-olds are 22% and 7%, respectively (FARS 1989), and for Singapore for the over-60-year-olds, 42% and 35%, respectively (Wong 1987). Differences in demographics and transportation patterns, and maybe safety, are some factors that can account for these variations.

**Elderly Car Drivers**

Substantial differences between younger (<60 years) and older drivers (≥60 years) in terms of crash characteristics and injuries were found. Some of the changes in crash characteristics and injuries with age started as early as 50 years. However, the fatality risk with exposure increased substantially after the age of 70 years.

**Precrash Phase**

*Responsibility* - Responsibility in initiating multivehicle crashes increased with age as has been found by others (Verhaegen et al 1988, Cerelli 1989, Cooper 1990, Hakamies-Blomqvist 1993). Almost nine of ten fatally injured elderly were found to initiate the crash. This does not necessarily reflect that elderly drivers, in general, almost always initiate the crash, since the present study was limited in that only those who are fatally injured were investigated.

*Intoxication* - The proportion of drivers who were intoxicated decreased with age: blood alcohol was detected in 33% of the younger drivers compared to 6% of the older ones. A recent study from Finland also showed that 7.3% of elderly drivers had alcohol in their blood (Hakamies-Blomqvist 1994). Studies from the United States have reported that 40% of fatally injured elderly are intoxicated (Baker et al 1970). The present findings taken together with others (Fell 1987, Öström & Eriksson 1993) suggest that intervention focused on intoxication in Sweden needs to be directed mainly to younger drivers.

*Time of crash* - Our findings showing that older drivers were more often injured in the day-time and on weekdays, are in line with others (e.g. Planek & Fowler 1971, Mortimer & Fell 1989, Cerelli 1989, Cooper 1990). This suggests that older drivers avoid driving in the darkness and it is consistent with the fact that older drivers avoid driving in difficult traffic circumstances. This indicates that the elderly compensate for their own limitations (Hakamies-Blomqvist 1994). This can also be a symptom arising because the traffic environment is not adapted to accommodate for the limitations of the elderly driver.

*Intersections* - As found by others (Hauer 1988, Cerrelli 1989, Viano et al 1990), older drivers are more likely to be involved in multivehicle crashes, and be injured at intersections than
younger ones. Older drivers had problems with giving way to other vehicles, and with left turns; this is also consistent with others (Waller 1977, Harrington et al 1970, Cooper 1990). Much attention has been focused on intersections, particularly in the United States, where 40% of elderly drivers are fatally injured at intersections (Hauer 1988). Thus, crashes involving older drivers are characterized by problems related to perception, driver attention and decision making (Scialfa et al 1987, Verhaegen et al 1988, Hakamies-Blomqvist 1993). It has also been shown experimentally that the performance of older drivers deteriorates in complex situations (Cremer et al 1990). According to Hauer (1988), the safety of older drivers can be increased by improving the design of intersections.

Older drivers were also more likely than younger ones to cross over to the wrong side of the road and crash with an oncoming vehicle suggesting that divided highways can make the traffic environment safer for the elderly.

Environmental factors - Environmental factors played a minor role in crashes with the youngest (18-24-years) and the oldest (>70 years) drivers compared to the other age groups. This suggests that in these age groups, non-environmental factors are more important. A factor was regarded to be causal if its absence would have meant that the crash would not have occurred. However, one needs to keep in mind that a crash is seldom solely caused by one factor independent of confounding influences from other components (Evans 1991).

Crash Phase

Side impacts - Our findings that vehicles driven by older drivers had a higher proportion of side impacts than those driven by younger drivers are in line with others (Verhaegen et al 1988, Viano et al 1990, Evans 1991). The older drivers were more likely to have fatal head injuries in side impacts than in frontal impacts. The injury pattern in the younger drivers, however, did not differ between the two impact types. Others have also pointed out the importance of side impacts on serious head injuries (Siegel et al 1990, Mackay et al 1990). These results taken together with findings of Otte et al (1984) suggest that in side impacts, particularly in the elderly, protection of the head is important.

Thus, when developing crash safety systems for side impacts, the age of the car occupant needs to be taken into account. Viano et al (1990) suggested that softer interiors which are particularly suited for occupants with lower thresholds of injury, should be favoured. It has also been shown that safety belts are effective in reducing injuries in both frontal and side impacts.

Injuries and safety belt use - The proportion of fatal head injuries decreased and that of chest injuries increased with age; this was consistent with another Swedish study (Håland et al 1993). Crash injury experimental studies have also shown that the incidence of chest injuries increases with age and that an impact load that just begins to produce rib fractures with no displacement when applied to the chest of a younger person, may well generate life threatening injuries in an older person (Mackay 1988).

Since we found that both chest injuries and safety belt use increased with age, and as chest injuries can be caused by seat belt loading (Hill et al 1994), the injury pattern in the belted group was compared with that in the non-belted group in older and younger drivers. Fatal chest injuries were more common in the non-belted group than in the belted group as has also been found by Cushman et al (1990) and States et al (1990). In extremely severe crashes, fatal chest injuries, however, also occur in seat belt users (Arajärvi & Santavirta 1989). The nature of the steering assembly in cars also influences the severity of chest and abdominal injuries in car drivers (Horsch et al 1985). However, fatal head injuries were more common in the belted drivers than in the non-belted ones, particularly among the younger drivers. Further assessment of this issue was not possible due to the small size of our sample.

It is generally accepted that safety belt use is effective in reducing injuries (Marine et al 1994). It is, however, possible that the design of the belt restrain system needs to be adapted for use by older drivers by distributing the load absorbed by the chest over a larger area. Airbags are, however, effective in reducing injuries regardless of age of driver (Evans 1991, Huelke et al 1992). Airbag-only protection can reduce driver fatalities by about 30% (Zador & Ciccone 1993). Drivers with airbag-only protection have, however, a higher fatality risk than those with belt only (Evans 1990). Thus, a safety belt restrain system complemented by an airbag is probably the best intervention available today.

Environment - Roadside hazards were involved mostly in crashes involving younger drivers. This was an expected finding as roadside hazards play a major role in single crashes which involve mostly younger drivers (Öström & Eriksson 1993). Others have also pointed out the

Postcrash Phase
The most common cause of death in older drivers was chest injuries, and that in younger drivers head injuries. Fatally injured older drivers had a lower ISS than the younger ones, and they were more likely to die of late complications than the younger ones. Thus, older drivers died as a consequence of less severe injuries than younger ones. Others have also shown that similar injuries in the young and old have a poorer prognosis in the older persons (Baker et al 1974, Oreskovich et al 1984, Smith et al 1990). Smith et al (1990) found that the mortality in the elderly increased with the number of complications and suggested that the greatest improvement in survival of elderly trauma victims may be achieved by anticipating and preventing complications by optimal trauma care. Recently, Broos et al (1993) also stressed the need for more aggressive trauma care for the elderly.

Elderly Pedestrians

Precrash Phase
We found a higher rate of alcohol intoxication among the pedestrians fatalities (one in six) compared with the other crash categories (one in sixteen). Others have also demonstrated the importance of alcohol as a factor in adult pedestrian fatalities (Haddon 1961, Wyss 1990, Everest 1992). There is also an association between the degree of alcohol inebriation in pedestrians and their responsibility (Waller 1972). Control of pedestrian intoxication is, however, an issue that is difficult to deal with.

The design of pedestrian crossings and the timing of pedestrian signals merits attention, since just over a quarter of the elderly pedestrians were fatally injured at pedestrian crossings. A recent study on fatal pedestrian-truck crashes suggested that pedestrians and trucks need to be separated at crossings by time and space by setting the white painted stop lines for motor vehicles farther back from the crosswalks (Retting 1993). Furthermore, the timing of pedestrian signals are not always based on the walking speed of old people; in a recent study it was shown that 27% of elderly pedestrians did not get enough time to cross a light-controlled intersection (Hoxie et al 1994).

Motor vehicle drivers also need to show more respect for pedestrians at pedestrian crossings since all pedestrian fatalities and 60% of hospital-treated pedestrian injuries occurred
in collisions with motor vehicles. Furthermore, improvement in the lighting in the traffic environment and the use of reflectors by pedestrians may also reduce the number of casualties, since almost half of the pedestrians were fatally injured in the darkness. Others have also shown that darkness has a major effect on pedestrian casualties (Smeed 1968). Modifying the crossing behaviour of older persons is, however, not an effective countermeasure (Wiener 1968).

**Crash Phase**
We found that fatal head injuries were common in pedestrians. The exterior shape of the vehicle is of importance in the nature of injuries that a pedestrian suffers (Bunketorp 1983, Mackay 1988, Retting 1993). A British study showed that fatal injuries in 25% of pedestrians might have been less severe if trucks were fitted with side rails (Riley et al 1985).

**Elderly Bicyclists**

**Precrash Phase**
We found that all fatally-injured bicyclists and 22% of hospital-treated bicyclists were injured in collisions with motor vehicles, mostly at intersections, suggesting that the most effective way of reducing fatal injuries would be to totally separate motor vehicles from bicyclists by having bikeway systems. A Scandinavian study demonstrated that this countermeasure reduced the risk of injury in bicyclists associated with motor vehicles, by about 44% (Kallberg et al 1982). We found that alcohol played a negligible role in elderly fatally-injured bicyclists. Recently, Li & Baker (1993) also found that fatally-injured elderly bicyclists are the less likely to be intoxicated compared to other age groups.

**Crash Phase**
In line with other reports (Fife et al 1983, Björnstig & Näslund 1984, Friede et al 1985, Öström et al 1993), we also found that head injury was the most common severe injury and cause of death in bicyclists, and 14% of hospital-treated injuries in bicyclists were head injuries. Thus helmets are to be recommended, as they are effective in preventing head injury (Thompson et al 1989, Björnstig et al 1992, Öström et al 1993). Recently it was reported that the helmet protection potential may be higher in elderly bicyclists than in younger ones: 47% of ≥65-year-old bicyclists might have survived if a helmet had been used compared to 33% of 0-14 year-old bicyclists (Olkkonen 1993).
Most research on medical impairment in drivers has been limited by the inability to define some conditions, inadequate sample selection, poor definition of excessive crash risk, ignoring of comorbid conditions or human-environmental interactions, and failure to examine the interaction of aging and medical conditions (Waller 1992). Sudden incapacitation or sudden death among drivers precipitated by preexisting medical conditions is a matter of concern, and effective screening methods which include a thorough medical assessment are needed to identify drivers at risk (O'Neill 1993).

Natural death in traffic
A number of studies have investigated natural deaths in traffic (e.g. West et al 1968, Kerwin 1984, Öström & Eriksson 1987), and it has been found that sudden natural deaths play a minor part in traffic crashes and tend not to result in serious injuries. One quarter of all drivers fatalities in the traffic environment are attributed to natural deaths, the dominant cause is ischemic heart disease; coronary atherosclerosis with recent or old myocardial infarctions were commonly found (Öström & Eriksson 1987). Öström & Eriksson (1987) found that the mean age of car drivers who died due to natural death was 59 years pointing out the importance of medical impairment not only in elderly drivers but also in younger ones.

Medical impairment in traumatic deaths in traffic
The contribution of medical impairment in traumatic deaths in traffic has, however, not received much attention, probably because this is a more difficult issue to investigate. We investigated this issue by developing a grading system to assess the probability of contribution of medical intrinsic factors (MIF) to the crash. This system takes into account both the risk of sudden incapacitation, based on the medical history and pathological autopsy findings, and extrinsic non-medical contributing factors. Since it is difficult to be completely certain that MIF contributed to the crash, the method of using a probability scale gives a measure of probability that MIF was a major contributing factor in the crash. Obviously the present approach has limitations; for discussion on this refer to paper VII.

Medical Intrinsic Factors - Since most sudden deaths in traffic are correlated with cardiovascular diseases (Peterson & Petty 1962, West et al 1968, Öström & Eriksson 1987), and subjects with coronary heart disease show abnormal electrocardiographic changes during driving
(Bellet et al 1968), we considered atherosclerosis, coronary thrombosis, and myocardial infarction as the most important MIF determining the risk of incapacitation. Furthermore, since epilepsy and diabetes mellitus has been found to have an increased traffic crash risk (Kasteleijn-Nolst et al 1987, Hansotia & Broste 1991, 1993, Krumholz et al 1991, Dionne 1993), they were also considered as MIF.

Almost one quarter of the drivers were found to have MIF that were considered to constitute a risk of sudden incapacitation. This can be compared to findings reported in a study on autopsied drivers: Gerber et al (1966) found severe coronary atherosclerosis in 25% and occlusions in 4% of the drivers in which death was caused by crash-related trauma.

**Age and Sex** - Medical intrinsic factors were more common in males than in females (cf Öström & Eriksson 1987, Myerburg & Davis 1964). We found that with advancing age, MIF became more common and the grade of sudden incapacitation increased; 85% of the ≥70-year-old group had MIF. This is in line with other findings showing that moderate and severe heart disease at autopsy is, as expected, more common in older drivers than in the younger ones (Baker & Spitz 1970, Gerber et al 1966).

**Crash Characteristics** - Extrinsic precrash factors played a smaller role in drivers who had MIF compared to those who did not have MIF. Drivers with MIF usually crossed over to the wrong side of the road and collided with an oncoming vehicle. It is possible that MIF influenced the driver in such a way that he/she lost control of the car which resulted in the crash. Even in a recent study, it was found that 39% of crashes where medical conditions played a role, would probably have been prevented with some form of highway dividing barrier (Dischinger et al 1993).

**Responsibility** - Drivers with MIF were more often responsible for initiating the crash than those who did not have MIF. These findings suggest that there is reason to believe that MIF plays a causal role in the crash. Baker & Spitz (1970), however, found no correlation between driver responsibility for crash and autopsy evidence of disease or physical disability. On the other hand, it has been reported that drivers with cardiovascular diseases have more crashes and violations per unit distance, and are more often responsible than drivers known not to have chronic medical diseases (Waller 1965, 1967, 1969).

**Causal Role of MIF in Crash** - In 6% of the drivers, MIF probably played a causal role in the crash; the mean age of these drivers was 67 years. In 1.3% of the drivers, the probability that MIF
played a causal role in the crash was strong; 83% of these drivers were aged $\geq$60 years. Our findings are in fair agreement with those of Peterson & Petty (1962) who showed that in 4% of fatally-injured drivers, autopsy evidence of disease may have been the causal factor in the crashes. Our findings again reflect that the importance of medical impairment in elderly drivers as an underlying precrash factor. Thus, it seems that fatally-injured younger drivers are more likely to be intoxicated (paper VI), but the older drivers are more likely to be medically impaired. This issue of whether medical impairment may be replacing alcohol as an important factor in crashes caused by older drivers was also raised by Baker & Spitz (1970).

In a recent study of 124 crashes which resulted in serious injuries requiring trauma centre care, it was found that in 5.6% of the crashes, a medical condition (diabetes, epilepsy, heart attack) was the primary event that precipitated the crash, and for an additional 4%, the medical condition was possibly the cause of the crash (Dischinger et al 1993). Even though these findings are not directly comparable with our autopsy findings, they are interesting as they are surprisingly similar to our results.

**Summary** - Medical impairment was probably an underlying cause in 1 of 17 fatal crashes (1 of 5 in the elderly) in Northern Sweden; the probability was strong in 4% of the elderly drivers. The exact association between most autopsy findings and the degree of impairment at the time of the crash still remains unclear. Thus, as to what degree pathological autopsy findings correlate to driving safety is an issue that still needs to be investigated.

**Ischemic Heart Disease**

As discussed above, ischemic heart disease was the most common medical impairment in drivers and the dominant cause of natural death (Öström & Eriksson 1987). In Sweden, people suffering from ischemic heart disease are required to have permission from a specialist in internal medicine to drive (SOSFS 1984:31). If the patient has a pacemaker, the physician must be a cardiologist. However, victims do not necessarily have to have symptoms prior to a crash (Öström & Eriksson 1987, Antecol & Roberts 1990). Moreover, there can be drivers who can die of cardiac causes in traffic with no previous documentation of heart disease (Norman 1958, Öström & Eriksson 1987). On the other hand, a recent study on medical conditions in truck drivers showed that drivers with coronary heart disease did not have more crashes than those in good health (Dionne et al 1993).
Diabetes
We found only one case of insulin-dependent diabetes in the 480 fatally-injured car drivers in Northern Sweden, but this was not considered as a strong contributing factor to the crash (paper VII). Drivers with diabetes mellitus have been found to have no (Ysander 1966) or only a slightly increased risk of traffic crashes (Hansotia et al 1991). However, a recent study showed that truck drivers with diabetes have more crashes than healthy drivers (Dionne et al 1993).

In Sweden, the diabetic patient is required to have good control of the blood glucose, particularly to avoid hypoglycemia. It is interesting that persons with type 1 diabetes show cognitive changes even during asymptomatic hypoglycemic blood concentrations (Pramming et al 1986). In Sweden, the patient is controlled every five years, or if diabetes has been present for more than ten years, every other year. Persons with insulin-dependent diabetes are not allowed to drive commercially (SOSFS 1984:31, TSVFS 1991:29).

Disorders of the Central Nervous System
Epilepsy - We found only two cases of epilepsy among the 480 drivers fatally-injured drivers, and in one of these cases, epilepsy most probably played a causal role in the crash (paper VII). Hansotia et al (1991) worked out a standardized crash mishap ratio and suggested that further driving restrictions are not warranted for epileptic patients.

In Sweden, a seizure-free interval of two years, and EEG free from bilateral synchronized spike-wave activities is required before a driver with epilepsy can be permitted to drive. In addition, the epileptic driver must be examined by a physician with experience in neurology, and is required to be followed up after one, two and five years (SOSFS 1984:31).

Other Disorders - The role played by dementia in crashes is an issue that is receiving increasing attention (Donnelly & Karlinsky 1990, O'Neill 1993, Drachman & Swearer 1993, Waller et al 1993). Dementing illnesses are found in 6% of the population aged 65 years and over. (Cummings & Benson 1992). Some studies have shown that there is an association between dementia (Lucas-Blaustein et al 1988, Friedland et al 1988, Dubinski et al 1992, Drachman & Swearer 1993), acquired brain damage (Van Zomeren et al 1987) and high risk for traffic crashes. Preliminary results from an ongoing study in Sweden show that seven of the first 27 elderly (≥65 years) car driver fatalities had morphological signs of Alzheimer's encephalopathy; 52% fulfilled the neuropathological criteria (Johansson et al 1994). It has also been found that 60% of elderly drivers referred to a geriatric assessment centre, who were driving at the time of the assessment,
were diagnosed as having some degree of cognitive impairment (Carr et al 1990). Furthermore, it has been found that one-fifth of the cases with dementia continue to drive despite their cognitive impairment (O’Neill et al 1992). However, a recent study showed that drivers with early stages of Alzheimer’s disease did not have higher crash rates, and showed few differences in crash characteristics compared to controls, suggesting that Alzheimer’s disease is not a major problem from the standpoint of at least highway safety (Waller et al 1993).

Mental disorders and suicidal tendency will obviously increase the risk for intentional deaths in traffic. In line with a recent study from Great Britain (Kuroda & Pounder 1994), in Northern Sweden 1-2% of crashes have been estimated to be intentional, and in 57% of these crashes, mental disorders were documented (Öström et al 1994).

VIII. DRIVER SCREENING AND LICENSING

It has frequently been suggested that all drivers above a certain age should be screened by undergoing a medical examination to identify those whose declining skills increase the risk of crash involvement. Older drivers have a higher risk of traffic crash involvement and higher probability of serious injuries relative to younger drivers (paper VI, Williams & Carsten 1989). This is despite the fact that they tend to avoid driving in poor conditions (papers V, VI). Furthermore, medical impairment is more common in older drivers than in younger ones (paper VII). Since the risk of fatal injury starts to increase significantly at about the age of 70 years (paper VI), it appears warranted to begin screening at this age. On the other hand, since the mean age of drivers who die due to natural death in traffic is 59 years (Öström & Eriksson 1987), and the mean age of drivers where medical impairment plays a causal role in fatal injury crashes is 67 years (paper VII), screening of younger drivers can also be warranted.

Increased crash risk can result from many performance characteristics for which valid, cost-effective tests have not yet been developed. The problem has been to identify suitable criteria that can be used in a medical examination to effectively distinguish drivers who may be at risk of causing a crash due to their incapacitation from those not at risk (PF Waller 1988, 1991). Poor performance of elderly drivers in laboratory driving tests is not correlated with driving performance in traffic (Schlag 1993). Thus, because of an inability to predict driving performance on the basis of tests of skill and knowledge, licensing procedures have relied on specific points to demarcate the age at which a person can become a driver, but not the age at which a person is too old to drive. Chronological age per se is not a good predictor of ability when older persons
are considered, but the probability of developing medical problems does increase with age (cf paper VII). Moreover, a driving restriction based on age alone would, apart from triggering enormous opposition, result in the elderly using other forms of transportation. This in itself would hardly reduce morbidity or mortality associated with injuries since the elderly unprotected road users are more frequently injured and have a higher fatal-injury risk than elderly car drivers in the traffic environment (papers IV, V, VI).

Most European countries, except Sweden, require medical evaluation for routine licence renewal in the elderly (OECD 1986). However, the effectiveness of these medical tests is still questionable. In Israel, it was found that when 10,937 drivers aged ≥65 years were screened by standard vision and medical examinations, 27% of drivers got an added driving restriction; but only 7% of the drivers started wearing glasses while driving as a result of the vision acuity test (Zaidel & Hocherman 1986). Zaidel & Hocherman (1986) questioned the value of compulsory and costly medical examinations in traffic safety. However, standard static vision acuity findings may be less important than visual attention problems, indicated by the useful field of vision, in predicting vehicle crashes in older drivers (Ball et al 1993).

Those who die of natural causes while driving are not always aware of any underlying medical problems prior to the crash (Öström & Eriksson 1987, West et al 1968). It was beyond the scope of the present work (paper VII) to determine if medical intrinsic factors seen at autopsy or in the medical history can be used in some way to define criteria that can be used to distinguish drivers at risk from those not at risk; this obviously is a very difficult issue to investigate.

Driving licensing cannot be viewed as a way of screening out all the "bad" drivers. There are many factors that contribute to "good" or "poor" driving performance and licensing cannot realistically test for all of them (PF Waller 1988). According to Waller (1988), the most important modification that should be considered for older drivers is a graduated driving reduction program in which the impaired older drivers are gradually eased out of the driving population. Restrictions based on geographic area and time of day can also be feasible (Lange & Gerston 1990).

There are no simple solutions to this problem (review by PF Waller 1988). It is important to keep in mind that generalizations about older drivers are often confounded by inter-individual variability (Hakamies-Blomqvist 1993, PF Waller 1991). A balance must be sought between legislative action, medical tests and the level of motorization that would avoid social segregation and relegation of the elderly.
CONCLUSIONS

Even though the elderly make up 15% of the total number of injured persons who receive acute medical care, they account for 42% of the total cost of medical care showing a disproportional consumption of the health care resources expended on trauma care. Thus prevention and more efficient management of injuries among the elderly would have a considerable economic impact.

By applying findings from other reports to our results, we estimated the theoretical potential reduction in hospital-treated and fatal injuries among the elderly (Tables 3 & 4 below). The injury reduction potential is estimated for each measure assuming that none of the other injury reducing measures are taken. Due to the obvious overlap between the injury reducing potential of the different measures, it is not possible to estimate the injury reducing potential of all measures if used simultaneously in an injury prevention program.

We estimate that the greatest injury prevention potential for the elderly lies in environmental modification; about one quarter of hospital-treated injuries, mostly falls, and about one third of fatal injuries can theoretically be controlled by this means. According to Haddon & Baker (1981), the demands of an environment should be adapted to the ability of the people, and the design of any system should be based on expectations of minimum levels of human performance. Thus, elderly should not be expected to adapt to an environment designed for young and able people.

Falls are not only a dominant cause of injury among the elderly both in the home and the traffic environments, they also account for the highest cost of medical care compared to other injury categories. Elimination of environmental hazards involved in falls can theoretically result in reduction of about one quarter of all hospital-treated injuries in the elderly (Table 3). An improvement in the environment would also benefit elderly who fall and get injured due to intrinsic factors. Since snow/ice play a role in two-third of the pedestrian falls in the traffic environment and in one-eighth of falls in the home environment, and account for a substantial proportion of the total cost of injuries in the elderly, further countermeasures directed at reduction in slipperiness induced by ice/snow can have a significant injury reduction impact among the elderly. However, due to the multifactorial etiology of most falls, a "mixed injury prevention strategy" (Haddon et al 1981) is probably the most effective fall injury prevention approach in the elderly: environmental modification can be combined with other injury countermeasures, such as prevention of osteoporosis, improvement of orientation and protective
responses in the faller, and enhancement of local shock absorption by, for example, external hip protectors. We estimate that 5% of the hospital-treated injuries in the elderly can theoretically be reduced by use of external hip protectors and hormone replacement therapy for osteoporosis (Table 3).

Table 3. Estimation of potential reduction of hospital-treated injuries by different injury reducing measures in the health district of University Hospital of Northern Sweden based on one-year data on 1,313 elderly (Paper II)

<table>
<thead>
<tr>
<th></th>
<th>&quot;Faller&quot;</th>
<th>Car occupant</th>
<th>Pedestrian</th>
<th>Bicyclist</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental modification</td>
<td>360</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>360 (27%)</td>
</tr>
<tr>
<td>Hip fracture reduction</td>
<td>57</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>61 (5%)</td>
</tr>
<tr>
<td>Helmet use</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>12</td>
<td>12 (&lt;1%)</td>
</tr>
<tr>
<td>Alcohol</td>
<td>7</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>11 (&lt;1%)</td>
</tr>
</tbody>
</table>

1 Elimination of environmental hazards in falls according to papers III & IV
2 Estimated 50% reduction of hip fractures based on use of hip protectors (Lauritzen et al 1993) and hormone replacement therapy for osteoporosis (Pagani-Hill et al 1981) (papers II, III, & IV)
3 Estimated 20% injury reduction (Björnstig et al 1992), assuming that none of the bicyclists in our data was wearing a helmet (paper IV)
4 Estimated 100% reduction if none of the cases was intoxicated

Table 4. Estimation of potential reduction of fatalities by different injury reducing measures in the traffic environment in Northern Sweden based on 10-year data on 379 elderly (Paper V)

<table>
<thead>
<tr>
<th></th>
<th>Car occupant</th>
<th>Pedestrian</th>
<th>Bicyclist</th>
<th>TWMV</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental modification</td>
<td>89</td>
<td>29</td>
<td>8</td>
<td>3</td>
<td>129 (34%)</td>
</tr>
<tr>
<td>Helmet use</td>
<td>-</td>
<td>-</td>
<td>22</td>
<td>2</td>
<td>24 (6%)</td>
</tr>
<tr>
<td>Disease</td>
<td>22</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>22 (5%)</td>
</tr>
<tr>
<td>Shoulder belt/lap belt</td>
<td>14</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14 (4%)</td>
</tr>
<tr>
<td>Alcohol</td>
<td>3</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>13 (3%)</td>
</tr>
<tr>
<td>Airbag</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6 (1%)</td>
</tr>
</tbody>
</table>

1 Elimination of environmental precrash hazards and crash environmental hazards according to paper V
2 Estimated 40% injury reduction (Björnstig et al 1992), assuming that 80% of the TWMV riders and none of the bicyclists in our data was wearing a helmet (paper V)
3 Estimated 20% reduction of fatalities if drivers with medical impairment were removed from the driving population (paper VII)
4 Estimated 42% fatality reduction in drivers, 39% reduction in front-seat passengers, 18% reduction in backseat passengers based on Evans (1991), assuming that 20% of car occupants in our data were unbelted (paper VI)
5 Estimated 100% reduction if none of the cases was intoxicated
6 Estimated 8.5% fatality reduction in belted occupants in frontal crashes, 17% reduction in non-belted occupants in frontal crashes if airbags were installed based on Evans (1991), assuming that 20% of the occupants in our data were unbelted (paper VI)
More than half of the hospital-treated injuries in the traffic environment are pedestrian falls and only 44% are vehicle-related crashes. Vehicle-related crashes, however, result in the most severe and critical injuries and the most fatalities, and cost (total and mean) more than pedestrian falls. Thus, from the injury cost point of view, it is most important to prevent vehicle-related injuries, but when total frequencies are considered, pedestrian falls deserve to be given just as much priority in injury prevention programs as vehicle-related injuries, to make the traffic environment safer for the elderly population.

The bicyclist injury category account for almost half of the vehicle-related injuries treated at the hospital and one-seventh of the vehicle-related fatal injuries in the traffic environment. Moreover, elderly bicyclists have a much higher fatal injury risk than car drivers. We estimate that about 6% of the fatally injured and about 1% of the hospital-treated injured elderly would theoretically have less injuries if the bicyclists had used a helmet (Tables 3 & 4). Total separation of bicyclists from motor vehicles by having bikeways can also be an effective countermeasure for reducing fatal injuries and severe non-fatal injuries in the elderly bicyclists since all fatally injured elderly bicyclists are injured in collisions with motor vehicles.

Pedestrian-vehicle injuries, particularly fatal injuries is another dominant injury category; elderly pedestrians also have a higher fatal injury risk, and a higher mean cost of injuries than car drivers. All pedestrian fatalities and a majority of the pedestrian hospital-treated injuries occur in collisions with motor vehicles, most often at pedestrian/intersection crossings suggesting that the design of pedestrian crossings need to be adapted to the elderly pedestrian. Elimination of environmental hazards such as ice/snow involved in pedestrian-vehicle crashes is theoretically estimated to reduce about 8% of all fatal injuries in the elderly in the traffic environment (Table 4).

Elderly drivers have higher fatality rate and fatality risk than middle-aged drivers. Moreover, the elderly driver group contributes just as substantially to the total number of fatalities as the 18-24-year-old driver group. Thus, these findings do not support the myth that injuries in older drivers is not a significant problem due to their low frequency. The most recent figures show that today in Sweden there is a higher number of elderly (≥65 years) driving license holders than younger ones (18-24 years). Thus since the elderly drivers make a substantial contribution to traffic deaths and as the older driver population is expected to increase in Sweden,
the safety of the elderly drivers in traffic is an important issue and measures need to be taken today to make the traffic environment safer.

The older drivers more often initiate multivehicle crashes than younger drivers, they have problems with giving way and left turns at intersections, and they seem to avoid difficult driving conditions suggesting that the traffic environment is too complex for them. In the past, traffic planners have expected drivers to adapt to the traffic environment, but there is changing opinion that it should be the converse, with the traffic environment instead being adapted to the drivers. As suggested by Waller et al (1977), older drivers can be regarded as the "miner's canary" in the traffic environment to warns us of where the driving task is complex and thus give us an indication of passive safety improvements that are needed to make the traffic environment safer not only for the elderly but also for the entire driving population.

Screening and restriction of driving of older drivers based on age alone is controversial. Effectiveness of screening of drivers by a medical examination is still questionable due to the lack of suitable criteria that can distinguish drivers at risk from those not at risk (PF Waller 1988). Role of medical impairment in drivers, as investigated in paper VII, showed that disease was a precrash factor in 20% of fatally injured elderly drivers. We estimate that about 5% of all fatal injuries in all elderly in the traffic environment can theoretically be reduced (Table 4) if drivers with medical impairment were removed from the driving population. The problem is even if we had suitable criteria for screening of drivers, unacceptably large numbers of drivers would have to be screened and restricted for relatively small gain in fatal injury reduction (Haddon & Baker 1981). It is, however, interesting that at least theoretically, removal of elderly "medically-impaired" drivers would have a greater fatality reduction effect than air bag installation in all vehicles driven by elderly drivers (Table 3). On the other hand, air bag installation and an improvement in the traffic environment would benefit all drivers, even impaired drivers.

A "passive automatic" approach which does not require any action on the part of the elderly, is to be recommended when improving safety in the home and the traffic environments. In view of the population trends with the elderly population growing and along with it a growing elderly driver population, it is important that authorities and public health workers accept the challenge to continue and intensify the injury preventive work for the elderly.
ACKNOWLEDGEMENTS

I wish to express my deep appreciation and sincere gratitude to:

**Ulf Björnstig**, my supervisor and my friend, for his enthusiastic support, encouragement and interest, for elaborate discussions and criticism, for making me sometimes feel "great minds think alike", and for introducing me to the field of injury research. He always believed in me even when I had my moments (many) of doubt about injury research and started to glorify Immunology research. I also thank him for being my body guard on research trips in different cities in the United States, especially downtown Portland, and for carrying my many bags (he never quite understands why I need so many bags or for that matter why I insist on running marathons!).

**Anders Eriksson**, my co-supervisor, for introducing me to fatal injury research, for his enormous support, encouragement, enthusiasm, optimism, for always being willing to read my manuscripts, and for believing in me before I myself ever did. I also thank him for giving me inspiration and opening new horizons for my art work.

**Mats Öström**, my research colleague for generous support and many discussions, for sharing with me the secrets of writing a "thesis", and teaching me to make piles of paper on the floor. Our discussion in the Arizona desert resulted in *paper VI*.

**Lolomai Örnehult**, the institution’s secretary and my friend who has helped me with manuscripts, slides, computer problems with ever increasing number of new programs with their ever increasing complexity (no new computer programs, please!), and many other things including watering and "debugging" my plants.

**Anna Maria Astlind Nygren**, my colleague and good friend for coding the data in the mid 1980s, for giving me support in my research, and for always being there in difficult times of my life.

**Jeanette Jonsson** for support and much valued friendship in those early years of research.

**Elisabeth Sonntag-Öström, Lars Johansson, ElsMarie Henriksson and Johanna Björnstig** for help and support.

**The staff of the Institute of Forensic Medicine** for their support, especially the running team "Rätt så Trött" - we shall hit BIG time one day! Think BIG!

**Lory Jonson-Eriksdotter & Gunnila Östberg** for their help.

**My friends at Medical School**, especially Erna, Eija, Margaret and the "snus" guys for their support and "Good Times".

**My mother, father, sister and brothers** for always supporting me even across the seas.

**George, Sonja, Andreas, Michael and Tony, my dear family**, for their love, great patience, and understanding, and for being my greatest supporters in all situations in my life, including marathon training; without them nothing is meaningful.

**Without snus, coke, masarines, my knee injury, and the summer of 1994 (the summer that Sweden got bronze in football), garden party in uptown Tavelsjö, my IBM laptop, this thesis was never possible.**

This work was financially supported by The Faculty of Medicine, Umeå University, Fonden för ograduerade forskare, and The Swedish Road Safety Office.

*Now this thesis has come to the end of a long road, new roads lead to........................the Boston marathon.............*
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