CHILDREN INJURED IN TRAFFIC FROM A MEDICAL AND PSYCHOSOCIAL PERSPECTIVE – CAUSES AND CONSEQUENCES

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"They're funny things, accidents. You never have them till you're having them."

Eeyore

To my family

ABSTRACT

Aim: To examine the causes and consequences of road traffic injuries in children from a physical and psychosocial perspective, and to identify unfavourable circumstances and children who are at risk of injury and disability.

Methods: Study I was a systematic review of the literature on posttraumatic stress disorder (PTSD) and PTSD symptoms (PTSS) in children injured in road traffic accidents. Study II and III were follow-up studies investigating residual physical (II), psychological and psychosocial problems (III) in a sample of children (< 16 years), registered with a traffic injury at the A&E department of the children's hospital in Gothenburg in year 2000. Study II included 341 children and Study III 292 children. Data from a questionnaire were linked to the accident and injury data obtained from the hospital. Study IV, including 4 246 cyclists injured in 1993-2006, investigated the use and protective effect of helmets and changes in injury patterns during a period of increased helmet use. The injury severity was classified according to the Abbreviated Injury Scale (AIS).

Results: One third of the children fulfilled the diagnostic criteria of PTSD or PTSS after one month and about half of that group after 3–6 months. A perceived threat and high levels of distress was associated with PTSD/PTSS, especially in girls. Physical problems were reported for 16% of the children and psychological and psychosocial problems for 22% of the children in the follow-up studies (Study II and III). Residual problems were not associated with the injury severity. Severe physical problems were rare and most often reported by moped riders. Age and neck injuries were associated with residual physical problems. Residual physical problems, foreign extraction, treated as an inpatient, collision with a motor vehicle, injured as pedestrian, and skull/brain injuries were all associated with residual psychological problems. Children with residual problems reported limitations in daily living activities after the crash more often than those without residual problems. In study IV, helmets were used by 40% of the injured cyclists at the beginning of the study period (1993-2006) and by 80% at the end, much less frequently by teenagers, especially girls. Helmets had a considerable and significant protective effect against head injuries. The proportion of children with skull/brain injuries of any severity did not change significantly during the study period. The proportion with facial injuries decreased, and the proportion with non-negligible injuries to the upper extremities increased. The ratio between the number of children with head injuries and those with extremity injuries decreased during the period.

Conclusions: Trauma care should include procedures that can identify children at risk of posttraumatic stress and other residual psychological and psychosocial problems, which may otherwise be overlooked as it is not related to the injury severity. The risk of residual physical problems should be recognised in older children after moped crashes, and in children with neck problems. Teenagers must be informed about the high risk of severe skull/brain injuries in cycle crashes without a helmet. Injuries to the upper extremities in cycle crashes merits attention.

Keywords: Posttraumatic stress, PTSD, PTSS, trauma care, road traffic accidents, children, follow-up, risk factors, disability, injury, physical consequences, sequel, bicycle accident, helmet, injury severity, upper extremity injury, head injury, psychological problems, psychosocial problems.

LIST OF PAPERS

I. Olofsson E, Bunketorp O, Andersson A L. **Children and adolescents injured in traffic - associated psychological consequences: a literature review.** Acta Paediatr 2009;98:17-22.

II. Olofsson E, Bunketorp O, Andersson A L. **Children at risk of residual physical problems after public road traffic injuries – a one-year follow-up study**. Injury 2012;43:84-90.

III. Olofsson E, Bunketorp O, Andersson A L. **Trafikskadade barn och ungdomar riskerar kvarstående psykiska och psykosociala problem - möjliga riskfaktorer**. Socialmedicinsk tidskrift 2012;6:500-12.

IV. Olofsson E, Bunketorp O, Andersson A L. **Helmet use and injuries in children's cycle crashes in the Gothenburg region.** Manuscript.

CONTENTS

ABBREVIATIONS

A&E	Accident and Emergency
ADHD	Attention Deficit Hyperactivity Disorder
AIS	Abbreviated Injury Scale
CI	Confidence Interval
CNS	Central Nervous System
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders fourth edition
FET	Fisher's exact test
HRQOL	Health Related Quality of Life
ICD	International Classification of Diseases
ISS	Injury Severity Score
MAIS	Maximum AIS
OR	Odds Ratio
QOL	Quality of life
QSCH	Queen Silvia Children's Hospital
PMI	Permanent Medical Impairment
PTSD	Posttraumatic Stress Disorder
PTSS	Posttraumatic Stress Disorder Symptoms
WAD	Whiplash-Associated Disorder

DEFINITIONS

AIS

Abbreviated Injury Scale. The AIS scale classifies the severity for each well-described injury, and the code includes a digit between 1 and 6 corresponding to the threat to life of the injury. 1= minor; 2=moderate; 3=serious; 4=severe; 5=critical; 6=maximal. The grades 4 – 6 are considered life threatening.

Body regions

Skull/brain, face, neck (including the cervical spine), upper extremity (including the shoulder), upper trunk (including the thoracic spine), lower trunk (including the lumbar spine and external genitals), and lower extremity (including the pelvis).

Skull/brain injuries

Include superficial injuries (abrasions or contusions) and wounds to the scalp, fractures of the vault or skull base, and injuries to or bleeding in the brain or brain stem.

Facial injuries

Include superficial injuries and wounds, fractures of the facial skeleton, and injuries to the eye and external ear.

Injuries to the trunk and extremities

Include superficial injuries and wounds, distortions/dislocations and fractures, as well as injuries to internal organs, great vessels and nerves in the thorax and abdomen, and the spinal cord.

MAIS

Maximum AIS. MAIS in the whole body is a descriptor of the overall injury severity. MAIS can also be defined for each of the specified body regions.

Psychosocial

Relates to one's psychological condition in interaction with ones social environment

Traffic accident

Collisions or incidents occurring on public roads and involving at least one moving vehicle

Vision Zero

A road traffic safety project started in Sweden in 1997 which aims to achieve a highway system with no fatalities or serious injuries in road traffic.

INTRODUCTION

Injuries in children are a major cause of pain, suffering and disability, which may influence the children's physical, psychological and social development, and globally will send many millions of children to hospitals or emergency departments (1).

Besides developmental and physical differences between children and adults making children more vulnerable to injuries, children also live in a world mostly created by and for adults, over which they have little power and control and under different socioeconomic and demographic conditions (1).

Road traffic injuries

Road Traffic Injuries are a major cause of death in children throughout the world and the leading cause of death among children 15–19 years old. It is also the second leading cause of death (after lower respiratory infections) among children aged 5–14 years (2). In children 1-4 years old, road traffic injuries are ranked as the ninth cause of death (1,2).

According to the World Health Organisation (WHO) and the United Nations Children's Fund (UNICEF), one fifth of global road traffic deaths in 2004 affected children and the mean incidence was 10.7/100 000 children per year (2). The mortality rate, however, varies widely, with the highest rates in Africa and Eastern Mediterranean regions (2). Sweden has achieved continuous improvement towards one of the lowest rates globally. The mean annual number and incidence of road traffic fatalities in children in Sweden decreased from 43 or 2/100 000 in 1999-2003 to 20 or 1.04/100 000 in 2011 (1,3,4).

Although the mortality rate is not as high in Europe, road traffic injuries still cause about one fifth of the fatalities in children in the European Union, regardless of ages (Table 1).

Table 1. Ranking of leading causes of death in persons aged 0–19 years in the WHO European region, 2004 (2).

Rank	Cause of death
1	Perinatal causes
2	Lower respiratory infections
3	Diarrhoeal diseases
4	Congenital anomalies
5	**Road traffic injuries**
6	Self-inflicted injuries
7	Meningitis
8	Drowning
9	Leukaemia
10	Violence
11	Upper respiratory infections
12	Poisoning

In addition to fatalities, tens of millions of children require hospital care for road traffic injuries each year. A substantial number will suffer from long-lasting impairments, and road traffic injuries are the leading cause of disability due to unintentional injuries in children (2). However, there is a lack of follow-up data, particularly from low-income and middle-income countries. Combined data on unintentional injuries from South and East Asia (5) indicate that, for each fatally injured child below 18 years of age, 12 children are admitted to hospital or permanently disabled and 34 need medical care or miss school or work. Long-term sequelae after injuries have been reported from Israel (1999) (6) and France (2000) (7), and a significant impact on health burden after severe injuries was found in a study in Belgium 2011 (8). A study from Canada in 2003 (9) reported long-term functional disability after severe road traffic injuries. Karlsson et al. (10) reported from a follow-up of children injured in a road traffic accident in Gothenburg during 1983-1984, where at least 11% stated residual problems two years after the accident. Two other Swedish studies from 1965-1966 and 1991-1992 reported physical consequences (15%) in children five years after a road traffic injury (11), and disability, pain or distress (13%) one year after the accident (12).

Sweden has achieved remarkable reductions in children's injury rates during the last 50 years (2). Ragnar Berfenstam (13) and Stina Sandels (14), two pioneers deeply committed to children's safety, initiated a prolonged development in this field, not only in Sweden. In 1997, the Swedish Parliament mandated the Vision Zero strategy, aiming to eliminate death, serious injury and disability in its road traffic system and to adapt the design and performance of the transport system to this goal (15). It was also stated that no one should have to lose their health in the road transport system which should be designed for the human biological conditions (15).

Although death rates have declined considerably, road traffic is still one of the greatest health problems in Sweden, especially among children and adolescents. Eighty-two children (0-17 yrs.) died because of an injury in year 2011, 52% due to an accident, 44% due to suicide and 4% due to assault (4). Figure 1 shows the causes of death due to accidents in 43 children, 0-17 years old in Sweden in 2011.
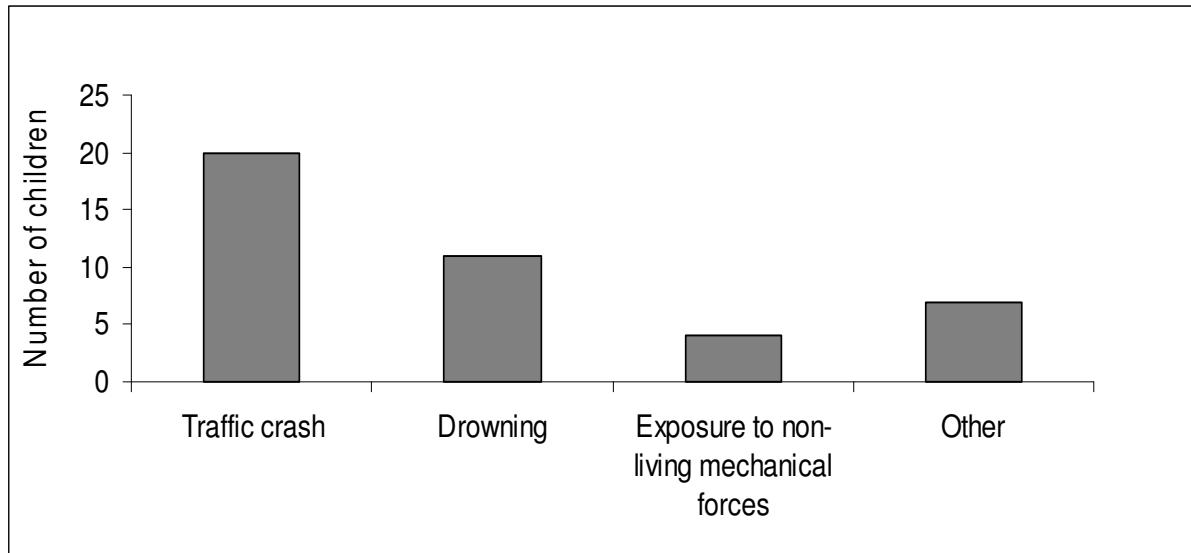

Figure 1. Number of children (0-17 yrs.) who died in an accidental injury by cause in Sweden in year 2011, n=43
Source: (4) Exposure to non-living mechanical forces: accidental injuries caused by contact with objects, tools and machinery, shot from firearms, explosions, exposure to noise and vibration, and foreign object that penetrated through the eye, natural body orifice or through the skin (3).

During the early 2000s, a growing number of children were hospitalised due to road traffic injuries, but the trend soon turned downward and the number in 2009 was almost back to the same level as in 2000 (3). An average of 3 578 children (185/100 000) were hospitalised due to road traffic injuries in Sweden in 2005-2009. The mean number and the incidence of children attending accident and emergency (A&E) departments because of traffic injuries were estimated at 25 300 and 1 314/100 000 respectively during 2007-2009 (3).

Injury prevention

Due to the WHO, road traffic injuries have been overlooked for many years, although they are predictable and preventable. Preventing road traffic injuries not only includes improvements to road and vehicle safety, but also improved post-crash care and rehabilitation and should therefore involve the health sector to ensure the best possible care (16-18).

Various prevention models have been proposed and the classic model includes
- primary prevention: preventing new injuries
- secondary prevention: reducing the severity of injuries
- tertiary prevention: decreasing the frequency and severity of disability after an injury (2).

Prevention programmes considering children's various developmental issues, risk taking behaviours, levels of activity and the child's degree of dependence have been shown to be the most effective interventions to reduce children's injury rates (2).

However, there are many factors that may influence the difference in injury risk between children and adults. Socioeconomic and demographic factors should also be taken into account.

Difference in injury risks between children and adults

During the 1960s, Stina Sandels, professor of development psychology, made some important remarks about why children are injured in traffic. At the time, it was often said that accidents involving children were caused by children's carelessness, imprudence, and recklessness (14). Children were perceived as small adults and it was therefore assumed that the behaviour of children could be made perfect by instruction. The smaller physical stature of children limits their ability to see or be seen over certain heights, such as hedges and parked cars. Children's sensory facilities are also less well developed. Their ability to co-ordinate eyesight and hearing is limited, which can lead to their missing danger signals, thereby increasing their risk of road traffic injuries (14). According to Sandels, no child can be trained on its maturity and no adult can accelerate the maturation progress, and children cannot cope on their own in complex traffic environments until 11-12 years of age.

Except that children are under mental and cognitive development they are also physically vulnerable. A pioneering work on children's anatomical characteristics and how they differ from adults was published in 1969 (19). Child's head, chest, abdomen, and limbs are all during growth and make a child physically more exposed to the impact of injury than an adult.

- The child's head is relatively larger and the neck is weaker than in adults. Rapid relative movements between the head and the trunk can traumatise the neck structures. The infant's skull is softer, which increases the risk of brain injuries in young children.

- The organs of the chest in children are extremely vulnerable to non-penetrating impacts to the chest, as the child's thoracic cage, unlike that of adults, is elastic and highly compressible. The abdominal organs are also less well protected, due to the undeveloped pelvis, a higher rib cage and underdeveloped abdominal muscles.

- The growth of the long bones in children is a function of the activity of the epiphyseal cartilage zones. Abnormalities of body stature and limb mobility may result from injury to these zones.

A study that examined differences in injury patterns between children and adults who were multiply injured, mostly in road traffic accidents, found that fatalities resulted more often in children than in adults, following head, thoracic or abdominal injuries (20). Spinal cord injuries, especially to the cervical region, also carried a higher risk of mortality in children than in adults (20).

Due to these differences, children need extended protection, such as a booster cushion in cars to prevent the seatbelt passing across the pelvis, thereby causing abdominal injuries, and firm dorsal support to prevent great relative movements between the head and the trunk, likely to result in permanent neurological disability or death. It is also important to place the child's seat backwards in the car. This was recommended by the Swedish physician Bertil Aldman already in 1964 (21), and was shown to be effective by Aldman et al. in 1987 (22). Helmets have been used for head protection for many years, also in traffic contexts. However, mandatory use of bicycle helmets was introduced in Sweden as late as in 2005, but only for children (<16 years).

Socioeconomic and demographic factors

Socioeconomic factors may influence the injury risk in children, and differ between rich and poor countries as well as within countries (1). For most traffic injuries, mortality and morbidity rates are often higher among children with lower social status and from more deprived areas (23,24). Ownership of bicycle helmets has been shown to be lower among children from deprived areas compared with children from wealthier areas. However, helmet legislation seems to increase helmet use by all children and particularly by those in low-income areas (24). One study showed that a poor social environment was related to higher accident rates among children injured in Gothenburg during one year in the mid-1970s (25). Eleven per cent of the children were injured as cyclists, moped riders or car occupants. In a large study including school-age children living in Stockholm County in 1998, socioeconomic attributes did not affect the risk of injuries sustained by pedestrians and cyclists. However, a "protective effect" on injuries was noted for motor vehicle riders who lived in less wealthy areas, possibly because poor families did not own motor vehicles as often as rich families (26). Besides, the effect of socioeconomic differences on the risk of injury is not necessarily constant over time, according to an additional Swedish study (27). The absolute differences were highest among 15-19-year-olds and negligible in 0-4-year-olds.

Immigration has increased in Sweden during the last decades. Karimi et al. (28) found a significantly higher risk of fatal transportation-related injuries among male children with a non-Swedish background than among native Swedish children. Another study by the same authors (29) found a significantly higher risk of hospitalisation among children with the lowest parental education level compared with those with the highest parental education level, also after stratification by cause (transportation-related injuries, drowning, poisoning, fall, burns and fire).

Age and gender

Children's risk of traffic crashes increases with age, reflecting both increased exposure and differences in how children of different ages use the road and transport system. Boys are more likely to be involved in traffic crashes than girls, and their global fatal road traffic injuries rates are almost twice those of girls (13.8 vs. 7.5 per 100 000 per year) (2). In Sweden, the age and gender distributions for hospitalised children and children attending A&E departments are quite similar (Figure 2). During 2005-2009, 80% were over 10 years old, and 60% were boys (3).

Figure 2. Rates of children/100 000 hospitalised for traffic injuries in Sweden, average/year 2005-2009, by age and gender. Source: The National Patient Register, National Board of Health and Welfare (30).

Road user categories

Road use patterns among children vary by country (1). In 70 countries – mainly middle-income and high-income countries – that provide sufficiently detailed mortality data to the WHO, about 33% of all children killed in road traffic around the world are pedestrians, while 65% are car occupants or bicycle or motorcycle riders (1). Data on road traffic deaths among children 0-15 years by type of road user in selected OECD countries (n=19) show that Republic of Korea has the highest rate as pedestrians (80%), Turkey for car passengers (just over 70%), and Netherlands for cyclists (just over 50%). The proportion of road traffic deaths in

Sweden is 25% for pedestrians, about 55% for car passengers and just below 20% for cyclist (1).

Most road traffic casualties among hospitalised children in Sweden during 2005-2009 affected unprotected road users (Figure 3). Cyclists represented 41%, motorcycle or moped riders 28%, car occupants 16%, pedestrians 3% and other categories 12%. Most of the crashes, close to 50%, occurred on public roads and streets within and outside of urban areas. Ten percent occurred on walking/bicycle lanes and 40% in residential areas, sport fields or other areas (31).
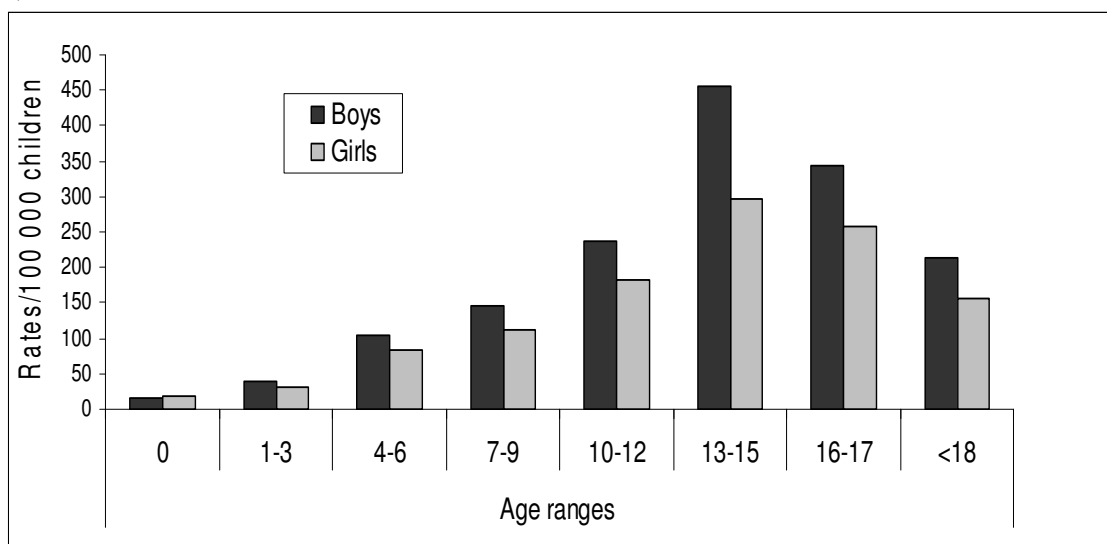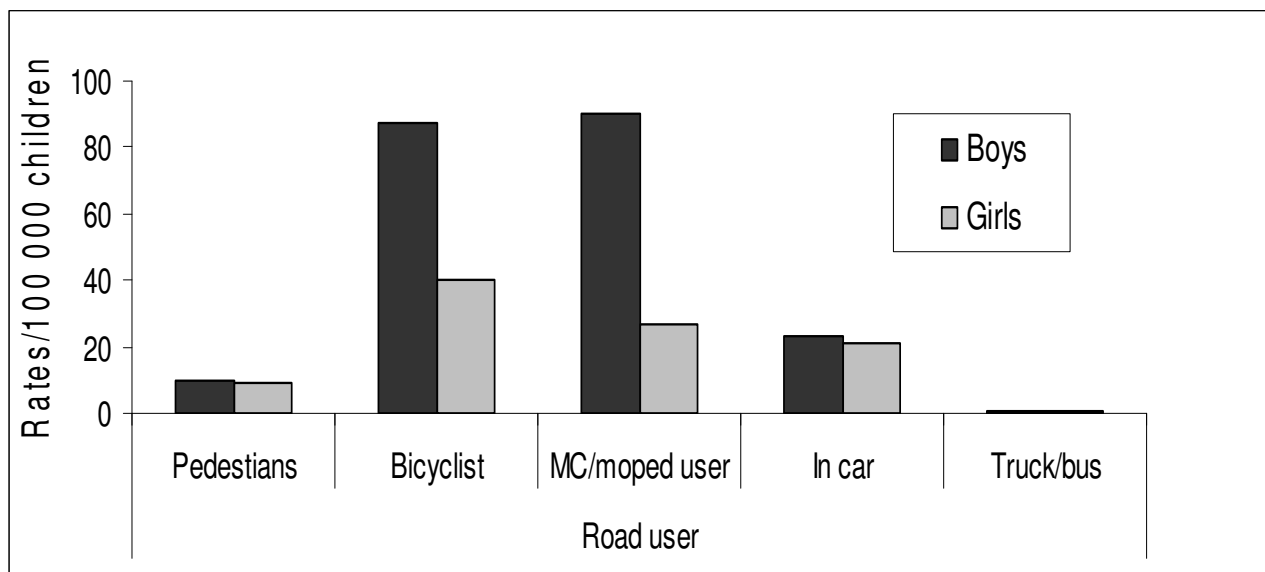

Figure 3. Rates of children/100,000 hospitalised for traffic injuries in Sweden, average/year 2005-2009, by road user and gender. Source: The National Patient Register, National Board of Health and Welfare (30).

Injuries

Head injuries predominate in all age groups in children injured in traffic accidents in Sweden, closely followed by upper extremity injuries in the age group 7-14 years, and lower extremity injuries in the oldest age group (Figure 4) (32). The severity of the injuries varies, depending on the age of the child, the type of road user and whether protective devices were used. Chest and abdominal injuries, although not as common as head and limb injuries, may be very serious because of the organs involved and the difficulty of managing such injuries. Globally, multiple traumas have been reported in approximately 10%-20% of children involved in road traffic accidents (1).

Figure 4. Number of children severely injured in road traffic crashes in Sweden (hospitalised for at least 24 hours), by injured body region and age group, 2011. Source: (32).
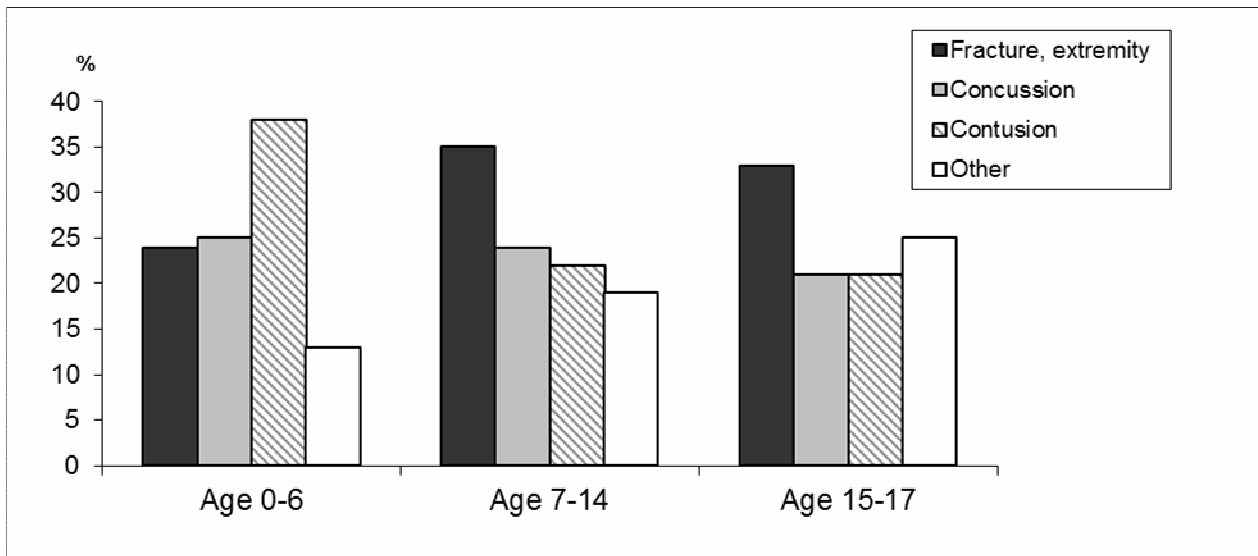
According to Transport Analysis (32) hospitalised children injured as pedestrians most commonly sustain injuries to the head and the lower extremities, with extremity fractures and concussion as the leading injury types. Cyclists most commonly sustain injuries to the head and the upper extremities, with concussion and extremity fractures as the leading injury types. Moped/MC users most often sustain injuries to the lower extremities and the head, with extremity fractures and concussion as the leading types of injury, and car occupants usually sustain injuries to the head and neck/trunk/pelvis, with concussion and contusion as the leading injury types (32).

Changes in injury patterns

Statistics from Transport Analysis (32) report changes in injury patterns in hospitalised children in Sweden during the last decade, with decreasing proportion of head injuries for all categories except pedestrians, and an increasing proportion of upper extremity injuries. Furthermore, the proportions of injuries to the neck, trunk and pelvis have increased in age group 0-6 years, mainly in cyclists and car occupants; in age group 7-14 years mainly in pedestrians and cyclists; and in the oldest age group, mainly in car occupants and moped/mc riders (32).

The most common type of injury in hospitalised children is fractures of the upper and lower extremities, except for in the youngest children where contusions dominate. The proportion of these types of injuries increased during 1998-2011 while the proportion of concussion decreased. The frequency of fractures of the neck, trunk, pelvis, and skull decreased, while the frequency of internal injuries increased during the period (32).

Posttraumatic stress

Along with the physical suffering and distress from the injury and subsequent medical interventions, paediatric injuries often lead to emotional and psychological consequences, for both the children and their parents. Traumatic events may cause high stress levels when an exposed individual is unable to cope with the stress reactions (33). These experiences induce overwhelming feelings of terror, horror or helplessness and may lead to reactions of various types and degrees.

Posttraumatic Stress Disorder (PTSD) and Posttraumatic Stress Disorder Symptoms (PTSS)

Unidentified and untreated acute stress responses in children may result in Posttraumatic Stress Disorder (PTSD) (34,35), the most common psychiatric disorder that develops after exposure to trauma. Exposure to unexpected extreme traumatic stressor or witnessing serious injuries or unexpected death of a beloved one may cause PTSD. PTSD is diagnosed when the reactions are severe, continues, and interfere with daily functioning. The main diagnostic criteria are re-experiencing, avoidance, and hyper arousal that continue for more than one month, causing significant distress and affecting the individual's ability to function socially, educationally and domestically (35). PTSD Symptoms (PTSS) may also cause distress or functional impairment in children, and should be suspected when a person fails not meet full diagnostic criteria but reports at least one symptom from each PTSD cluster as well as impairment associated with these symptoms (36). The lifetime prevalence of PTSD (all ages) varies among different populations from 0.3% in China to 6.1% in New Zealand and 6.8% in the general US population. PTSD may appear at any age but is more common in young adults due to greater exposure to stressful situations (37).

Symptoms of PTSD and PTSS in children

Because of development factors, children's symptoms of PTSD may differ from adults. Children's knowledge and language development affect the way in which they encode and understand their experience of the trauma and the development of emotion regulation, memory retrieval and cognitive inhibition affects how they resolve their traumatic experience (38). Therefore children may manifest their symptoms of trauma through (37-39):

- repeated and intrusive thoughts
- extreme distress when confronted by anything that reminds them of the event
- nightmares
- repetitive drawings or play that resembles the event
- behavioural problems
- separation anxiety
- anger and irritability
- difficulty paying attention and concentrating

- withdrawal
- somatic symptoms

There are recommendations that the fifth edition of the Diagnostic and Statistical manual of Mental disorders (DSMV-V) should ensure attention to age-related manifestations and selective modification of the diagnostic criteria for PTSD that incorporate prominent developmental properties (40).

As exposure to childhood trauma may result in a variety of negative consequences, it is not unusual for PTSD to co-exists with other mental disorders, like Attention Deficit Hyperactivity Disorder (ADHD) entailing a risk of an ADHD misdiagnosis when the diagnosis is PTSD (36,41). Depression, anxiety and substance use disorders may also co-exist with PTSD (36,37).

Over the last decade a growing number of studies have reported long-term psychological consequences after injuries (not only traffic injuries) in children such as PTSD, PTSS, psychological distress, travel anxiety, behaviour disturbances, depression, anxiety and sleeping disorders (39,42-67). Most of the injured children were studied in the US and the UK, but also in Australia, Switzerland, Norway, Austria, Netherlands, Germany, France and Belgium. A recent review concludes that the relatively high prevalence of PTSD following traffic injuries underscores the need for increased attention and active management to moderate the adverse consequences on the health and development of young crash survivors (68). They also discuss the lack of studies conducted in low-income and middle-income countries, settings that account for over 90% of the global burden of road traffic injuries.

In 1975, Thorsson reported the outcome of road traffic injuries in the Uppsala hospital region in Sweden five years after the accident (11). He found that 5% of the children suffered from psychological effects and 6% from social effects as a result of their injuries. This was a milestone study at the time. At least two percent of the children reported psychological problems two years after the accident in Karlsson et al. (10).

Health Related Quality of Life (HRQOL) in children

A paradigm shift has taken place in paediatrics as a result of advances in medical care. Mortality is not viewed as the only end point when considering the efficacy of medical interventions. Issues of Quality of Life (QOL) have become important, and Health Related QOL (HRQOL) assessments can facilitate improvements in clinical decision-making and estimation of the healthcare needs of a population. HRQOL is, briefly defined, according to Bowling (69), as optimum levels of mental, physical, role and social functioning, including relationships and perceptions of health, fitness, life satisfaction and well-being. It should also include an assessment

of the patient's level of satisfaction with the treatment, outcome and health status and with future prospects (69). Knowledge about the child's HRQOL provides insight into the child's evaluation of his or her physical and psychosocial health status. A recent study (70) found that children who had sustained road traffic injuries had a significantly worse HRQOL 12 month after the accident (70) than those injured in other types of accident (falls 31%, other types 4%), and children with head injuries had significantly worse HRQOL than those with other injuries.

Injuries in cyclists

The risk of being killed in road traffic as a cyclist is about six times that of car occupants and since 2008, cyclists comprise the largest group of severely injured road users in Sweden (32). The annual number of seriously injured (treated as inpatients) road users increased in Sweden in 2013 for the first time since 2008. Injured cyclists accounted for the increase (6%) from the previous year. Almost half of all seriously injured road users were cyclists, according to the Swedish Transport Agency. Children injured in road traffic accidents are most often cyclists, and they most commonly receive injuries to the head and upper extremities (3). In a study from Umeå (a municipality in northern Sweden), including 1 172 children below 13 years of age injured in road traffic accidents during 1999- 2008, cyclists accounted for 81% of the moderate or more severe injuries (261/884 = 29.5% of the cyclists), and car occupants for 4% (14/163 = 8.6% of the car occupants) (71).

Head injuries in cyclists

Although the incidence rate of traumatic brain injuries is low in Sweden, brain injury is a significant cause of permanent disability in children. Traumatic brain injuries accounts for two thirds of all post neonatal mortality (72). Negative effects of traumatic brain injuries may influence school results, leisure activities and thoughts about future life situation (73). A study of 2 333 children, aged 0-14 years, with bicycle-related injuries attending trauma centres in the US and Canada, found that those with a head injury were four times as likely as those with no head injury to be treated in intensive care units, and were almost twice as likely to develop complications (74). Head injuries were also associated with an increased risk of in- hospital fatality and high prevalence rates of communication and behaviour impairment at discharge. Children with pre-existing mental disorders (not further explained), who did not wear a helmet or who were injured on roads had a significantly increased likelihood of head injuries (74). Cyclists comprised the majority of trauma cases admitted to a paediatric intensive care unit in Gothenburg in 1990-2000, and the most commonly injured body region was the head (75).

According to statistics from Transport Analysis (32), the proportion of hospitalised children with head injuries sustained in a cycle crash declined between 1998 and 2011, mostly for children aged 15-17 and for children aged 7-14. Berg &

Westerling (76) analysed the trends of bicycle-related head injuries based on their main diagnosis and external cause of injury in the Swedish population 1987-1996. The results show a decrease in bicycle head injuries in hospitalised children (0-15 years old), probably related to the increasing helmet use during the study period, as there was no significant change in non-head injuries and the incidence of both head and other injuries increased in adults.

Bicycle helmets

In order to reduce the risk of head injuries helmet legislation was implemented in Sweden in January 2005 for children below 16 years of age. Despite this, only just fewer than 60% of children used a helmet in 2012 when cycling to and from school (77). Among all cyclists (children and adults) injured during 2012 in Sweden only 32% used a helmet (78).

Although many studies have shown that bicycle helmet use by children reduces the risk of head injuries (79-91), this has also been questioned (92-95). Reasons, such as the brain can be injured without impact to the head (94,95), helmets may not provide significant protection in collisions with other vehicles (92), car drivers taking less care when maneuvering around cyclists who wear a helmet, and helmeted cyclists taking more risks than non-helmeted cyclists, might explain why helmets fail to reduce effectively the overall level of head injuries and death (92,93). Bambach et al. (85) found that non-helmeted cyclists were more likely to display risky riding behaviour and more likely to sustain serious injuries to other body regions than the head. Pless et al. (96), however, reported no association between indicators of risk-taking behaviour and the use of protective equipment. Furthermore, the compulsory usage of bicycle helmets has been said to be detrimental to public health, as cycling decreased sharply after the legislation was implemented (97,98).

Upper extremity injuries in cyclists

The second most commonly injured body region in bicycle crashes are the upper extremities, and the proportion with upper extremity injury has increased in hospitalized children during 1998- 2011 (32). According to the study from Umeå, 37% of the cyclists sustained injuries to the upper extremities and 28% to the head (71). Another study in children with fractures seen at the same hospital found a 59% increase in the incidence of fractures over the period 1998-2007 (99). The most common fracture site was the distal forearm and this was also the most common fracture requiring admission to hospital. Bicycles accounted for 66% of the traffic related fractures (12% of all injury mechanisms). However, the study was unable to identify a single activity or mechanism of injury responsible for this increase in the incidence of fractures (99).

AIMS

The overall aim of the thesis was to investigate the causes and consequences of road traffic injuries in children from a physical and psychosocial perspective, and to identify unfavourable circumstances and children who are at risk of injury and disability.

Specific aims

Study I   To assess the prevalence of PTSD and PTSS among children injured in road traffic accidents and identify predictors of such posttraumatic stress.

Study II   To describe physical problems one year after a road traffic injury with respect to demographic and accident-related factors and the impact on daily living activities after the accident.

Study III   To describe psychological and psychosocial problems one year after a road traffic injury with respect to demographic and accident-related factors and the impact on daily living activities after the accident.

Study IV   To describe the protective effect of bicycle helmets and changes in injury patterns in children in cycle crashes during a period of increasing helmet use.

METHODS

The thesis is based on four studies. Study I was a systematic review of the literature, and the Studies II-IV were based on traffic injury data from a children's hospital (Queen Silva Children's Hospital, QSCH) in Gothenburg. Gothenburg is the second largest city in Sweden with a population of about 700 000 in the Gothenburg region (the city and neighboring municipalities). The Studies II-III were retrospective follow-up studies on children injured in traffic accidents in 2000. Study IV was a retrospective study on children injured as cyclists during 1993-2006. Accident and injury data in Studies II-IV were collected, controlled, and processed by the Traffic Injury Register, a hospital-based organisation, established at Sahlgrenska hospital in Gothenburg in 1978. The word "accident" and the word "crash" are used through out the thesis, even if "crash" would be a more appropriate word, lacking the coonotation of randomness. The Studies II-IV were approved by the Ethical Review Board, University of Gothenburg.

The Traffic Injury Register

Traffic casualties treated at the A&E departments are documented on a traffic injury form (Appendix), containing structured information on relevant accident data, such as personal ID, the date, time and site of the accident, the type of road user and counterpart, the type of accident, the type of traffic environment, the purpose of the transport, the use of protective equipment, and the influence of alcohol, if applicable. The form is routinely filled in by the patient, by relatives or by the staff at the A&E department. These data and the medical records are checked and processed by the staff of the Traffic Injury Register to determine the diagnosis and the severity of the injuries. Many follow-up studies, based on questionnaires, have been made by The Traffic Injury Register.

Injury severity

The severity of each injury is classified according to the Abbreviated Injury Scale, which is an international standard for the rating of injury severity (100). The AIS code includes a digit between 1 and 6, the AIS grade for each well-described injury, coarsely corresponding to the threat to life of the injury, defined on an ordinal scale as: 1=minor; 2=moderate; 3=serious; 4=severe; 5=critical; 6=maximum. Grades 4-6 are considered life-threatening injuries. The maximum AIS (MAIS) is the maximum injury grade of all injuries to the body. The Injury Severity Score (ISS) (not used in this thesis), which is based on the AIS scores, indicates the overall injury severity (101). The MAIS is also used to describe the overall injury severity. MAIS can also be defined for specific body regions.

Study I

A systematic literature review was made to investigate the prevalence of PTSD and PTSS in children injured in road traffic. A search was conducted, using the databases PubMed with and without the nursing filter, PsycINFO (Ovid), and Cochrane (Table 2). Reference lists of identified studies were scrutinised to find additional publications. Titles and abstracts were assessed and if they were likely to be relevant, the full manuscripts were obtained. Finally, papers fulfilling the selection criteria were reviewed. These papers had used validated instruments for PTSD and PTSS, assessed by means of structured interviews with children and adolescents attending an emergency department after a road traffic accident. The search initially recovered 670 citations. Twelve papers, assessing PTSD and PTSS in children below 19 years, were finally reviewed. PTSD data were obtained for 922 children in nine studies and PTSS data were obtained for 410 children in five studies.

Table 2. Electronic databases, search terms and search results for study I

Database	Search terms	No. of citations used	No. of articles used
PubMed	Traffic accidents AND Children	96	9
	Traffic injury AND children	126	4
	Paediatric traffic	41	0
	Injuries AND children AND vehicle	257	1
	Post-traumatic stress AND children AND injury	44	3
PubMed with nursing filter	Nursing AND traffic AND children AND posttraumatic stress	37	2
PsycINFO	Post-traumatic stress AND children AND injury	23	2
Cochrane Systematic reviews	Children AND traffic injury	25	0
	Children AND posttraumatic stress	10	0
	Posttraumatic stress AND traffic injury	1	0
	PTSD AND Traffic injury	1	0
	Children AND PTSD	5	0
	Children AND traffic injury	0	0
Cochrane Clinical Trials	Children AND PTSD	4	0

Study II and III

Study II and III used a retrospective, cross-sectional, observational design and investigated residual physical (Study II) and psychological/psychosocial problems (Study III) in a sample of children injured in traffic accidents in 2000. Data from a study questionnaire (Appendix) were linked to the original accident data obtained from The Traffic Injury Register through the personal ID and the date and time of the accident. The MAIS was used as a descriptor of the overall injury severity. The maximum AIS was also calculated for each of the following regions: skull/brain, face, neck (including the cervical spine), upper extremity (including the shoulder),

upper trunk (including the thoracic spine), lower trunk (including the lumbar spine and external genitals), and lower extremity (including the pelvis).

The study questionnaire

The study questionnaire was sent by post at least one year after the accident. The parents and/or the child were asked to describe any residual problems. Two reminder letters were sent within a month, and after another two weeks, attempts were made to telephone non-responders. Some parents agreed to a telephone interview rather than to completing the questionnaire. The same type of questionnaire has been used in several follow-up studies on children and adults since the 1980s, with some modifications related to the type of accident and the injuries. The questionnaire used in the present study was designed in the same way and supplemented with items recommended by the Nordic Association for the Needs of Sick Children (NOBAB). The questionnaire included 14 main questions on residual physical, psychological and psychosocial problems, social factors, and extraction (Swedish or foreign; of foreign extraction means that at least one of the parents was born outside of Sweden). For Study II, the respondent was asked to mark the localization of the residual physical problems on a diagram of the body. The problems were further described in words by the respondents and categorised independently by the authors for pain, stiffness, discomfort, functional loss, and cosmetic complaints. For study III, the questionnaire included the following primary question to be answered with yes or no: "Does your child still have psychological or psychosocial problems because of the accident?" If the answer was yes, the following questions were: "Does your child feel angry, frightened or worried in general, frightened or worried in situations similar to the accident, tired, have a headache, have pain in another part of the body not due to the injuries, find it difficult to go to sleep or have nightmares, often think about the accident, have some other problem?". In the original study (Study III), psychological or psychosocial problems were termed psychological problems. The questionnaire also included questions on whether the injury influenced activities such as school work, sports and other activities, whether it hampered the parent's work, and whether there was a need for service to transport the child to and from school.

Subjects in Study II and Study III

A total of 633 children, aged 0-15 years, were registered during 2000. Altogether, 213 cases were excluded; the vast majority because they were injured in places not intended for public road traffic and a few had no diagnosed injury (Table 3). As these studies focused on traffic injuries, not on injuries sustained when playing outdoors in environments without traffic, these cases were excluded. Follow-up questionnaires were sent to the remaining 420 cases and of these, 79 declined to participate. The remaining 341 cases (81%) constituted the study group in Study II. The questionnaire was answered by a parent alone in 292 cases, and they

constituted the study group in Study III. The mean follow-up time was 15 months (SD 1.4, range 12-20).

Table 3. Recruitment of the study groups in Study II and Study III.

Children and adolescents involved in transport accidents	Number
Total number registered at QSCH[*] year 2000	**633**
Excluded (not in traffic environment)	191
Excluded (no diagnosed injury)	22
Remaining group invited to study	**420**
Declined participation	79
Returned questionnaire = Study group in Study II	**341**
Questionnaire not answered by parent only or respondent unknown	49
Answered by parent only = Study group in Study III	**292**

[*] Queen Silvia Children's Hospital

The most commonly injured body parts were the head and the extremities. Children with skull/brain injuries were treated as inpatients three times as often as those without such injuries. Moderate or more severe injuries (MAIS2+) were noted in 36% of the cases in Study II and in 37 % in Study III.

Bicycle helmets were used by slightly over 60% of the study groups. Boys and teenagers injured as cyclists used bicycle helmets to a lesser extent than girls and younger children. Cyclists and moped riders of foreign extraction used helmets to a much lesser extent than children with Swedish extraction. The proportion of MAIS2+ and MAIS3+ head injuries did not differ between cyclists of Swedish extraction and those of foreign extraction.

The study group in study II included fewer pedestrians, 7% vs. 14% among the 79 non-responders. No differences were noted between the study group in Study III and the 128 cases that were not included in the study group.

Study IV

Study IV was a retrospective observation study on cyclists injured during 1993-2006. Helmet use was investigated for the injured children with respect to age and gender. The maximum injury severity in the head (skull/brain and face) was analysed with respect to demographic and accident-related factors and the use of helmets. Changes in the distribution of injuries in the same body regions as in study II and III during the whole period were analysed with no regard to helmet use. The ratio between the number of subjects with head injuries and the number of subjects with extremity injuries was used to estimate the protective effect of helmet at a population level.

We consider the internal validity of this study to be good, as helmet use was assessed at the time of the crash. Furthermore, all injuries were classified in a

standardized way on the basis of medical records. The same well-trained staff members were responsible for both recording and injury classification, and the same AIS system was used during the whole period 1993-2006.

Subjects in Study IV

A total of 4 318 injured cyclists, 0-15 years old, were registered. Two subgroups were used for the analyses: the first comprised 4 246 children with diagnosed injuries and this was used for analyses of injury changes during the period (with no regard to helmet use). The second subgroup comprised 3 711 children with diagnosed injuries; and 2 146 (58%) of them wore a helmet at the time of the crash and 1 565 did not. The second subgroup was used for analyses of the protective effect of helmets.

Boys constituted 64% of the study groups. Single accidents dominated (86%), followed by crashes with another cyclist (7%) and with a car (5%). Most of the children sustained injuries to the extremities and the head and 22% were treated as inpatients. Moderate or more severe injuries (MAIS2+) were noted in 36% of the children. Children excluded from the first subgroup (children without diagnosed injuries n=72) were significant older and significant more often injured in crashes with a counterpart. The children excluded from the second subgroup (with known injuries, where helmet use was not known n=535) had significant fewer AIS2+ skull/brain injuries and AIS1+ facial injuries. No difference was found regarding AIS3+ skull/brain injuries or AIS2+ facial injuries.

STATISTICAL METHODS

Age distributions and MAIS scores were analysed using the Mann-Whitney U-test. Differences between groups were analysed with the Chi square test for categorical variables or, when necessary, with Fisher's exact test. Logistic regressions were performed to explore the effects and size of a single exposure on the outcome. Multivariate logistic regressions were performed to explore the effects of more than one variable. Stratified analyses were carried out to examine further the outcome of specific subgroups. If not otherwise specified, injury outcomes were described as odds ratios; i.e. the odds of sustaining at least one injury of a specified severity to a specified body region divided by the odds of sustaining no injury at all to the region (including the 95% confidence intervals). Comparisons were made between excluded cases and the study groups. In study IV the ratio of the number of subjects with head injuries and the number of subjects with extremity injuries of any severity and of at least moderate severity was used to estimate the protective effect of helmets at population level. All tests were two-sided, and statistical significance was determined where p values were less than 0.05.

RESULTS

PTSD and PTSS in children as described in the literature (Study I)

One third of children injured in traffic accidents fulfilled the diagnostic criteria of PTSD/PTSS after one month, about half of that group after 3–6 months (Table 4).

Table 4. Summarised data on PTSD/PTSS at specific time points in 12 studies. Some studies assessed both PTSD and PTSS.

Disorder	Number of studies	Assessment time	Number assessed	% with disorder
PTSS	2	<4 weeks	122	29
	2	4-7 weeks	111	22
	2	3-6 months	209	13
	1	12 months	68	18
PTSD	4	1-2 months	539	27
	6	3-6 months	676	13
	1	2-18 months	50	14

There were significant methodological variations. Numbers assessed, age ranges, gender distributions, accident types, injury severity, type of admission, inclusion and exclusion criteria, diagnostic instruments, and post-accident times of assessment varied. Some studies had a low participation rate. In the PTSD outcome group, three studies of nine had a participation rate of over 60%. In the PTSS group, three of five studies had a participation rate of over 60%. The reasons why so many refused to take part were rarely presented but in some cases, "the child was still too distressed" (56,61), "did not want to talk about it", or "wanted to forget about it" (55,56).

Children not assessed

Children younger than five years and children with learning disabilities and inability to speak the language were not assessed. Five studies excluded children with severe head injuries.

Predictors of PTSD and PTSS

Risk factors for the development of PTSS/PTSD in multiple studies were:
- Perceived threat of the accident and high levels of distress during and immediately after the accident
- Female gender
- Anxiety and depression symptoms

Factors predictive of PTSD/PTSS in single studies were:
- Increased parental vigilance following the accident as reported by the children
- Child's PTSS and severity of fathers PTSD at 4–6 weeks, which contributed to the prediction of child PTSS at 12 months
- Involvement in car accidents

Residual physical problems after a road traffic injury in the Gothenburg region (Study II)

Table 5 shows the occurrence of residual physical problems by demographic and accident related factors. Of the 341 children, 53 (16%) reported residual physical problems, most often moped riders and car occupants, and less often cyclists, although cyclists (and moped riders) had the highest proportion of serious (AIS3+) injuries. Children ten years of age or older reported residual physical problems more than twice as often as younger children (Table 5). The MAIS did not influence the occurrence of residual physical problems.

Table 5. Occurrence of residual physical problems by demographic and accident related factors, n=341.

Factor	Spec	n	With residual physical problems %	OR	OR 95% CI		p value
					Lower	Upper	
Age	<10y	129	8.5	2.650	1.311	5.359	.005
	>=10y	212	19.8				
Gender	Boy	207	13.5	1.466	.813	2.644	.222
	Girl	134	18.7				
Foreign extraction[a]	No	283	14.1	1.880	.928	3.810	.103
	Yes	55	23.6				
Care	Outpatient	251	13.9	1.543	.823	2.891	.178
	Inpatient	90	20.0				
MAIS[b]	1	216	15.9	.827	.307	2.229	.815
	2+	123	13.5				
Pedestrian	No	317	15.5	1.094	.358	3.339	.776
	Yes	24	16.7				
Cyclist	No	138	23.2	.382	.210	.697	.002
	Yes	203	10.3				
Moped/mc rider	No	274	12.4	2.794	1.471	5.306	.002
	Yes	67	28.4				
Car occupant	No	296	14.9	1.432	.645	3.179	.379
	Yes	45	20.0				
Single accident[c]	No	128	18.8	.698	.386	1.262	.281
	Yes	209	13.9				
Against a motor vehicle	No	249	13.7	1.741	.933	3.248	.089
	Yes	88	21.6				

[a] Extraction unknown in 3 cases; [b] MAIS unknown in 2 cases; [c] Counterpart unknown in 4 cases.

The residual problems were located to the lower extremities in 31%, upper extremities in 20%, face in 14%, neck in 14%, upper trunk (including the thoracic spine) in 8%, lower trunk (including the lumbar spine) in 8%, and skull/brain in 3%. Knee problems dominated in the lower extremities. Neck problems were reported by 13 children, but eight of them had no diagnosed neck injury. Eight children with neck problems had been injured as car occupants, three of them without a diagnosed neck injury. Injuries to the neck and the upper trunk (including the thoracic spine) caused more residual physical problems then would be expected from the injury rate in these regions (Figure 5).
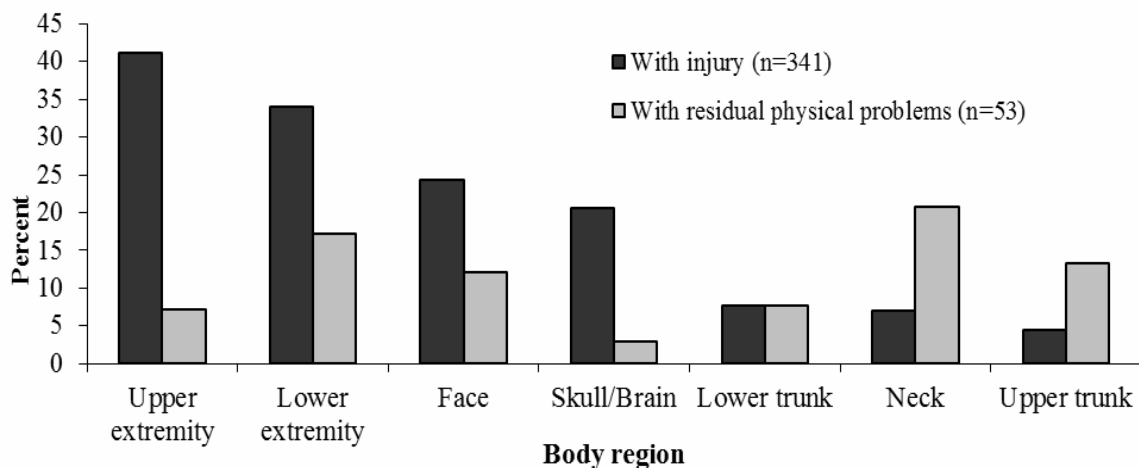

Figure 5. Proportions of children with injuries to the different body regions and the proportions of children with residual physical problems in the same regions.

Of the 341 children, 53 (16%) reported 91 different residual physical problems (Table 6). One moped driver, injured in a collision with a car, had serious problems with significant permanent impairment.

Table 6. Number and proportion of 53 children with 84* different types of 91 residual physical problems by road-user category.

	Total	Pain		Stiffness		Discomfort		Functional loss		Cosmetic	
		n	%	n	%	n	%	n	%	n	%
Pedestrian	24	2	8	-	-	-	-	1	4	2	8
Cyclist	203	15	7	2	1	-	-	11	5	5	2
On moped/mc	67	14	21	2	3	4	6	8	12	4	6
In car	45	9	20	3	7	1	2	1	2	-	-
Other	2	-	-	-	-	-	-	-	-	-	-
Total	341	40	12	7	2	5	1	21	6	11	3

*Seven children reported the same type of problem in more than one body region, but the problem is counted only once in the table.

Factors associated with residual physical problems

In logistic regression models with age and injured body regions as the independent factors, age and neck injury were the only factors that were associated with residual physical problems. Logistic regression analyses were also carried out for each category of road users by age, gender, type of care, MAIS, and extraction. Age was the only significant factor associated with residual physical problems, and only for cyclists.

Helmet use by cyclists and moped users, and seat belt use by car occupants, were not related to residual physical problems in logistic regressions adjusted for age and gender.

Limitations in daily activities

Children with residual physical problems reported limitations in daily living activities more often than those without residual problems (Table 7). Temporary or residual school problems were reported for 14.5% of the children, and a need to interrupt sports or other leisure activities was reported for 4.8%. Only one child, a moped rider, had serious residual problems after a collision with a car, with a considerable restricting effect on daily activities.

Table 7. Impact on daily living activities in children with (n=53) and without (n=288) residual physical problems. The number of respondents who answered each question varied.

	Residual physical problems				P(Chi2)
Impact on daily living	No		Yes		
	n	*%*	n	*%*	
School problems, at least temporary	30	*11*	19	*36*	<0.001
School problems, still	0	*0*	4	*8*	<0.001
Ended sport or other activity	5	*2*	11	*23*	<0.001
Parents care days for sick children >7 days	5	*6*	9	*38*	<0.001
Transportation service to school	5	*2*	4	*8*	.015

Residual psychological and psychosocial problems after a road traffic injury in the Gothenburg region (Study III)

Residual psychological or psychosocial problems were reported for 64 (22%) of the 292 children included in Study III (Table 8), more frequently for children with residual physical problems, of foreign extraction, treated as an inpatient, injured as a pedestrian, where the counterpart had been a motor vehicle, and after a skull/brain or face injury. Residual psychological or psychosocial problems were less frequently seen in children injured as cyclists and after injuries to the upper extremities.

Table 8. Occurrence of residual psychological and psychosocial problems by demographic and crash related factors, n=292.

Factor	Spec	With residual psychological problems		OR 95%CI			p-value
		n	%	OR	Lower	Upper	p value
Residual physical problems	No	249	15,3	8,492	4,208	17,138	,000
	Yes	43	60,5				
Age	<10y	109	16,5	1,697	0,926	3,111	,107
	≥10y	183	25,1				
Gender	Boy	174	19,5	1,404	0,803	2,454	,251
	Girl	118	25,4				
Foreign extraction[a]	No	246	18,3	3,395	1,722	6,690	0,001
	Yes	44	43,2				
Care	Outp.	212	17,9	2,205	1,228	3,957	,011
	Inp.	80	32,5				
MAIS[b]	1	181	21,0	1,179	0,668	2,079	,563
	2+	109	23,9				
Pedestrian	No	270	18,5	7,700	3,064	19,347	,000
	Yes	22	63,6				
Cyclist	No	118	33,1	,340	,192	,602	,000
	Yes	174	14,4				
Moped/mc user	No	233	21,0	1,280	0,658	2,490	,483
	Yes	59	25,4				
Car occupant	No	257	21,4	1,271	0,563	2,871	,522
	Yes	35	25,7				
Singel accident[c]	No	105	31,4	,428	,242	,755	,005
	Yes	183	16,4				
Against motor vehicle[d]	No	216	16,2	3,291	1,813	5,974	,000
	Yes	72	38,9				
Skull Brain injury	No	234	18,8	2,273	1,207	4,280	,013
	Yes	58	34,5				
Face injury	No	221	19,0	1,914	1,045	3,504	,047
	Yes	71	31,0				
Neck injury	No	272	21,3	1,581	0,582	4,296	,401
	Yes	20	30,0				
Upper extremity injury	No	167	26,3	,532	,295	,960	,045
	Yes	125	16,0				
Upper trunk injury	No	280	21,8	1,197	0,314	4,557	,729
	Yes	12	25,0				
Lower trunk injury	No	270	22,6	,541	,155	1,889	,429
	Yes	22	13,6				
Lower extremity injury	No	192	19,3	1,549	0,877	2,736	,138
	Yes	100	27,0				

[a] Psychological and psychosocial problems, [b] unknown in two cases, [c] unknown in two cases, [d] unknown in four cases, [e] unknown in four cases.

Factors associated with residual psychological and psychosocial problems

In multivariate logistic regression models with significant factors in Table 8 as the independent variables, residual physical problems, foreign extraction, treated as an inpatient, counterpart being a motor vehicle and injured as pedestrian were all associated with residual psychological problems. If children with residual physical problems were excluded (n=43), head injuries (skull/brain and face separately)

were also associated with residual psychological and psychosocial problems. Being of foreign extraction increased the odds of residual psychological and psychosocial problems by 3.4, although these children did not have more severe injuries than the other children.

Types of problem

"Feeling frightened or worried in situations similar to the accident", "often think about the accident", "other problem" and "headache" were the most commonly reported problems. "Feeling frightened or worried in situations similar to the accident", "often thinking about the accident", "headache", "feeling tired" and "feeling angry" were reported more often for children of foreign extraction.

Children with residual psychological problems reported transient or continued restrictions to their daily life and activities after the accident more often than those without residual psychological problems.

The use and protective effect of helmet (Study IV)

Helmet use in the study group (n=3 711) increased from about 40% to about 80% during the period 1993–2006, almost equally for boys and girls. Helmets were used by over 60% of children below 11 years of age but significantly less often by older children, especially girls. Table 9 shows demographic and crash characteristics for injured cyclists with respect to helmet use (n=3 711).

Table 9. Demographic and crash characteristics in injured cyclists by helmet use, n=3 711.

	No helmet		Helmet		
Factor	n	*Row %*	n	*Row %*	p value
Gender					
Male	1040	*44.0*	1326	*56.0*	0.004[1]
Female	525	*39.0*	820	*61.0*	
Age, male					
0-3 y	21	*33.3*	42	*66.7*	
4-6 y	133	*25.4*	390	*74.6*	<0.001
7-9 y	150	*31.1*	332	*68.9*	df=4
10-12 y	284	*43.3*	372	*56.7*	Chi2=290
13-15 y	452	*70.4*	190	*29.6*	
Age, female					
0-3 y	16	*38.1*	26	*61.9*	
4-6 y	102	*26.0*	291	*74.0*	<0.001
7-9 y	86	*27.6*	226	*72.4*	df=4
10-12 y	145	*38.6*	231	*61.4*	Chi2=196
13-15 y	176	*79.3*	46	*20.7*	
Role					
Rider	1438	*40.6*	2103	*59.4*	<0.001[1]
Passenger	127	*74.7*	43	*25.3*	
Type of crash					
Single	1311	*41.2*	1873	*58.8*	
Against cyclist	115	*43.2*	151	*56.8*	
Against car	94	*54.7*	78	*45.3*	0.005 df=4
Other	41	*50.6*	40	*49.4*	Chi2=15
Unknown	4	*50.0*	4	*50.0*	
Type of crash place					
Bicycle- or walking lane	350	*36.5*	608	*63.5*	
Road	607	*46.1*	711	*53.9*	<0.001
Yard/private	301	*40.6*	441	*59.4*	df=4 Chi2=
Other	162	*39.1*	252	*60.9*	34
Unknown	145	*52*	134	*48.0*	
Type of activity					
Leisure time	1348	*42.2*	1847	*57.8*	
To/In/From school	173	*43.3*	227	*56.8*	0.8 df=3
Other	9	*40.9*	13	*59.1*	Chi2=1.1
Unknown	35	*37.2*	59	*62.8*	
Crash setting					
In Gothenburg	1111	*45.1*	1351	*54.9*	<0.001
Outside Gothenburg	419	*35.8*	751	*64.2*	df=2
Unknown	35	*44.3*	44	*55.7*	chi2=28.4
Period					
1993-1999	990	*48.3*	1061	*51.7*	<0.001[1]
2000-2006	575	*34.6*	1085	*65.4*	
Care					
Outpatient	1179	*40.7*	1715	*59.3*	0.001[1]
Inpatient	386	*47.2*	431	*52.8*	

Skull/brain injuries of all severities and non-minor facial injuries (AIS2+) were significantly less frequently noted in helmeted cyclists in univariate analyses. The protective effect of a helmet against non-minor skull/brain and facial injuries remained significant in multivariate binary logistic regression models. The adjusted odds of serious or more severe skull/brain injuries (AIS3+) and non-minor facial injuries (AIS2+) with a helmet were about one fourth of the odds without a helmet (Table 10). Age was a protective factor against facial injuries, lowering the odds by14% by year, on average.

Moreover, according to this model, the latter half of the period and collision with a motor vehicle were significant risk factors for severe skull/brain injuries. Crashing on a bicycle or a walking lane was a risk factor for facial injuries, if the injury severity was not considered.

Table 10. Factors in logistic regression models for skull/brain and facial injuries 1993-2006, n=3 711.

| | Skull/brain injury | | Facial injury | |
| | AIS2+ (n=326) | AIS3+ (n=22) | AIS1+ (n=1 113) | AIS2+ (n=21) |
Factors	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Used helmet[a]	0.45 (0.35-0.58)*	0.26 (0.10-0.69)*	0.75 (0.63-0.88)*	0.23 (0.09-0.63)*
Female gender[b]	1.08 (0.85-1.38)	1.98 (0.84-4.67)	1.01 (0.87-1.18)	1.01 (0.41-2.49)
Age, per year[c]	0.97 (0.93-1.00)	1.01 (0.88-1.16)	0.86 (0.84-0.88)*	0.86 (0.76-0.98)*
Latter half of the period[d]	1.04 (0.82-1.33)	3.82 (1.44-10.11)*	0.99 (0.85-1.16)	0.86 (0.33-2.21)
In Gothenburg[e]	0.85 (0.66-1.09)	0.56 (0.24-1.34)	1.14 (0.97-1.34)	1.71 (0.56-5.19)
Against motor vehicle[f]	1.50 (0.97-2.32)	4.76 (1.74-13.03)*	1.11 (0.81-1.53)	0.89 (0.12-6.87)
Bicycle/walking lane[g]	1.06 (0.81-1.38)	0.60 (0.20-1.83)	1.27 (1.07-1.50)*	1.32 (0.50-3.50)

* p<0.005. Reference values: [a] not wearing helmet, [b] male gender, [c] any age 0-15, [d] first half of the period, [e] not in Gothenburg, [f] not against motor vehicle, [g] not on a bicycle/walking lane.

The occurrence of AIS2+ skull/brain injuries in collisions with a motor vehicle (n=191) was lower in helmeted (10/89=11.2%) than in non-helmeted cyclists (18/102=17.6%), but the difference was not statistically significant. In a separate analysis for the latter half of the period (n=1 277) using the same model, collision with a motor vehicle remained a significant risk factor and the helmet a significant protective factor with regard to serious or more severe (AIS3+) skull/brain injuries.

Changes in injury patterns during 1993-2006 (Study IV)

The children most frequently sustained injuries to the head (skull/brain or face) and the extremities (Figure 6), with the most severe injuries (AIS4+) to the brain (10 children) and the lower trunk (5 children). The proportion with skull/brain injuries of any severity (varying between 14% and 22%) did not change significantly over the period. The proportion with more severe skull/brain injuries changed; however, in different ways (AIS2+ decreased and AIS3+ increased). The proportion with upper extremity injuries of any severity increased from 44% to 58% and the proportion with facial injuries of any severity decreased from 34% to 23%. The proportion with serious injuries to the upper extremities increased significantly during the period 1993-2006 for all age groups except for children below four years of age. No significant changes were noted for specific age groups for the other body regions.
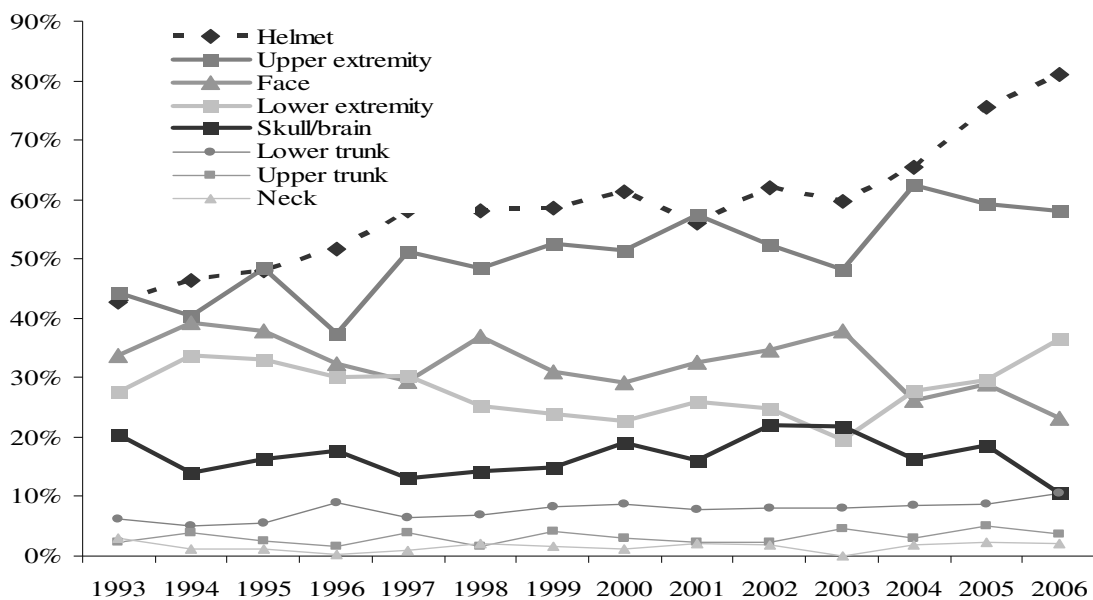

Figure 6. Helmet use in children injured as cyclists and injury patterns 1993-2006. The dashed line shows the proportion of 3 711 injured children with a helmet and the other lines the proportion of 4 246 children with at least one injury of any severity to the specified body region.

The ratio between the number of children with head (skull/brain or face) injuries and the number of children with extremity injuries (upper or lower) declined during the period (1993-2006) for injuries of any severity and for moderate or more severe injuries (Figure 7).
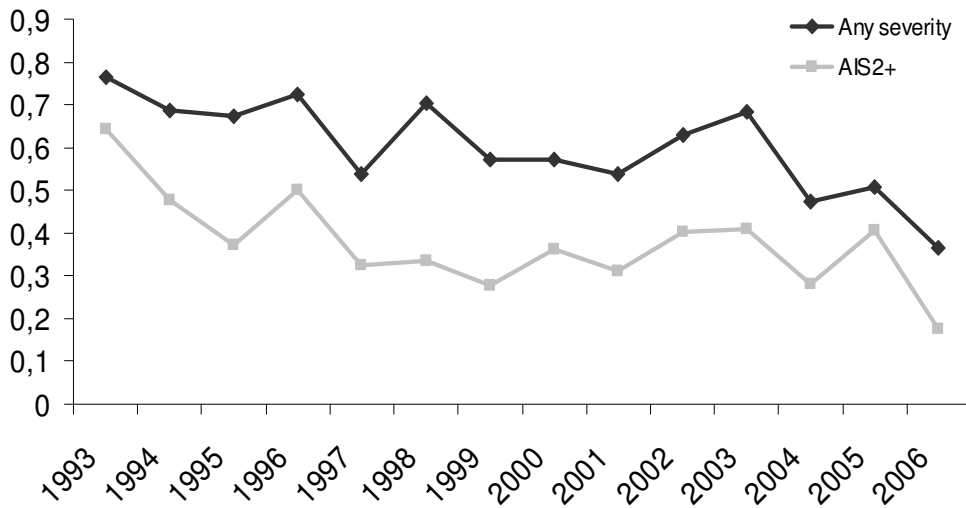
Figure 7. The ratio between the number of children injured as cyclists with head injuries and the number with extremity injuries during 1993-2006 in 4 246 children. The two lines represent injuries of any severity and at least moderate severity (AIS2+).

DISCUSSION

This thesis has shown that a non-negligible proportion of children injured in traffic crashes suffer from psychological, psychosocial and physical consequences. In addition, it was possible to identify unfavourable circumstances and children who are at risk of injury and disability.

The main findings to be discussed are:

- According to the literature, one third of children injured in traffic accidents fulfilled the diagnostic criteria of PTSD/PTSS after one month and about half of that group after three to six months.

- Of the children injured in traffic accidents in the Gothenburg region, one fifth had residual psychological or psychosocial problems and one sixth had physical problems one year later.

- Children of foreign extraction in the Gothenburg cohort were more often reported to have psychological problems after traffic injuries than other children.

- The use of bicycle helmets by children injured in traffic accidents has increased considerably in Sweden during the last decades, but it is far from 100%, despite mandatory use. Injured teenagers used bicycle helmets to a much lesser extent than younger children, especially girls.

- The protective effect of a bicycle helmet is obvious and considerable, not only against skull and brain injuries, but also facial injuries. Nevertheless, the occurrence of such injuries has not decreased as much as would be expected from the increased helmet use.

- The injury patterns have changed in children injured as cyclists, and upper extremity injuries have become more common.

Posttraumatic stress in children injured in traffic accidents (Study I)

All studies in the review assessed PTSD/PTSS directly in the children and, in some cases, in younger children, with assistance from their parents. Thirteen percent of children injured in traffic crashes fulfilled diagnostic criteria of PTSD after 3-6 months. An equal number were diagnosed with PTSS. Only two studies assessed

PTSD and PTSS after one year or more with occurrences of 14% and 18%, respectively. The variations in the methodologies used and the widely varying sample sizes make the mean prevalence questionable. However, a recent review (102), evaluating 21 studies designed to estimate the prevalence of PTSD among children and adolescents who survived a road crash, reported the occurrence of PTSD to be between 12% and 46% during the first four months and between 13% and 25% four to 12 months after the crash. Some investigations in Study I had a low participation rate, and the prevalence of PTSD/PTSS may be underestimated, as the reasons for declining was that the child was still too distressed (56,61), did not want to talk about it, or wanted to forget about it (55,56).

Risk factors
A perceived threat to life, high levels of distress during and immediately after the accident, especially in girls, and anxiety and depression symptoms are important risk factors and any child will be at risk, not just those with severe injuries. These risk factors are also reported from three other reviews (102-104) together with pre-trauma psychopathology, post-trauma parental distress, beliefs regarding initial symptoms (beliefs of being isolated, misunderstood, going crazy) and active thought suppression.

Other psychiatric disorders
Traffic injuries are also a leading cause of trauma-related psychiatric illness in older teenagers and adults (105-107). Bryant et al. (107), determined the range of new psychiatric disorders (besides PTSD) occurring after traumatic injuries in patients aged 16-70. Twelve months after the injury, 22% of 817 patients developed a psychiatric disorder that they had never experienced before. The most common disorders were depression, generalised anxiety disorder, and PTSD. Functional impairment was associated with these psychiatric illnesses and the authors concluded that identification and treatment of a range of psychiatric disorders are important for optimum adaptation after a traumatic injury.

Furthermore, Zatzick et al. (108) noted that high levels of PTSD and depressive symptoms in randomly sampled adolescent injury survivors (physical assault, motor vehicle crashes, work-related accidents) were associated with a broad profile of functional impairment during the year after hospitalisation.

Due to a recent publication from The National Board of Health and Welfare in Sweden (109), the proportion of young people cared for anxiety, depression, and substance abuse is steadily increasing. Any explanation for this rise is not given, but it is not unlikely that some kind of unidentified traumatic event such as a traffic crash may be in the history. Depression, anxiety and substance use disorders can co-exist with PTSD, as well as ADHD (36,37,41).

HRQOL

Issues of quality of life (69) have become important and knowledge about the child's health related quality of life (HRQOL) provides insight into the child's evaluation of his or her physical and psychosocial health status. Landolt et al. (64) provide evidence for a long-term negative influence of early PTSS on HRQOL in injured children.

Psychological and psychosocial problems after traffic injuries (Study III)

Residual psychological and psychosocial problems were reported in Study III for 22% of the children. This perception about the child's residual problems was related to residual physical problems, foreign extraction, inpatient care, collision with a motor vehicle, and being injured as a pedestrian. The severity of the injuries and their localisation were not related to residual psychological and psychosocial problems, except for head injuries.

Most of the symptomatic children felt frightened or worried in situations similar to the accident, often thought of the accident, found it difficult to go to sleep, or had nightmares. This may indicate posttraumatic stress symptoms, but this is uncertain as specific protocols for posttraumatic stress were not used.

Factors related to residual psychological and psychosocial problems

Injured in a collision with a motor vehicle

Injured in a collision with a motor vehicle and injured as a pedestrian were related to residual psychological and psychosocial problems in Study III. According to Study I, perceived threat of the accident and high levels of distress during and immediately after the accident are risk factors for PTSD/PTSS. A collision against a motor vehicle or being hit by a motor vehicle as a pedestrian may be more life-threatening than other types of accidents and may induce feelings of horror or helplessness with high stress levels as has also been reported by others. Sturms et al. (58) found increased levels of posttraumatic stress symptoms at follow-up in children injured in accidents with motor vehicles. De Vries et al. (47) compared accidents involving a motor vehicle with accidents without a motor vehicle, and found that the involvement of a motor vehicle was strongly associated with a higher PTSD score. Gofin et al. (110) investigated the outcome of injuries in 792 children injured in Israel who were injured in transport accidents and as a result of falls. A significant relationship with stress symptoms was only seen for being injured as a pedestrian or while riding two-wheeled vehicles.

Foreign extraction

Foreign extraction was significantly related to residual psychological and psychosocial problems in Study III. To some extent, this may be due to language

difficulties and misunderstandings. The possible influence of illiteracy and cultural differences was not evaluated. In Sweden, psychological illness is more frequent among people of foreign origin than among other residents (111). Refugees and their relatives have dominated immigration to Sweden since the 1970s, and many people fleeing from their native countries have been exposed to considerable stress. The flight may also have involved hardship and threats. After their arrival in the new country, a period of uncertainty awaits. Social conditions also differ depending on origin (111). Sturms et al. (58) examined HRQOL following a paediatric traffic injury and child and parental posttraumatic stress. They observed that parental stress was related to low socioeconomic status. Parental stress may also influence the children's stress, as was found in at least two studies (47,60). The higher level of distress reported for children of foreign extraction in Study III should be noted, as because an accident may evoke earlier stress reactions. Traffic crash es with appalling noise, bloodshed, fire or smoke odour and sirens may arouse memories of previously experienced civil unrest, war or other violent incidents. Due to three reviews on posttraumatic stress (102-104), pre trauma psychopathology was a risk factor for posttraumatic stress after injuries in children. Foreign extraction may indicate psychosocial conditions that need to bee considered.

Children treated as inpatients
Children treated as inpatients reported residual psychological and psychosocial problems more often than children treated as outpatients**.** It is possible that the medical treatment itself and other circumstances associated with hospital care constitute risk factors. Children undergoing hospital care after an injury have to cope with an unfamiliar environment, and being separated from home, relatives, and friends. They may have to undergo painful medical treatments, observe worry and anxiety among their relatives and friends and cope with lingering memories of the accident, sometimes for several days. A wide variety of stress-related symptoms may become apparent during the time the child is trying to cope with injuries that require hospital care (112).

Skull/brain injuries
Having sustained a skull/brain injury was significantly related to residual psychological and psychosocial problems. Children with skull/brain injuries were treated as inpatients three times as often as those children without such injuries. In most cases they were of a minor or moderate grade. Mild traumatic brain injuries are common in children and adolescents (113), and some of them may suffer from a range of post-concussive symptoms (114). Post-concussive symptoms include cognitive, somatic and emotional symptoms such as impaired concentration and memory, headaches, disturbed sleep, irritability and anxiety. Yates et al. (114) conclude in their study of children (8-15 years old) that mild traumatic brain injuries are more likely than orthopaedic injuries to result in transient or persistent

increases in post-concussive symptoms in the first year after injury. One third of the children sustained a skull/brain injury in Study III, reported residual psychological and psychosocial problems, but it is not sure that they had organic causes. Nevertheless, there are reasons for increasing the medical professionals' awareness of psychological effects on these children.

Children with residual physical problems were reported to have psychological and psychosocial problems more often than those without residual physical problems, maybe because it was difficult to distinguish between physical and psychological problems in the study as they can co-exist. Children may also manifest their symptoms of trauma through somatic symptoms (37,38,39).

As in the review (Study I), there was no association between residual psychological problems and injury severity in Study III. The child's personal appraisals of the event seem to be more important than the injury severity for the later development of posttraumatic stress.

Attention should also be paid to children whose parent has to stay at home to care for him/her for more than seven days. Children with injuries needing more support and assistance may experience the accident and its consequences as more threatening than those who recover quickly.

Medical service and psychological consequences

Medical services are readily available to those who have been physically injured, but consideration is rarely given to psychological consequences. These are often overlooked during the post-injury care, and it is crucial to raise the awareness of this issue among paediatric health care providers. Ziegler et al. (115) evaluated the current awareness and practices among a cohort of paediatric emergency care providers, regarding posttraumatic stress after a motor vehicle-related injury. Only seven per cent believed that children were likely to develop posttraumatic stress. Eighteen percent provided verbal guidance and only three per cent provided written instructions about posttraumatic stress to patients and families. Sabin et al. (116) assessed the primary care detection of posttraumatic stress after an injury in 90 adolescents (aged 12-18). After four to six months, 30% experienced high posttraumatic stress symptom levels, 11% high depressive symptom levels, and 17% had high levels of alcohol use. Only 24% of the injured adolescents had visited a primary care provider four to six months after the injury. When patients were seen, posttraumatic stress symptoms, depressive symptoms and alcohol-related disorders were not detected by the providers.

Identification of risk factors is important and could be used by nurses who are often at the frontline of care for children attending E&A departments or being admitted to hospital. Exposed children should be routinely screened and checked for risk

factors in order to prevent unfavorable long-term consequences that could have a negative influence on the children's development and functioning in daily life. Identification of risk factors also enabled the development of screening tools, such as the Screening Tool for Early predictors of PTSD (STEPP) (117) and the Child Trauma Screening Questionnaire (CTSQ) (118).

Most injured children (not only after road traffic accidents) recover over time (119,120) but there are subgroups that need attention, early identification, and follow-up in order to prevent stress disorders. The return to pre-injury status not only depends on optimum medical care for physical injuries but also on the awareness of possible psychological problems.

The severity of the problems and the occurrence of PTSD/PTSS were not estimated in Study III, as the main purpose was to investigate risk factors for unfavourable outcomes. The impression was that very few of the symptomatic children suffered from serious psychological problems. However, due to the review (Study I) and other reviews on posttraumatic stress (102-104) at least 13% (38 children) of the children in study III may have developed PTSD/PTSS one year after the accident.

Physical problems after traffic injuries (Study II)

Residual physical problems were reported in Study II for 16% of the children, less frequently than psychological problems (Figure 10). Other authors have also found a favourable outcome after injuries in children (not only road traffic injuries) in most cases (6-10,12,121-123) .
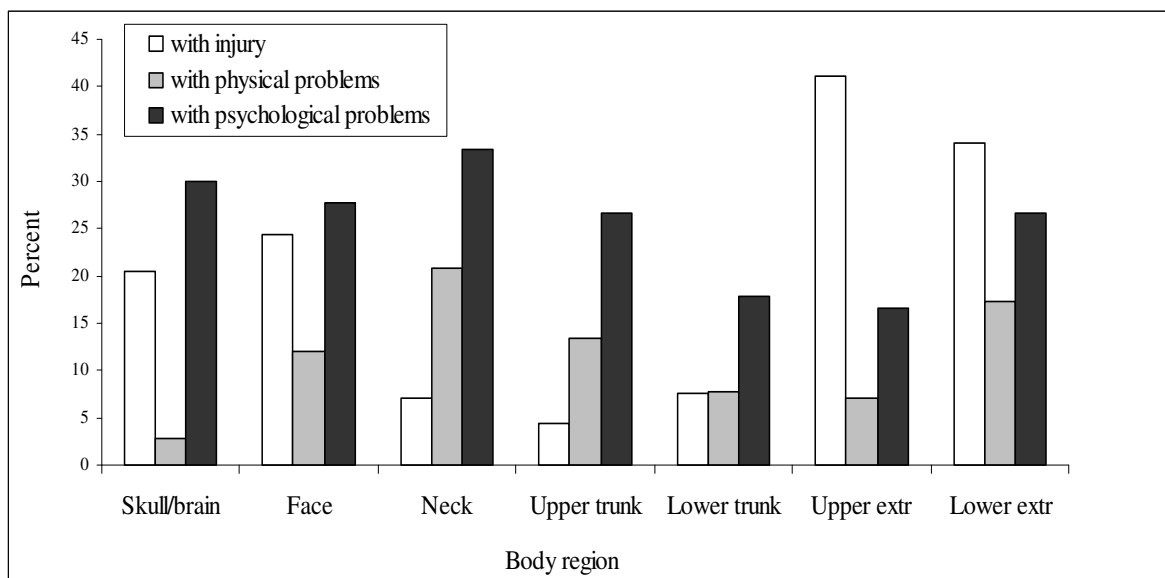

Figure 10. The proportion of children with at least one diagnosed injury to specified body regions, the proportion of these cases with residual physical problems in the same region, and the proportion with residual psychological problems after an injury to this region.

Factors related to residual physical problems

As other studies have been based on different types of trauma (not only road traffic accidents), used specific subgroups, and other selection criteria and outcome measures, comparisons with the results in Study II are difficult. Nevertheless, some subgroups that may need extra attention and follow-up were identified: older children, children injured as moped riders, and children with neck injuries. However, injury severity and residual physical problems were not related to each other. This is not unexpected, as the AIS grade is primarily a classification of the fatality risk of specific injuries, and the disability risk mainly depends on other factors. According to Tursz et al. (124) the maximum abbreviated injury scale (MAIS) appears to be a better predictor of long-term function than the ISS score.

In most studies referred to here, the caregiver was the respondent. Macpherson et al. (9) determined the influence of the mechanism of injury on functional outcome six months after severe multiple injuries (ISS≥12) in 489 children in Toronto, Canada. Compared with sports injuries, child pedestrians struck by motor vehicles had a 2.3 times greater risk of requiring assistance, child cyclists struck by motor vehicles were 2.2 times more likely, and car occupants 1.8 times more likely to require assistance. Van de Voorde et al. (8) in Flanders, Belgium, also evaluated the long-term outcome in 146 children after severe trauma (hospitalised >48 h) twelve months after an injury. A significant impact on the health burden could only be proven for the state of discharge, although there was a tendency towards worse factor scores after a traffic injury. The risk factors for disabilities reported in other studies, where most of the children were hospitalised with unintentional injuries (not only road traffic injuries), were older age (6-8), younger ages (9), the most severe injuries (6-9), and injuries to the central nervous system (9). In Sweden, the Thorsson study (11) including 402 children injured in traffic in 1965, indicated that 15% of the children and 38% of the adults suffered from some physical consequences four to five years post-crash. According to Karlsson et al. (10) older children more often reported residual problems than younger ones, particularly from the lower extremities, while younger children most often reported head problems. Maraste et al. (12) provided information on serious (in-patient treated) rod traffic injuries in Sweden in the 1990s in terms of loss of health (functional disability, pain and distress). The study was based on 476 road traffic casualties (73 below 15 years of age) treated as inpatients at four hospitals in Sweden during the period 1991-1992. In questionnaire data from 200 adults and 30 children, 13% of the children and 38% of the adults reported some functional disability, pain or distress at the one-year follow-up. At the final-follow up, 3.7 years after the accident, 10% of the children and 23% of the adults suffered from long-term consequences. They reported no risk factors for loss of health. A recent Swedish study (123) of long-term medical consequences in 2 619 children 0-12 years of age, who were injured in car crashes, found 55 children with permanent medical impairment (PMI) after one year, and 75% of the injuries were AIS1 or AIS2. The

head and the cervical spine were the body regions sustaining the most injuries resulting in PMI, and children over five with a cervical spine injury were at risk off PMI.

Neck problems
Problems of the neck were reported in Study II for 13 children, i.e. to a much greater extent than would be expected from the injury rates in these regions. This may indicate inadequate diagnostics. Neck pain in adults is common, potentially disabling, with a non-negligible rate of transition to chronic problems. The difficulty of understanding the aetiology and pathology of neck pain following rapid, non-coherent accelerations of the head and trunk, called whiplash-related disorders (WAD), has stimulated several primary research papers and a number of systematic reviews (125,126). WAD can be experienced by people of all ages, including children (126). It was not possible to evaluate whether the neck problems in Study II were WAD, but eight of the 13 children with neck problems had been injured as car occupants. Eight of the 13 children and three of the eight children injured as car occupants had not a primary diagnosed neck injury and the time delay before the onset of symptoms in adults is well known. Boyd et al. (127) studied the incidence and clinical course of WAD in children aged 4-16 years who were involved in car crashes. They identified 105 children, 47% of whom experienced WAD symptoms. Twenty-nine developed symptoms within 24 hours and 20 the following day. No child reported pain lasting more than two months, and the clinical course in children seems to be more favourable than in adults (127).

Not all children who reported neck problems in Study II had been injured in a car crash. Styrke et al. (128) examined the annual incidence of acute whiplash injuries after road traffic crashes in 15 506 persons (all ages), who were injured in vehicle crashes between 2000 and 2009 in Northern Sweden. Whiplash injuries were found in 3 297 cases, of which 86.4% were car occupants, 6.1% cyclists, and 1.5% moped riders. The incidence at population level per year was 4/100 000 among children 0-4 years, 35/100 000 among children 5-9 years, 73/100 000 among children 10-14 years, and 325/100 000 among adolescents and adults 15-64 years. The incidence has been relatively stable during the decade.

Even if children's neck injuries have a more favourable prognosis than similar injuries in adults, care providers should be aware of undiagnosed neck injuries in children. A recent overview of neck pain in adults (125) identified elevated posttraumatic stress symptoms at an early stage and highly catastrophic beliefs about pain as predictors of poor outcome. The question is whether the same findings apply to children?

Older children
High age was strongly associated with residual physical problems in Study II which is consistent with other studies (6,7). However, problems reported by teenagers may have many causes. Some may be related to developmental factors, and/or the impact of perceived limitations and the degree of acceptance. One reason why older children more often reported residual physical problems than younger children in Study II may be a reporting bias as it may be difficult for younger children to express potential problems related to the traffic injury and difficulties for the parents to identify such problems.

Moped riders
Residual physical problems were most often reported in Study II by moped users. Moped users (and cyclists) had the highest proportion of serious (AIS3+) injuries. However, injury severity and residual physical problems were not related. As most moped users are at least 15 years old, age-related factors may contribute to the problems. However, moped riders are unprotected road users; they often drive on roads together with motor vehicles, in many cases within excessive speed resulting in risk for more severe traumata.

Impacts on daily life and activities
Eleven children had interrupted sports or other leisure activities and four still had difficulties at school because of the accident. Only one child, a moped rider, had serious residual problems after a collision with a car, with a considerable restricting effect on daily activities. Thus, serious physical consequences due to traffic injuries seem to be rare. However, transient or continued impacts on daily life and activities were related to residual problems in Study II and III. This included schoolwork and sports activities, the parent's work, and the need for a service to transport the child to and from school. This emphasises the magnitude of the injury in the child's environment, physically or psychosocially, and its impact on the long-term outcome.

Helmet use and head injuries

Cyclists constitute the largest group of traffic casualties in Sweden, also among children. Cyclist's injuries are most frequently localised to the head and upper extremities, and so are also almost all of the more severe injuries. Brain injury is a significant cause of mortality and permanent disability in children and a bicycle helmet is expected to protect the head from such an injury (72-75).

Study IV was based on cases where helmet use was assessed at the time of the crash and all injuries were classified in a standardised way. The large sample also made it possible to control for several confounding factors.

The protective effect of helmets against head injuries

The results of Study IV are in accordance with other studies (79-91), which show that bicycle helmets have an obvious protective effect against head injuries in cycle crashes, regardless of the crash circumstances. The adjusted odds of serious or more severe (AIS3+) skull/brain injuries with a helmet in Study IV were about one fourth of the odds without a helmet. In a meta-analysis by Attewell et al. (81), based on studies from several countries (only one study from Europe, UK) published in 1987-1998, the summary odds ratio estimate for bicycle helmet efficacy (children and adults) was 0.40 (0.29-0.55) for head injuries, 0.42 (0.26-0.67) for brain injuries, and 0.53 (0.39-0.73) for facial injuries. Elvik (90) presented a re-analysis of the study by Attewell et al. (81) by including more recent studies (2000-2009) from Germany, Norway, Singapore, and France (83,84,87,129) to try to account for a time-trend bias in estimates of the effects of bicycle helmets. According to Elvik (90), the effects of a safety measure, like bicycle helmets, may change over time. The re-analysis showed smaller safety benefits associated with the use of bicycle helmets with summary estimates of effects, based on all estimates, by 0.51(0.47-0.56), for head injuries and by 0.74 (0.67-0.81) for facial injury. The results regarding head injury is consistent with the result in Study IV, when considering head injury severity of any grade (OR=0.50; 0.42-0.59). However, separate analyses for the two periods 1993-1999 and 2000-2006 in Study IV, showed a greater protective effect during the latter period; possibly due to better helmets, although this was not investigated.

Larsen (82) examined the preventive effect of bicycle helmets on head injuries in children 0-15 years treated after road traffic accidents in Denmark during the period 1993-1999. The use of helmets decreased the risk of head injuries by a factor of 0.4 (0.3-0.6), and the risk of concussion by a factor of 0.6 (0.4-0.8). Collision with a motor vehicle increased the risk of head injuries by a factor of 2.7 (2.0-3.7), and no effect of helmets uses was seen, possibly due to a type 2 error, as the number in this group was small. Collision with a motor vehicle was also a risk factor for severe skull/brain injuries (AIS3+) in Study IV, which also was found by Bambach et al. (85).

Curnow (94,95) stated that earlier studies take no account of the scientific knowledge about the types and mechanisms of brain injuries that are likely to be fatal and disabling. He suggests that earlier studies underrate the importance of rotation as a factor in brain injuries and points to deficiencies in the design and testing of helmets. He argues that hard shells are not applicable to most helmets used nowadays, and the occurrence of a head injury is not a useful proxy for intracranial trauma. The brain can be injured without impact to the head, and this may occur in any crash where an oblique impulse gives an angular acceleration of the head, including falls on the buttocks and whiplash effects (7-9,12). Hansen et al. (83) examined the effect of different helmet types on head and facial injuries in

991 cyclists (children <16 years, n=705), and confirmed that users of hard shell helmets (inner foam layer and outer hard shell) had a reduced risk of injuries to the head (forehead, scalp, skull, ears, brain), regardless of age group. There was no reduced risk among users of non-shell foam helmets in this study, and children less than nine years old wearing this type of helmet had an increased risk of facial injuries.

The type of brain injury and the type of helmet were not investigated, and no conclusions can be drawn about the risk of brain injuries or their consequences in different types of impact in Study IV. However, wearing a helmet had a significant protective effect against head injury of any severity, and this also indicates a protective effect against head injury sequelae. Bicycle helmets in Sweden were almost all either hard-shell or no-shell (sometimes with a vacuum-formed plastic cover) in the middle of the 1980s. Around 1990, a new construction technique was invented: in-mould micro-shell helmets. A very thin shell was incorporated during the moulding process. This rapidly became the dominant technology, allowing for larger vents and more complex shapes than in hard shell helmets. Recently, a new helmet has been developed in Sweden, which contains a moving inner layer, that reduce angular accelerations of the head, the Multi-Directional Impact Protection System (MIPS).

The protective effect of helmets against facial injuries

Helmets also protected against facial injuries in Study IV, and this is in accordance with other studies (80,83,84,87,129). Thompson et al. (130,131) found a protective effect against serious injuries to the upper part of the face, but not to the lower part. No attempts were made in Study IV to analyse which part of the face was injured. However, it seems reasonable that helmets covering a greater area of the face and more protruding helmets may provide better protection against facial injuries. It may also be important to wear the helmet properly attached, sufficiently far down on the forehead.

Helmet use

Injury prevention programmes and helmet legislation for children have resulted in a steady increase in helmet use in Sweden. Despite this, only about 60% of children used a helmet in 2012 when cycling to and from school and only about 40% of 13-15-year-olds (77). In Study II, cyclists (and moped riders) of foreign extraction used helmets to a much lesser extent than others, maybe due to differences in compliance with the use of protective equipment and less access to helmets. Laflamme et al. (24) found lower incidence of helmet ownership in lower-income areas; however, helmet legislation seemed to increase helmet use, particularly in those areas. This difference may have been levelled out as Sweden has had helmet legislation for children since 2005. Nevertheless, this indicates a need for better information to specific groups.

In Study IV, helmets were used by 60% of children below 11 years of age, but significantly less often by teenagers, especially girls. The same low helmet use by teenagers was seen during the two periods 1993-1999 and 2000-2006. Teenagers may not be aware of the great risk of serious or life-threatening head injuries in cycle crashes without a helmet, or they may neglect the risk. Sometimes, teenagers do not want to identify themselves with children. A helmet law for everyone, including adults, would mean that helmet use is not equivalent with being a child. Besides, children are more likely to do what adults do than what they say. A further increase in helmet use among children would probably be related to increased helmet use among adults.

The great risk of serious or life-threatening head injuries without a helmet must be emphasised, especially for teenagers. Paediatric health care professionals can serve their patients well by highlighting risks associated with cycling without a helmet and thus play an important role in making cycling a safe activity.

Changes in injury patterns during a period of increased helmet use (study IV)

The injury patterns changed during the period with a decreasing proportion of non-minor (AIS2+) head (skull/brain or face) injuries and an increasing proportion of upper extremity injuries.

Head injuries

The proportion with skull/brain injuries of any severity in Study IV did not change significantly during the period but the proportion with more severe skull/brain injuries changed; however, in different ways; AIS2+ decreased and AIS3+ increased. The proportion with facial injuries of any severity decreased during the period. These results are hard to interpret as the lack of exposure data is a problem when analysing injury data. Statistics from Transport Analysis (32) report changes in injury patterns in hospitalised children (called "seriously injured") during the last decade, with a decreasing proportion of head injuries (skull/brain and face), for all road user categories, except pedestrians. The reasons may be a combination of increased helmet use, other indications for admission, and a decrease in cycling. Berg &Westerling (76) reported a decrease in bicycle head injuries in hospitalised children (0-15 years) in Sweden between 1987 and 1996, probably related to the increasing helmet use during the study period, as there was no significant change in non-head injuries and the incidence of both head and other injuries increased in adults.

The protected effect of helmets at a population level

In order to estimate the protective effect of helmets against head injuries at population level in the absence of exposure data, the number of subjects with

extremity injures was used as a measure of exposure to the risk of cycling trauma (assuming equal exposure to head and limb injuries) as was made by Walter et al. and Povey et al. (133,134). The ratio between the number of children with head injuries and the number with extremity injuries decreased for all injuries and for moderate or more severe injuries in Study IV. This may indicate a protective effect of bicycle helmets in the population.

During this period of increasing helmet use in Sweden, continuing improvements in road safety, including separation of vulnerable road users from other users, have also played a vital role in reducing the frequency of crashes and the severity of the injuries sustained. Information campaigns to promote helmet uses preceded the helmet legislation resulting in an increase in helmet use during the whole period 1993-2006.

Walter et al. (133) assessed the effect of mandatory bicycle helmet legislation on cyclist head injuries (adults and children), against the background of the on-going debate in Australia, with regard to the efficacy of this measure at population level. Head injury rates decreased significantly more than limb injury rates among cyclists but not among pedestrians at the time of introduction of the legislation. Povey et al. (134) also used cyclist limb injuries as a measure of exposure to the risk of cycling trauma (adults and children) during a period of increasing helmet use in New Zeeland between 1990 and 1996. Bicycle helmet use became mandatory under New Zealand law in January 1994. Cyclist head injuries decreased with increasing helmet-wearing rates in all types of cycle crashes. No increase or decrease in the severity of head injuries for which cyclists were hospitalised during this period could be detected, probably, according to the authors, due to the small and highly variable number of "high severity" injuries. A Cochran review (135) assessed the effects of bicycle helmet legislation on bicycle-related head injuries and helmet use and concludes that helmet legislation appears to be effective at increasing helmet use and decreasing head injuries in the populations for which it is implemented. The review also point out that there are very few high quality evaluative studies that measure these outcomes and none that reported data on possible reductions in bicycle use.

Opponents of mandatory bicycle helmet legislation argue that cycle helmets may not be especially effective at reducing head injuries and that such a restrictive law would violate people's freedom and reduce their autonomy (92). Legislation will also reduce cycling rates entailing a loss of health benefits (97). Clarke et al. (136) have recently evaluated the bicycle helmet law in New Zealand and find that the helmet law has failed with regard to promoting cycling, safety, health, accident compensation, environmental issues and civil liberties. Castle et al. (137) determined whether increasing helmet use changed the injury patterns in trauma patients, below 18 years of age in Los Angeles County, before and after helmet

legislation during 1992-2009 (helmet law was enacted in California in 1994 for cyclists <18 years). Only eight percent of the injured cyclists were helmeted before legislation and 12% after legislation and the injury patterns, with head injuries predominating, did not change after the helmet law.

In an international perspective, the rate of helmet use in children is high in Sweden, and the risk that children give up cycling, due to the helmet law to such an extent that it affects their health, seems low.

Upper extremity injures

In Study IV the proportion of upper extremity injuries of all severities increased while the proportion of moderate or more severe (AIS2+) lower extremity injuries decreased. The increasing occurrence of injuries to the upper extremities, but not to the lower extremities, was not expected. Other analyses in Sweden also show that upper extremity injuries in children have increased in cyclists (32,71).

Whether the increasing proportion of upper extremity injuries is related to increased helmet use is difficult to determine as cyclists with helmets are less likely to sustain injuries to the head and probably do not seek medical care as often as cyclists without a helmet. Risk compensation may be important, but studies on this topic are contradictory (85,93,96,). Lasenby-Lessard et al. (132) found that children (cycling, rollerblading) display risk compensation when wearing safety gear. The extent varied, based on the level of experience and the children's level of sensation-seeking.

More advanced bicycle models may have been used during the second half of the period 1993-2006. Modern bicycles may stimulate or enable faster riding and more risky behaviour. As cyclists may try to protect their head when falling, more injuries to the upper extremities would be expected. Information about the increasing risk of arm injuries in children in bicycle crashes is needed, but it is important to emphasise that the brain is the most sensitive body part and the most important to protect. It is difficult to measure various injury consequences, but a cognitive disability may complicate life to an entirely different degree than a functional reduction in a limb.

Assessing trauma outcomes in children

Assessing trauma outcomes in children is important but problematic due to differences in cognitive abilities depending on age. It is reasonable to set high standards for the measurement methods, but not to measure is a bad option. At the beginning of the 2000s, only a few methods for measuring children's psychological outcomes of trauma had been developed, and very few studies included both parent's and children's reports (138). Despite the fact that a range of instruments exists today for assessing outcomes in paediatric populations, parents continue to

be the most frequently used proxy raters of their children's health (139). This despite the fact that the relationship between the child's own and the parents proxy reports has been shown to be poor in some respects (140); for example, that problems in children tend to be underestimated by their parents (141-144). In future studies on children injured in road traffic accidents, there are strong arguments for obtaining information both from the parents and the children, whenever possible. HRQOL protocols may also give a better description of the outcome after traffic injures in Swedish children.

LIMITATIONS

Study I

The review (Study I) attempted to identify, appraise and synthesise all studies that meet the inclusion criteria. The procedures were defined in advance, in order to ensure that the exercise was transparent and could be replicated and had clear inclusion/exclusion criteria. However, the searches were restricted by language and by electronic databases, and a quantitative pooling of data was not possible due to methodological differences including the assessment tools. The variation in the methodologies used and the varying sample sizes in the source studies reporting the prevalence of PTSD/PTSS might challenge the validity of the study.

Study II and III

Studies II and III were based on a questionnaire. It included several questions, which could be answered by yes or no. It also included some general, non specific and subjective questions, the validity of which had not been tested. However, the same type of questionnaire had been used in several follow-up studies by the Traffic Injury Register to investigate outcomes of traffic injuries and differences between various road user categories, types of accidents, and traffic environments. Furthermore, there was no promise of a reward if the questionnaire was answered, and the rate of completion of the questionnaire was satisfactory. Over-reporting was not a major issue, as detailed information was given about the study. The severity of the consequences was not graded, and validated instruments were not used to assess the impact on daily living.

In Study II a parent answered the questionnaire in most cases. The respondent was unknown in 27 cases. There is reason to believe that parents answered the questionnaire also in most of these cases, as the letter was sent to the legal guardian. In order to limit the influence of responder bias in Study III, 49 cases in which the questionnaire was not answered by the parent alone or where the respondent was unknown, were excluded. Some results reported by parents not born in Sweden may be uncertain due to language difficulties and misunderstandings.

Children injured when playing outdoors in an environment not intended for public road traffic and children without injuries were excluded. This sampling bias may have affected the results.

The results in Study II and III may be affected in that the children attended a children's hospital and they met professionals educated to care for sick children,

which does not apply for all children in Sweden. To meet an injured child is quite different from meeting an injured adult.

Study IV

Children without injuries and with injuries not leading to a visit to an A&E department were not included; hence the results only describe cycling injuries in a subgroup of children. On the other hand, the large sample means that several confounding factors could be controlled for, and by relating the number of children with head injuries to the number with extremity injuries, the protective effect of helmets in the general population seems obvious. The type of brain injury and the type of helmet were not investigated, and no conclusions were drawn about the risk of brain injury from different types of impact. The injury risk was graded according to the AIS, which predicts the fatality risk and not the risk of permanent impairment. It seems reasonable, however, that the protective effect of a helmet against brain injury would also be expected to apply to brain injury sequelae. As excluded cases with missing data on helmet use or injury severity amounted to only 14% of the total sample, differences between the study groups and the excluded cases would not have had any significant influence. The excluded children were older and more often injured in crashes with a counterpart. As older children used helmets less often than younger children, it is reasonable to assume that the excluded children also used helmets less often. Excluded children with known injuries, where helmet use was not known, had fewer AIS2+ skull/brain injuries and AIS1+ facial injuries, and this may weaken the results if a majority of them did not use a helmet. However, as no difference was found for AIS3+ skull/brain injuries or AIS2+ facial injuries, the results seem to be reliable.

CONCLUSIONS

- One third of children injured in traffic accidents fulfilled diagnostic criteria of PTSD/PTSS after 1 month and about half of that proportion after 3–6 months. A perceived threat to life and high levels of distress during and immediately after the accident are important risk factors.

- Any child will be at risk of PTSD/PTSS, not just those with severe injuries. Awareness of traumatic stress disorders can help care providers identify children and families at risk of disability.

- Residual physical problems were reported in about one sixth of the study group and children at risk were more often, injured as moped users, and had sustained neck injuries.

- Children are quite rarely afflicted by severe physical impairments after traffic injuries. Psychological and psychosocial problems are more common; however, not often recognised.

- Children in the study group at risk of residual psychological or psychosocial problems one year after a traffic accident were more often children with residual physical problems, a parent of foreign origin, had been treated as inpatients, injured as pedestrians, or had collided with a motor vehicle.

- Head injuries were also associated with residual psychological and psychosocial problems, if children with residual physical problems were excluded. Children with skull/brain injuries were also treated as inpatients three times as often as those without such injuries.

- The child's personal appraisal of the event and early post-injury distress seem to be more important than injury related variables for the later development of posttraumatic stress disorders and psychological and psychosocial problems.

- Residual problems are easily overlooked, as they are not related to the severity of the injury.

- Children at risk of disability must be identified, and proper measures must be taken to prevent the negative effects of road traffic injuries. Medical professionals have the primary responsibility in this respect, and healthcare programmes should be introduced for this purpose as soon as possible.

- Bicycle helmets have an obvious and considerable protective effect against head injuries in cycle crashes, regardless of crash circumstances.

- The great risk of serious or life-threatening head injuries in cycle crashes without helmet use should be emphasised, especially for teenagers.

- The use of bicycle helmets should be stimulated in children of foreign extraction.

- Attention should be paid to the increasing occurrence of non-negligible injuries to the upper extremities in cycle crashes and preventive measures should be taken.

- Future studies on bicycle safety should include risk compensation.

FINAL CONSIDERATIONS AND THE FUTURE

The acquired knowledge in this thesis will hopefully increase the awareness of children's risk of undesirable consequences and improve post-crash care and rehabilitation to make sure of the best possible care

Posttraumatic stress and psychological problems may develop after traffic accidents, also after crashes causing only minor injuries, and psychological problems are more common than physical problems in children injured in traffic accidents. These problems may interfere with the way the child functions in daily life and have a negative influence on the child's development, thereby undermining the child's confidence and feeling of security also as an adult. Little is known about the effect of road traffic injuries during childhood on the persons quality of life during adulthood.

Most children injured in road traffic are cyclists. Awareness of the risk involved in cycling, combined with safe cycling practices and proper traffic planning can prevent great suffering in children and their families. The cyclists' most important safety equipment is the helmet. Paediatric health care professionals should emphasise the great risk of fatal and serious injuries in children who cycle without a helmet. As a paediatric nurse, practising at a children's clinic and meeting many families on a daily basis, this will be my task.

The increasing proportion of children with upper extremity injures from cycle crashes may be related to the lower risk of head injuries in cyclists wearing a helmet. Risk compensation might be another explanation. Future studies on helmet use and injuries in bicycle accidents should also include crash participants who are not injured. A qualitative interview method could possibly be used.

The results presented in this thesis are supported by a large number of other studies, and it is high time for paediatric health care providers to act. Early recognition and follow-up are needed to identify children at risk of the serious long-term consequences of traffic injuries. There is an urgent need for Swedish intervention studies resulting in guidelines that could be used for this purpose.

SUMMARY IN SWEDISH (Svensk sammanfattning)

Trafikskador är en viktig orsak till dödsfall och funktionsnedsättning hos barn. De kan även medföra posttraumatisk stress med långvariga och kvarstående psykiska och psykosociala besvär. Barn skadas i trafiken mestadels som cyklister.

Syfte

Att undersöka orsaker till och konsekvenser av trafikskador hos barn ur ett fysiskt och psykosocialt perspektiv samt att identifiera riskfaktorer för skada och funktionsnedsättning.

Studie I

Förekomsten av posttraumatiskt stressyndrom (PTSD) och PTSD symtom (PTSS) undersöktes i en systematisk litteraturstudie. Tolv studier granskades. PTSS förekom hos 30% inom en månad och PTSD hos nära 30% efter en till två månader efter skadehändelsen. Förekomsten av båda tillstånden halverades efter tre till sex månader. Upplevt hot mot eget liv, hög nivå av stress och rädsla i samband med och omedelbart efter händelsen, symtom på ångest och depression och att vara flicka var riskfaktorer. Skadans svårighetsgrad var inte relaterad till PTSD/PTSS.

Slutsats: Alla barn riskerar posttraumatisk stress efter skada i trafik, inte bara svårt skadade. Traumavården behöver rutiner för att identifiera och förebygga stressreaktioner hos barn efter trafikskada.

Studie II och III

Dessa studier beskriver fysiska (Studie II) och psykiska/psykosociala (Studie III) problem ett år efter trafikskada med avseende på demografiska-, olycks- och skaderelaterade faktorer samt effekter på dagligt liv. De omfattar trafikskadade barn (<16) som behandlats på barnsjukhuset i Göteborg år 2000. En enkät besvarades 12-20 månader efter olyckan. Kvarstående fysiska problem rapporterades för 16% av barnen, i ett fall med svår funktionsnedsättning. Äldre barn, barn som skadats på moped och barn med nackskador hade oftare kvarstående fysiska problem. Psykiska och psykosociala problem rapporterades för 22% av barnen. Kvarstående fysiska problem, förälder med utländsk härkomst, behandling i sluten vård, skadad som fotgängare eller av motorfordon ökade förekomsten av psykiska och psykosociala problem. Huvudskada ökade också förekomsten för psykiska och psykosociala problem hos dem utan fysiska problem. Skadornas svårhetsgrad var inte relaterad till kvarstående problem.

Slutsats: Även om trafikskadade barn sällan får svåra, långvariga besvär bör akutsjukvården utveckla rutiner för identifiering och tidig uppföljning av barn som riskerar långvariga besvär.

Studie IV
Studie IV omfattade 4 246 barn (<16), som behandlats på barnsjukhuset i Göteborg sedan de skadats som cyklister 1993-2006. Cykelhjälm användes av 40% av de skadade i början av perioden och av 80% i slutet, av tonåringar i betydligt mindre utsträckning, särskilt flickor. Hjälmens skyddseffekt mot svåra och livshotande hjärnskador var avsevärd i alla typer av cykelolyckor. Hjälmen skyddade även för ansiktsskador. Andelen barn med icke försumbara armskador ökade tydligt under perioden.

Slutsats: Cykelhjälm används av allt för få barn trots lagtvång, i synnerhet gäller detta tonåringar. Risken för svåra hjärnskador i cykelolyckor minskar påtagligt med hjälm. Den ökade förekomsten av icke försumbara armskador bör uppmärksammas.

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