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Hand injuries in young children

Incidences, aetiologies, injury patterns and costs

by

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Malmö 2008



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Illustration front page: “A sad child with an injured hand” by Solei Langéen

To myself

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LIST OF PUBLICATIONS

The thesis is based on the following papers, which will be referred to in the text by their Roman numerals:

- I. Ljungberg E, Rosberg HE, Dahlin LB. Hand injuries in young children. J Hand Surg 28B: 376-80, 2003. Erratum in: J Hand Surg 29B: 642, 2004.
- II. Ljungberg E, Dahlin LB, Granath F, Blomqvist P. Hospitalized Swedish children with hand and forearm injuries: a retrospective review. Acta Paediatr 95: 62-7, 2006.
- III. Ljungberg EM, Steen Carlsson K, Dahlin LB. Risks for, and causes of, injuries to the hand and forearm: a study in children 0 to 6 years old. Scand J Plast Reconstr Surg Hand Surg 40: 166-74, 2006.
- IV. Ljungberg EM, Carlsson KS, Dahlin LB. Cost per case or total cost? The potential of prevention of hand injuries in young children – retrospective and prospective studies. BMC Pediatr 8: 28, 2008.

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INTRODUCTION

In the newborn, all body movements are involuntary. Only primitive reflexes are present. During the first year of life, gross motor, fine motor, and adaptive skills increase from the head downward to different areas of the body (in a cephalad to caudal direction) (*Erhardt and Lindley, 2000*). At about 4 months of age, development reaches the closed fist, which during the first months has gradually opened (*Erhardt, 1994*). Both hands can now meet and grasp an object by ulna-palm prehension. Partial thumb opposition, and transfer of objects between hands, can be seen at 6 months. By the age of 7 months, the thumb-palm grasp is achieved, and at about 9 months the child can drink from a cup held in the hand with assistance. The child is now also able to sit or stand up, and the hand can reach nearby objects. By the age of 10 months, voluntary movement of the fingertips enables the child to grasp small objects, like candies and nuts, as the pincer grasp is fully evolved.

“The hand grasps everything the eye sees; the eye looks at everything the hand grasps”

(*cited in Erhardt, 1994*)

Increasing crawling, walking and running skills by the age of about one year, together with improved grasping ability and coordination between the hand and the eye, make these children vulnerable (*Erhardt, 1994*). As the fine motor ability further develops, new skills become possible: scribbling with crayons, throwing a ball, and building a tower with blocks. The child is often able to open a door lock at 2 years of age, and can use scissors by the age of 3 (*Hwang and Nilsson, 2003*). Even though will and concentration is good enough, preschool children have many more problems performing fine motor tasks compared to gross motor tasks. Muscles and nerves are not yet fully developed, and the fingers are still thick and short.

The developmental skill level may not always be adequate in relation to the level of skill required in a specific situation. As young children explore new environments, unknown hazards may cause more or less harm to different parts of the body. The word accident has for a long time been used to describe such events. An accident in previous science was often defined as being sudden, and unintentional, resulting in something negative (*Injuries and injury prevention: an anthology: www.raddningsverket.se*). Within medical research, the concept accident is now more and more left ahead, as it is meant to mislead the thoughts to something random and unpreventable. Instead the concept of injury relates to the somatic consequences that occur when the body is unable to prevent external forces.

Injuries accounted for approximately 15% of medical spending in American children in 2000 (*Miller, et al., 2000*). Among children and adolescents between 5 and 19 years old, it even rivals the common cold in frequency (*Miller, et al., 2005*). Colds, however, are much less likely than injuries to have lasting effects. The hand is used by children and adults every day for play, conversation, expression, sensation, and later in life work. A hand injury, though non-fatal, brings a risk for complications and reduction of significant hand function, and may have consequences for a child's future development.

BACKGROUND

Swedish injury research

In Sweden, there is a tradition of injury research in young children, and our country has been a forerunner internationally (*Berfenstam, et al., 1957; Bergman and Rivara, 1991; Gustafsson, 1977; Nathorst Westfelt, 1982*). This work started in the 1950s with Dr Berfenstams and Dr Ehrenpreis epidemiological studies of children suffering injuries in Stockholm and Uppsala. The information of mortality rate (450 children died from injuries in 1954 in Sweden) was given attention from politicians and authorities. The Joint Committee for the Prevention of Accidents to Children was founded, and succeeded in transferring child injuries from being a medical problem, to being a society problem. This committee was the precursor of the National Child Environment Council, the Children's Ombudsman, and the Child Safety Commission set up by the Swedish Government in 2001. The mortality rate decreased to a fifth in the 80s (49 children died from injuries in Sweden). This has been ascribed to common efforts in different sections of society to prevent childhood injuries, together with a positive economical and social development. In a report from UNICEF (2001), Sweden still had the lowest mortality rate among the rich nations (*Child Injury Atlas: www.regeringen.se*).

The main focus of injury research, and prevention, has been traffic accidents and drowning. This is natural, as these aetiologies may have fatal consequences. Hence, the goal of injury prevention has not been to prevent all injuries, and take the important exploration phase from the children, but to identify the factors involved in the most severe injuries, with the purpose to prevent these. A certain goal for traffic accidents was founded by the government in 1997 in terms of "Vision Zero". This means that it is unacceptable for anyone to get killed or severely injured in traffic accidents. Another Swedish sector that is active in child safety work is the Work Environment Sector, responsible for the school and day care centre environment. Still, the great majority of injuries in children are considered to occur in the home environment, and during leisure (*Lafamme and Eilert-Petersson, 1998*). National laws and directives are less developed within these areas in Sweden, and the circumstances of injuries sustained at home could be further established in research, and noticed by authorities (*Child Injury Atlas: www.regeringen.se*).

Gustafsson evaluated what factors have an impact on the occurrence of injury (*Gustafsson, 1977*). The following factors were taken into account: 1) The environmental Hazard (**H**), or the sum of all risk factors in a child's environment. 2) Accident Proneness (**P**), depending on the individual physical and personality characteristics of a child. 3) The extent and adequacy of the Supervision (**S**) of a child. 4) The education (**E**) about risks and behaviour in hazardous situations

which a child receives and is able to apply. He furthermore presented these terms in an equation:

$$\text{HP} \Leftrightarrow \text{SE} \quad (\text{Gustafsson, 1977})$$

The equilibrium was a simplified way to express these causative factors involved in the chain that eventually leads to an injury. The relation between the different factors is difficult to establish, and there are lots of other factors that should be taken into account. However, expressed simply, the equilibrium means that normally the parents compensate for the environmental hazards, and the child's accident proneness, by supervision and education. If HP outweighs SE the risk for an accident increases. If SE outweighs HP, there is a risk for overprotection of mild injuries and a sudden "tip over" to the left side can cause severe injuries.

Continuing his theories, Laflamme and Eilert-Petersson emphasized that there is a need for a problem-oriented approach to analyse injuries in children (*Laflamme and Eilert-Petersson, 1998*). In their study on data from a community-based injury register from Falköping, Sweden, injuries to preschool children in home settings were classified and five different patterns were observed. "Crush and pinch injuries" often occurred to the fingers, and were mentioned as a new important group of injuries that has received little attention in the literature. These injuries were found to concern all preschool ages (0-6 years), and non gender specific, but were not further analyzed.

Hand injuries in children

The importance of a paediatric hand injury is emphasized by the fact that it has been reported as the second most common injury in the pioneering research of Swedish injuries mentioned above (*Gustafsson, 1977; Nathorst Westfelt, 1982*). Hand injuries still constituted 23% of paediatric injuries in a Swedish register report from 2004 (*Statistics of injuries among children in Sweden – intentional and unintentional: www.socialstyrelsen.se*). Only head and neck injuries were slightly more common (25%).

Incidence

Literature of paediatric hand injuries is obtainable from different parts of the world, and dates back as far as the 1980s (Table 1). Risk populations have not always been announced. The occurrence of hand injuries has instead been measured as proportion of all paediatric injuries attending an Emergency Department or a certain hand injury type. In some studies, risk populations have been defined, and incidences were calculated in number of children that suffer

hand injuries per 10 000 or 100 000 children in the study population per year (written throughout the thesis as no/10 000 children/y or no/100 000 children/y). Children with hand injuries range from 2 to 6% of all children examined in Emergency Departments (*Bhende, et al., 1993; Fetter-Zaręka and Joseph, 2002; Usal and Beattie, 1992*). The incidence of children with skeletal and soft tissue hand injuries, referred to a hand centre in England, was recently estimated at 56/10 000 children/y in 0 to 16 year old children, and 28/10 000 children/y in 0 to 5 year old children (*Vadivelu, et al., 2006*). Apart from this study, information about the incidence of hand injuries in general has not been found.

Incidence of hand fractures has been calculated more extensively (Table 1). The hand is, next to the forearm, the most fractured part of the body, reported in a large study of 8 682 fractures in children treated at Malmö University Hospital between 1975 and 1979 (*Landin, 1983*). Landin estimated an annual incidence of fractures distal to radius and ulna (scaphoid bone excluded) at 58/10 000 children/y, and fractures were less common if calculations were limited to 0 to 6 year old children (13/10 000 children/y). The incidence of children with carpal, metacarpal and phalangeal fractures, referred to a Department of Plastic Surgery in Canada, has also been estimated at 2/10 000 children/y (*Mahabir, et al., 2001*), as well as 26/10 000 children/y referred to a Department of Orthopaedics in England (*Worlock and Stower, 1986*) (Table 1).

In conclusion, the incidence of children with hand injuries referred to a Hand Surgery Department has been calculated in one recent study in young, as well as in old, ages (*Vadivelu, et al., 2006*). The study was only performed from April to September. The incidence of hand fractures ranges from 2 to 58 per 10 000 children per year, discrepancies explained partly by referral rate, age differences, and time between the performed studies.

Table 1. Summary of previous literature on paediatric hand injuries

Author	Year	Country	Department	Age criteria	No of patients	Design of study	Injury type	Incidence ¹	Admission rate (%)	Referral rate (%)
Landin	1983	Sverige	Orthopaedic	0-16	Hand fractures: 1256	Retrospective radiological	Fracture	13 ² (0-6 y) 58 ² (0-16 y)	-	-
Hastings	1984	USA	Emergency Orthopaedic	0-17	354	Retrospective clinical	Fracture	-	-	-
Worlock	1986	England	Orthopaedic	0-12	136	Retrospective radiological	Fracture	26 (0-12 y)	-	-
Usal	1992	Scotland	Emergency	0-14	133	Retrospective clinical	Fracture & soft tissue	-	6	6
Bhende	1993	USA	Emergency	0-18	464	Retrospective hospital note	Fracture & soft tissue	-	3	-
Thomas	1998	India	Emergency	0-16	155	Prospective	Fracture & soft tissue	-	-	-
Macgregor	1999	Scotland	Emergency	0-14	188	Retrospective hospital note	Finger tip	-	15	-

Barret	1999	The United States	Burn Hospital	-	120	Retrospective hospital note	Burn	-	100	-
Doraiswamy	1999	Scotland	Emergency	0-14	283	Prospective questionnaire	Finger	-	-	-
Doraiswamy	2000	Scotland	Emergency	0-14	283	Prospective questionnaire	Finger	-	-	-
Al-Hoqail	2000	Saudi Arabia	Plastic surgery	0-12	101	Retrospective hospital note	Fracture & soft tissue	-	-	-
Mirdad	2001	Saudi Arabia	Emergency	0-16	136	Prospective	Fracture & soft tissue	-	-	-
Mahabir	2001	Canada	Plastic Surgery	0-16	232	Retrospective hospital note	Fracture	2	5	-
Rajesh	2001	England	Emergency	0-16	280	Radiology	Fracture	-	-	-
Fetter-Zarzeka	2002	The United States	Paediatric Emergency	0-16	382	Retrospective hospital note	Fracture & soft tissue	-	1	-
Vadivelu	2006	England	Hand centre	0-16	360	Prospective	Fracture & soft tissue	28 (0-5 y) 56 (0-16 y)	-	35

¹ Number of injured children per 10 000 children per year. ² Number of fractures per 10 000 children per year.

Etiological factors

Etiological factors behind paediatric hand injuries have been defined by taking a history from the patients in an Emergency Department (Table 1) (*Mirdad, 2001; Thomas, et al., 1998*). In 0-16 year old children from Saudi Arabia, the most common hand injury was a crush injury caused by a domestic door (52%) (*Mirdad, 2001*). Almost all Saudi houses had heavy metallic doors at the entrance, causing severe damage to children's hands. Children from India, in the same age group, were called to help out on the farms (*Thomas, et al., 1998*). As a result, a third of all hand injuries were caused by a fodder cutting machine named Toka. In addition, other machines caused 17% of the injuries. The main types of injuries observed were severe amputations and lacerations (66%).

Details of children with isolated finger injuries have as well been recorded in questionnaires completed by the medical staff at an Emergency Department in Scotland (*Doraiswamy, 1999; Doraiswamy and Baig, 2000*). As in Saudi Arabia, domestic doors caused most of the injuries among 0 to 16 year old children. Forty per cent of these doors were located in the living room and 25% in the toilet or bath room. Children less than 10 years old were pinched on the hinge side, but the older children were pinched on the lock side. A sibling closed the door more often. Finally, safety equipment for doors were discussed (*Doraiswamy, 1999*). No questionnaire studies have been found limited to young children. Specific circumstances around curious and explorative toddlers and preschool children have therefore not been defined, and may differ a lot, as compared to older children.

Hazards

Other etiological studies have instead started from hazards in children's environments, causing hand injuries. Etiological reports of hazards to the paediatric hand are merely smaller studies from specialist clinics, or Emergency Departments, with the purpose to serve as a basis for prevention (*Al-Arabi and Sabet, 1984; Benson, et al., 2000; Brown, et al., 1997; Carman and Chang, 2001; Dublin, et al., 2008; Gaffney, 2000; Han, et al., 2005; Hollyoak, et al., 1994; Joseph, et al., 1981; Lebrer, et al., 1997; MacCollum, 1938; Marshall and Lourie, 2003; Perks, et al., 1991; Rob, et al., 2000; Yanofsky and Morain, 1984*). Generally, risk populations and incidences are not measured. Detailed information about injury occurrence has been possible to retrieve mainly from hospital notes, but also from the patients.

Almost every household in the West has a domestic iron (*Brown, et al., 1997*). A common event is when a curious, two years old, child is in direct contact with the hot surface of the iron, or reaches the electric cord and pulls the iron down on herself. The result is linear or triangular shaped mild injury, predominately to the palm (*Gaffney, 2000*). There is, however, a risk for hypertrophic scars and scar

contracture, especially to the thinner skin of the dorsal side of the hand (*Holbyak, et al., 1994*). If irons are the major cause of contact hand burns in the paediatric population of the West, their counterpart in the Orient is an electric rice-cooking machine (*Rob, et al., 2000*). Ejection of steam from the cooker draws a child's curiosity, and causes second-degree burns to the index finger. Another well known kitchen hazard is the oven door (*Yen, et al., 2001*). Woodstove-related injuries in children less than 4 years of age principally involve the hand or forearm (*Yanofsky and Morain, 1984*). In infants, contact burns to the hand occur when the child touches the stove intentionally, or pulls itself to a standing position. The older children trips or are pushed into the stove. Glass injuries cause wounds on the volar surface of the hand, as children fall on to stray broken glass. In addition, several cases involve glass bottles, windows, or doors (*Joseph, et al., 1981*).

Growing commitment to physical fitness in the United States in the 90s brought with it potential risks for children's hands (*Lehrer, et al., 1997*). Exercise bicycles caused injuries by impingement of the fingers between the chain and sprocket wheel, or by the spinning wheel spikes (*Perks, et al., 1991*). The child itself, or a sibling, often rode the bicycle (*Benson, et al., 2000; Lehrer, et al., 1997*). Exercise bicycles cause injuries that often need primary surgery: crush injuries, digital amputations, digital fractures, and lacerations (*Carman and Chang, 2001*). As treadmills became more popular, young children touched the uncovered moving belt, while an adult was using the treadmill (*Banever, et al., 2003*). With American equipment becoming popular in other countries, e.g. Korea, injury patterns become similar (*Han, et al., 2005*). Treadmills cause abrasions and lacerations, with less need to be operated on immediately, but early action to prevent scar contracture is important (*Marshall and Lourie, 2003*).

Wringers were described as early as in 1938 (*MacCollum, 1938*), and were among the first electric household machines that adults used, and in which the youngest children were injured. A child is attracted by the rollers, and puts the hand in to the space between them. He or she may not be released from the steam roller press immediately, and have to spend up to 35 minutes caught between the rollers, before the fire department can free him or her. There is risk for a thermal injury, a crushing injury, and/or an avulsion of the skin (*Cabbabe and Korock, 1983; Dablin, et al., 2008*). Meat mincers are used seldom now in Scandinavia, but is an old, well known, threat to the hands. One to 3 year old children have been brought to the hospital with the machine still attached to their hands. The extent of damage (finger amputations) depends on the age of the child. The smaller the hand, the further it will go into the meat funnel (*Al-Arabi and Sabet, 1984*).

The aetiology and hand injury trend naturally differs between risk populations, due to cultural and economical variance. Incidences of injuries from specific hazards may therefore be difficult to translate to other countries, or even counties and municipalities. Some of the studies mentioned above date back as far as the

early 1980s. It is unclear if they represent current trends, as product-safety designs and measures may have been introduced since then.

Hand injury patterns in general

Previous reports of paediatric hand injury patterns are mainly retrospective hospital note studies from Emergency Departments. Paediatric hand injuries constituted from 2 to 6% of all injury attendances in three retrospective surveys of Emergency Departments in Scotland and The United States (Table 1) (*Bhende, et al., 1993; Fetter-Zarzeka and Joseph, 2002; Usal and Beattie, 1992*). Fingertip injuries ranged from 14 to 21% of all hand injury attendances. Among the most common diagnoses were lacerations (13-38%) and other mild soft tissue injuries (30-44%), followed by fractures and dislocations (16-23%). Injuries that comprised less than 5% were burns, flexor and extensor lacerations and amputations.

Children with hand injuries attending a Saudi Arabian Plastic Surgery Clinic showed a somewhat different pattern (Table 1) (*Al-Hoqail and Al-Shlash, 2000*). Fingertip injuries instead accounted for 50% of the cases. Apart from lacerations or minor skin loss (32%), injuries ranged from arterial injuries (16%), amputations (13%), and digital nerve injuries (13%) to flexor (12%) and extensor (5%) tendon injuries. Fractures and dislocations comprised only 8% of all hand injuries.

The referral rate to a hand centre in England was 22% from the Emergency Department among toddlers (0-2 years) and preschool children (2-5 years) (Table 1) (*Vadivelu, et al., 2006*). This study included 0-16 year old children (n=360), but data were reported from different age groups separately. Fingertip injuries were not categorized as a specific injury type, but crush injuries accounted for 59% of the injuries in toddlers and 77% in preschool children. These age groups included a low number of cases (n=59) and diagnoses were simply divided in skeletal or soft tissue injuries. Fourteen per cent of the toddlers had skeletal injuries and 86% soft tissue injuries. Thirty per cent of the preschool children had skeletal injuries and 70% soft tissue injuries. The injuries mainly occurred at home (83% and 87%, respectively). A predominance of girls was seen in both age groups (57% and 62%, respectively).

Specific types of injuries

In addition, different types of hand injuries have been described in the literature. Patterns of children with hand fractures attending Emergency Departments have been reported extensively in the ages 0-17 years (Table 1) (*Hastings and Simmons, 1984; Mahabir, et al., 2001; Rajesh, et al., 2001; Worlock and Stower, 1986*). Boys sustained more fractures than girls, often in their early teens due to sport. The most fractured bone was the fifth metacarpal bone.

Fingertip trauma from doors accounted for 2% of all 188 injured children (0-14 years) attending an Emergency Department in Scotland (*Macgregor and Hiscox, 1999*). Twenty two per cent of all children with fingertip injuries were proven to have a fracture. Simple soft tissue injuries with swelling and bruising accounted for 57% of all injuries, as for instance lacerations that were simply cleaned, steristripped, and dressed at the Emergency Department. One fourth of the children had more severe injuries, such as nail avulsion, and amputation of a part of the fingertip. Fifteen per cent were admitted at the Plastic Surgery Department for treatment under general anaesthesia (Table 1). These children were young and were all discharged home the following day.

Admitted children with isolated palm injuries in a Burns Hospital have been reviewed in The United States (*Barret, et al., 2000*). Flame burns, and contact burns with hot coals, produced deep injuries with a longer period of wound healing (> 3 weeks). These injuries had 40% sequel after conservative treatment. Scald burns had 20% sequel. In spite of these patterns, palm burns in children generally were considered to have a good prognosis.

A large register study of American children has described characteristics of paediatric traumatic amputations treated in Hospital Emergency Departments (*Hostetler, et al., 2005*). Results were reported separately for 0-2, 3-5, 6-12 and 13-17 year old children. Children 0 to 2 year old had a higher percentage of finger amputations (95%) in relation to the other age groups. In addition, they were almost five times more likely to sustain an amputation caused by a door, as compared to the 13 to 17 year old children. Eighty per cent of the door related amputations occurred at home and 12% in school. Doors were associated with the highest proportion of partial amputations (43%) and almost all children with door related amputations were treated and released without admission (99%). In contrast, children with amputations related to power saws were almost three times more likely to require admission to hospital. Girls accounted for a higher percentage of injuries among young children, and a much lower percentage among adolescents. Paediatric tendon injuries, nerve injuries, and fingertip amputations have been studied with the aim to evaluate treatment methods, but with less epidemiological approaches, and will not be reported here.

Costs of injuries in children

Costs within the health care sector arise from ward stay, diagnostic procedures, surgery, physician visits, and rehabilitation. These costs are often referred to as direct costs. In addition to health care costs, parents may have to stay home and take care of their injured child, leading to less income for the families, less profits for the employers, and less tax for the government (*Miller, et al., 2005*). In this way, injuries sustained during childhood may have an impact on the productivity of the

parents and also the child's future work. Lost productivity is an important measure of indirect costs of injuries.

Health care costs and lost productivity do not fully describe the burden of injuries (*Miller, et al., 2005*). Anxiety associated with injuries may reduce the quality of life for the child and the rest of the family. Children who are permanently disabled by injury may have life-long pain, or suffer permanent loss of motor or sensory function. To measure such consequences, less easy to quantify, quality of life losses are reported. These are given in years, Quality-Adjusted Life Years (QALY), instead of monetary terms. QALYs will not be calculated in this thesis.

Costs for hand injuries in children are poorly documented (*Moore, et al., 2000*). Generally, costs are more and more reported within injury research in order to translate injuries to a common metric, and possibly compare them to other health diseases. Much information comes from the United States. Current prices and organizations of the health care system differ between countries. Studies of costs of injuries in Swedish children have not been found.

In the United States, injuries account for approximately 15% of medical spending for children between 1 and 19 years of age (*Miller, et al., 2000*). The costs of injuries in American children and adolescents totalled 106 billion dollar in 2000 (*Miller, et al., 2005*). These costs mainly (77%) resulted from future work losses by injured children and adolescents, and current work losses by their care givers. Medical costs accounted for 23% (24 billion dollar) of the total cost.

Another American study, estimating costs by injury type and injury cause, found that transportation injury was the most costly category (*Malek, et al., 1991*). Falls produced only a slightly smaller cost, and were particularly important for children less than 10 years old, accounting for 39% of their injury costs. The relation between cost (medical cost and lost productivity cost), and injury cause was furthermore analysed using American national and state data (*Miller, et al., 2000*). Falls, being struck by or against an object or person, motor vehicle traffic, burns, anoxia, cutting, and piercing caused most injuries. These causes contributed substantially to overall injury costs, because the combination of their frequency in the population and the average cost per case were exceedingly high. Leading causes of injury costs varied across the age groups. Burns showed up as being among the five leading causes of injury costs only for infants and young children ages 0 to 4, while drowning was among the 5 leading causes of injury costs only for children ages 10 to 14.

Conclusion of previous research

The proportion of hand injuries in Swedish children is the second highest in relation to other parts of the body. Yet, the incidence of paediatric hand injuries

in Sweden has not been estimated. In addition, hand injury patterns among Swedish children have not been found on a national or regional level. Causes and consequences of injury vary substantially by age and developmental stage, reflecting differences in children's cognitive, perceptive, and motor abilities, as well as environment and exposure to hazards. In spite of this phenomenon, analyses of hand injuries in specific child ages are so far almost missing. This kind of research is now important to perform, in order to target preventive efforts in areas where young children spend most of their time, and against causes of injuries defined in the most explorative ages. Costs for injuries by cause has been shown to vary across child age groups, but has not been estimated for hands.

AIMS AND OBJECTIVES

The overall aim of this thesis was to increase the knowledge of unintentional hand injuries in Swedish children, and to establish data that may be utilized in preventive efforts.

The objectives were

- To calculate the incidence and overall pattern of hand injuries in children between the ages of 0 and 6 years old and referred for treatment or follow up. (I)
- To analyse the cohort of Swedish children between the ages of 0 and 14 years old and hospitalized for hand injuries, as to incidence and in order to find risk groups. (II)
- To estimate if age, gender, and national background have an impact on the occurrence of hand injuries in children between the ages 0 and 6 years old referred for treatment or follow up. (I and III)
- To assess environmental risk factors and circumstances that recurrently contribute to the occurrence and severity of hand injuries in children between the ages 0 and 6 years old and referred for treatment or follow up. (III)
- To estimate what factors that have an impact on the health care costs for hand injuries in children between the ages 0 and 6 years old and referred for treatment or follow up, and in addition calculate the cost for lost productivity. (IV)

PATIENTS AND METHODS

Study population

Sweden

Sweden had 8 973 000 residents in 2003, of which 1 584 000 were 0 to 14 year old children. Forty nine per cent were girls (*Statistics Sweden, 2003*). The private hospital sector is very small in Sweden, and the provision and financing of health care services is a public sector responsibility. The primary level is the level of the health care system to which people are able to turn to with any health problem. It treats diseases and injuries that do not require hospitalization. Medical services are provided at county level, and regional level, for hospital treatment. Nine university hospitals have a wider range of specialist and sub-specialist fields, for example neurosurgery, plastic surgery and hand surgery (www.socialstyrelsen.se).

Malmö

Malmö municipality had 267 000 residents in 2003, of which 18 900 were 0 to 6 year old children. Forty nine per cent were girls (*Statistics Sweden, 2003*). The city of Malmö has one hospital, Malmö University Hospital (UMAS), treating essentially all injuries needing hospital care. The private sector is very small (3%) and rarely treats emergency trauma. Children with hand injuries requiring hospital treatment attend the Emergency Department of Orthopaedics. Injuries needing specialist care are referred to the Department of Hand Surgery. Severe hand injuries from other parts of southern Sweden (population 2003: 1 700 000 inhabitants) are referred from the local hospitals in the region to the Department of Hand Surgery for specialist treatment.

General inclusion criteria

Diagnostic criteria

All soft tissue injuries (including burns) distal to the elbow, and fractures distal to radius and ulna, were included in all studies. Infections and bites of the hand and forearm were included, except in study II. I had no access to the hospital notes in study II, and was not able to confirm the origin of infections and bites. Soft tissue injuries to the forearm were included as these injuries traditionally are referred to a hand surgeon in Sweden. Throughout the thesis, all hand injuries and soft tissue injuries to the forearm together are denominated hand injuries. The diagnoses of all patients included in study I-IV were coded by the Swedish version of WHO's International Classification of Diseases 9 (1987-1996) and 10 (1997-2003). All

studies were approved by the local Ethics committee at Lund University, Sweden (Dnr LU 451-03, LU 731-03, LU 707-01).

Ambulatory and hospital care

Children referred to the Department of Hand Surgery, Malmö University Hospital, were included in study I, III and IV, whether they were treated as outpatients or were hospitalized. No national data from ambulatory care (children treated as outpatients) were available in the Hospital Discharge Register during 1987-2001. Therefore, in study II, only children admitted to hospitals (children that have to stay at least one night at the hospital during treatment) were included.

Age criteria

The age criteria 0 to 6 years were established to find specific incidences, aetiologies, injury patterns, and costs among young children (study I-IV). In study II also older children (7-14 years) were included with the purpose of a large study material, and the ability to make comparisons between younger and older children in Sweden. Children from 15 years of age were excluded from this study, as the injury mechanisms from this age were considered to receive a more adult pattern with work related injuries.

Details and statistics of each study

Retrospective hospital note study (1996-2000) (I)

The children included in the study suffered unintentional hand injuries between January 1996 and December 2000, and were treated at the Department of Hand Surgery, Malmö University Hospital. They were identified from the hospital register by ICD-9 (800A-999X) and ICD-10 (S00.0-T98.3). Date of injury, localisation of injury, aetiology, location and type of injury, age, gender, treatment, length of hospital stay, number of physician visits, and national background were retrieved from the hospital notes. The injuries were classified as fingertip injuries, fractures (proximal to the distal interphalangeal joint and distal to radius and ulna), burns, skin and soft tissue wounds, nerve injuries, tendon injuries, complex injuries, sprains/dislocations, infections and bites. A complex injury was defined as either an injury to more than one of the anatomical components of the hand (bone, flexor/extensor tendon, joint, nerve and artery) or total/subtotal amputation through the middle or proximal phalanges. A combined tendon and digital nerve injury was considered a tendon injury.

Descriptive analysis of age was performed and median values and ranges were calculated. The annual incidence was calculated by comparing the number of children from Malmö included in the study to the total number of children at risk (*population in Malmö 1996-2000: Statistics Sweden*).

Between the years 1996 and 2000, a percentage of all outpatients treated at our hospital were not given a registered diagnosis. In the years 1996 and 1997, the number was unknown, and between 1998 and 2000 it ranged from 38% to 28%¹. Hence, there may be more hand and forearm diagnoses in reality during the early years of the study period. An additional search in the register for all 0 to 6 year old children that were treated at the Department of Hand Surgery between 1996 and 2000, independent of diagnosis, showed that the number of children in ambulatory care that were missed in study I and IV, were 7 children during 5 years. This probably influences my results only marginally.

Retrospective register study (1987-2001) (II)

The Swedish Hospital Discharge Register was used to retrospectively find all children (0-14 years) with a hand injury admitted to Swedish hospitals during 1987-2001 (for diagnoses included, see Appendix 1). In addition to a National Registration Number (NRN), data from the register include information of age, gender, place of residence, domicile, hospital, department, dates of admission and discharge (date when the patient leaves the hospital), length of stay, mode of admission and discharge, main diagnosis, secondary diagnoses, external cause of injury (E-code: for E-codes included, see Appendix 2), and surgical procedures. Hand injuries at index admission were categorized and analysed for characteristics as for instance age, gender, and incidence.

Descriptive analysis of patients, diagnoses, external causes, and hospitals was performed. Median values and Interquartile Ranges 25 and 75 were calculated. The incidence was calculated by comparing the children's first admissions for a hand injury to the total number of children at risk (*population in Sweden 1987-2001: Statistics Sweden*). The incidences of different types of injuries were analysed by Poisson regression with calendar year, age, and gender as explanatory variables.

Prospective questionnaire study (2002-2003) (III)

All children suffering unintentional injuries between February 2002 and January 2003, and treated at the Department of Hand Surgery, Malmö University Hospital, were invited together with their parents to participate in the study. A

¹ Personal communication by e-mail with Helen Manger, controller, Malmö University Hospital

questionnaire was completed by the parents and/or with the aid of the medical staff during hospital stay. The same details from the hospital notes were retrieved as in study I.

Statistical methods used included calculations of incidence rate ratios (IRR), standard descriptive analysis, and 95% confidence intervals (CI) (*StataCorp, 2003*). In a study from the Department of Plastic and Reconstructive Surgery, Malmö University Hospital, an overrepresentation of children with a foreign background was found among scalds (*Freccero, et al., 2000*). In study III, one of the main purposes was therefore to define how many children with a true foreign background in the questionnaire (the child was born abroad, or both parents were born abroad). The difference was calculated using incidence rate ratios (IRR) with 95% confidence intervals (CI).

Retrospective hospital note and questionnaire study (1996-2003) (IV)

Study IV is a fusion of study I and III, and the inclusion criteria are mentioned above. The information of health care resource use was collected from the hospital notes. From the questionnaires we had information on if, and for how long, each of the parents was absent from paid work as well as their normal profession and occupation. The cost of lost productivity was calculated from the number of days the parents stayed at home to take care of their injured child, using the human capital approach (*Byford, et al., 2000*). The costs within the health care sector were calculated using the fees paid by a referring hospital, for patients registered outside the region of Skåne, and included overhead cost using year 2000 prices.

Based on the diagnoses and the mechanisms of injury, together with experience from my earlier studies, I constructed seven case categories that correspond closely to alternative prevention strategies. These were; A) burn injuries caused by hot objects, B) fingertip injuries caused by jamming in doors or other pinch objects, C) fractures, dislocations and sprains caused by falls or hits, D) tendon and nerve injuries and wounds caused by sharp objects, E) complex injuries caused by falls with sharp objects, F) complex injuries caused by machines and rifles and G) other injuries.

Data is described using median, 25th and 75th percentiles, for the total sample. Multiple regression analysis was used to analyse what factors were associated with the variation in costs (*Greene, 2000*). The negative binomial regression model was used in the analysis of factors associated with the variation in length of stay. All analyses started by including all the available variables that were hypothesised to have an influence on costs. The least significant variable was then excluded and

the model rerun. This procedure continued until only variables significant at the 5% level remained (reduced model) (Rosberg, *et al.*, 2003; Rosberg, *et al.*, 2005).

RESULTS

Hand injuries in young children (I)

The average incidence of young children with hand injuries referred to the Department of Hand Surgery, Malmö University Hospital, was 27/10 000 children/y during 1996-2000. The incidence increased from 17/10 000 children/year (1996) to 38/10 000 children/y (2000). Totally 455 children were referred from the Emergency Department, accounting for a referral rate of about 57%. Furthermore, 59% of all children included were admitted. The median age was 3.7 years (range 0.2-6.9) and 39% were girls. In May and September there was a peak in the number of injuries, which were in general more common during the summer months.

The most common type of injury was a fingertip injury (37% of all injuries) in the ages 1-5 years. The 166 children with fingertip injuries had either a soft tissue injury (18%), a nail bed injury (26%), a fracture of the distal phalanx (14%), a fracture and a nail bed injury (17%), or an amputation of the distal phalanx (24%). Multiple fingertips were injured in 14 children. The most common injury mechanism was jamming in a door. Fingers were also jammed in bicycles or in furniture and play tools. Among the fractures² (17% of all injuries), 72% were closed fractures and the proximal phalanx of the fifth digit was the most fractured bone (Figure 1). Falls and punches caused many of the fractures. Among the burns (16% of all injuries), 72% were of second degree. Burn injuries usually occurred when the children placed their hands on a hot plate or oven door, though some were scalds. Twenty three children suffered from flexor tendon injuries (5% of all injuries), of which 15 had a concomitant digital nerve injury. Fourteen children had nerve injuries (3% of all injuries). Falls when holding, or pressing against, sharp objects caused about a third of the tendon and nerve injuries, and a fourth of the complex injuries (4% of all injuries). In addition, mincer machines, wood cutters, wringers, and one rifle caused complex injuries.

The study did not include children treated in the Emergency Department and sent home without being referred. Additional information was therefore retrieved from the hospital register³. A number of 340 children with a hand or forearm diagnosis (according to Appendix 1) were registered as being examined at the Emergency Department during 1996 to 2000, but without requiring follow up at the hospital. There was no possibility to look through the notes of these children. There may be children who sustained an injury before 1996, intentional injuries or infections or wrong diagnoses. Thirty six per cent of these children had a contusion, 25% had a wound without a complication, 21% had a wrist distortion

² Proximal to the distal interphalangeal joint and distal to radius and ulna

³ Personal contact with Helene Manger, controller, at Malmö University Hospital

and 13% had a closed fracture of a finger phalanx. These injuries were considered to be minor injuries not requiring follow up. Those injuries included in study I were considered to need a follow up at the hospital. I was interested in hand injuries with a specific severity, requiring treatment at the Hand Surgery Department.

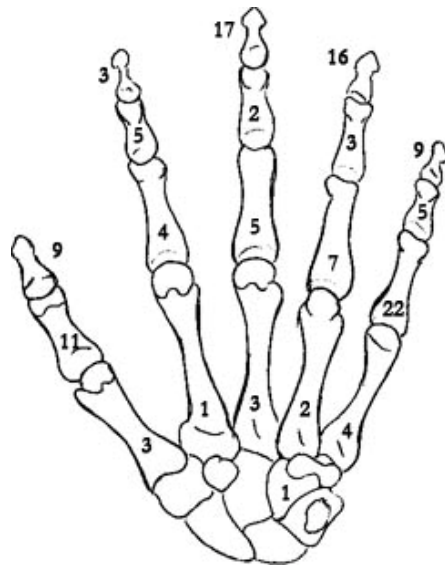


Figure 1. Localisation of fractures in 127 children (study I).

Hospitalized hand and forearm injuries in Swedish children: a retrospective review (II)

In a national study, 9 855 children with hand injuries were included, or an average incidence of 40/100 000 children/y and 42/100 000 children/y among young (0-6 years) and old (7-14 years) children. The total incidence increased from 1987 to 2001 both among young and old children. Wounds and fractures almost doubled over the study time from about 8 to almost 15 per 100 000 children and year. In contrast, the incidence of children with muscle and tendon injuries decreased from slightly less than 10 to about 6 per 100 000 children and year.

Different diagnostic categories showed specific patterns in relation to age (Figure 2). The relative incidence girls/boys (95% CI) was 0.64 (0.60-0.68) in young and 0.45 (0.43-0.48) in old children. The higher rate of boys was found in

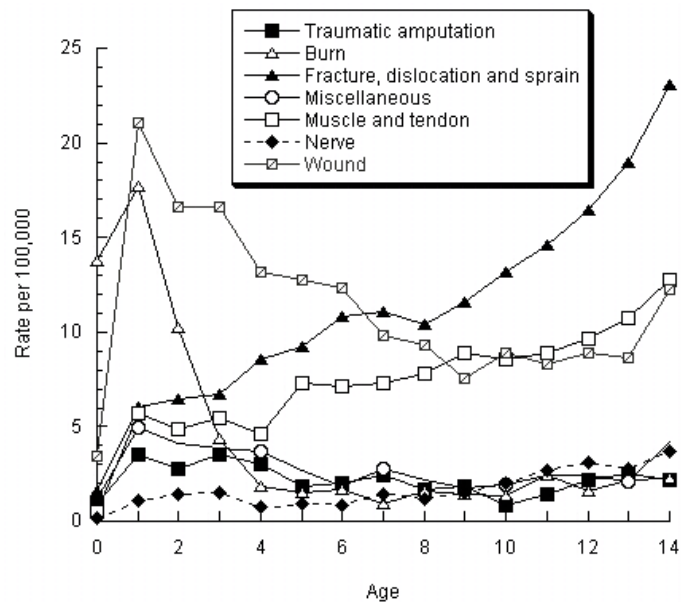


Figure 2. Incidence of children with different types of injuries as a function of calendar year of occurrence.

all diagnostic categories, though traumatic amputations in young children were quite as common among girls as boys [0.80 (0.65-1.01)].

Some information about injury patterns was available from the diagnoses settled. Among all fractures, finger phalanges (injured in 71% of all fractures) were injured more frequently than the metacarpal (21%) and carpal (5%) bones. Few injuries occur to the carpal bones in young children (*Landin, 1983; Mahabir, et al., 2001; Worlock and Stower, 1986*). Burn injuries were of second (in 57% of all burns), third (15%), and first degree (8%). Flexor injuries (accounting for 64% of all tendon injuries) of the hand and forearm were more common, as compared to extensor injuries (28%). The median nerve (injured in 25% of all nerve injuries) was injured more frequently than the ulnar (18%) and radial (3%) nerves, while digital nerves were injured in 51% of all children with nerve injuries. Traumatic amputations were localized to the thumb (in 17% of all amputations), other fingers (74%), multiple fingers (5%), and forearm (3%).

Interestingly, 5% of the young children were injured by contact with machinery, and 3% of the old children were injured by contact with handgun/firearm discharge or explosion of material. This means that children have access to dangerous equipment that is only meant for adult use. Caught, crushed, jammed

or pinched in or between objects was the overall most common injury mechanism in young children (26%).

Risks for, and causes of, injuries to the hand and forearm: a study in children 0 to 6 years old (III)

Ninety six children were referred and treated at the Department of Hand Surgery during the study period. Seventy-nine (82%) children answered the questionnaire and were included in the study. The median hospital stay was 2 days (range 1-20 days). Fifty four children underwent surgery and in 40 cases the operation started within 24 hours after the injury had occurred.

In 2002, seventy three percent of 1 to 5 year old children in Malmö were registered in a municipality or a private day care centre (*Skolverket, 2002*), but only 6 of all 79 children included in our study were injured in day care centres. Injuries were to a large extent sustained in the home environment (Figure 3).

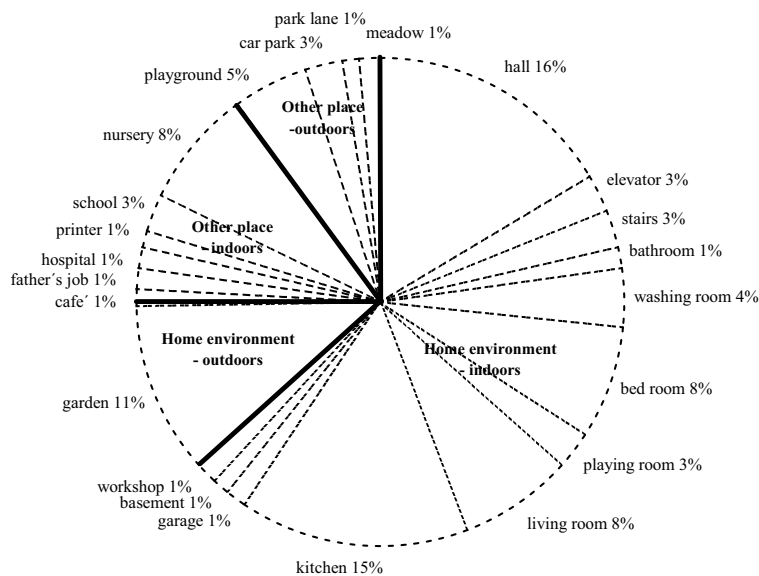


Figure 3. Location where 79 young children were injured (study III)

The risk for a hand injury was increased between 0 pm and 4 pm [IRR 3.50 (95% CI 1.37-12.50)] and increased further between 4 pm and 8 pm [IRR 5.17 (95% CI 2.12-17.7)].

Jamming in doors (n=40) caused most of the injuries, almost equally on the lock (n=20) and hinge (n=15) side. The front door (n=23) was the greatest hazard. A child, often the child itself (n=9) or a brother (n=7), closed the door rather than an adult (n=7). There was no difference in the presence of children (34/40: 85%) and adults (32/40: 80%) as door injuries occurred. Overall, adults were present when 66 of all 79 children were injured. Most injuries occurred during play (n=39).

Thirty nine per cent of the children (0-6 years) in Malmö municipality were born abroad or had parents that were born abroad (*Statistics Sweden, 2002*). Among the children registered as citizens of Malmö in our study (n=64), there was no difference in injury frequency between children with a Swedish background and a foreign background [IRR 1.19 (95% CI 0.64 to 2.28)].

Cost per case or total cost? The potential of prevention of hand injuries in young children – retrospective and prospective studies (IV)

The total annual health care cost for hand injuries in 533 children decreased from EUR 398 762 in 1996 to EUR 247 540 in 2000. The main contributor to the health care cost was ward days, followed by surgical sessions and physician visits. Lost productivity accounted for 14 percent of the total cost (health care cost + lost productivity). The median cost was higher, and the length of stay longer among patients from the area outside Skåne during the entire study period, partly associated with the fact that referrals from outside Skåne did not include milder cases/were predominantly more severe cases. The six defined case categories accounted for about two thirds of the costs, if the category “others” was excluded.

The cost per fingertip injury caused by jamming in door or other pinch object (B) was about EUR 2 500 (Figure 4 a and b). The total health care cost for these 188 cases was about EUR 570 000 during the study period. Fingertip injuries caused by jamming in doors or other pinch objects could be distinguished from the other cases known as relatively frequent from study I-III. Children with fractures from falls and hits (C) accounted for 47 cases, and had the lowest cost per case (less than EUR 1 000), due to few ward days needed and no operation was required. The total cost was therefore only about EUR 70 000, the lowest count of all cases. A burn injury caused by contact with a hot object (A) also had a low cost per case, about EUR 1 000, but a few children needed multiple dressings and treatment with antibiotics. Because of these outliers, the total health care cost for 82 cases (EUR 170 000) was more than twice as high as for fractures caused by falls or hits. Sharp objects caused a significant cost per tendon, nerve injury or wound (D) (EUR 4 000), but few cases were really expensive.

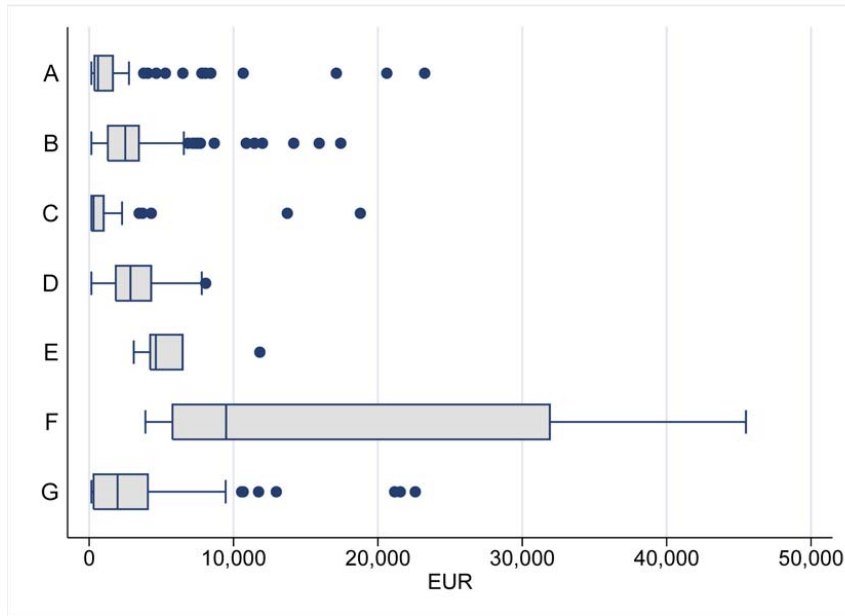


Figure 4a. Box plot of health care cost (EUR) by type of case, sorted by median cost.

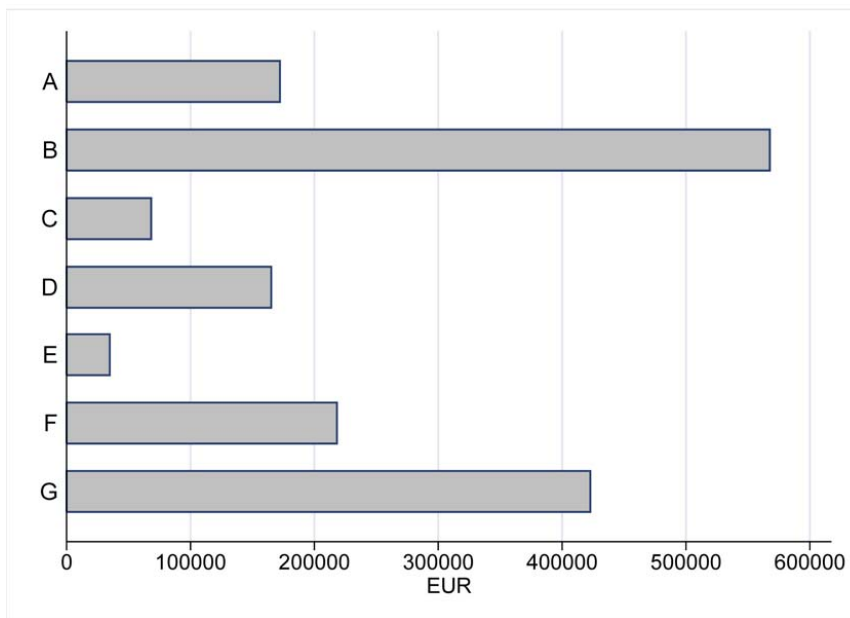


Figure 4b. Bar plot of health care cost (EUR) by type of case, sorted by total cost.

Even though they had a slightly similar frequency (n=55), the total cost (EUR 170 000) was more than twice as high as for fractures caused by falls and hits, and about the same as for burns caused by hot objects.

Complex injuries caused by machines or rifles (F) entailed almost EUR 10 000 per case. Despite the low number of cases (n=12), the total cost exceeded EUR 200 000. These children were admitted within one day after injury, often with an urgent transport by ambulance. In contrast, complex injuries caused by falls with sharp objects (E) showed the lowest total cost of all cases, about EUR 30 000. Though second highest cost per case (about EUR 5 000), the low frequency (n=6) in combination with only one outlier with extremely high cost per case, decreased the total cost.

An increasing age was associated with less ward days [IRR 0.99 (95% CI 0.99-1.00)], but age had no significant effect on the health care cost in regression analyses controlling for individual and injury characteristics. We found no difference between girls and boys when considering health care cost or length of stay. Having a foreign background was associated with more ward days [IRR 1.23 (95% CI 1.00-1.51)], but had no significant effect on health care cost.

In our data, 12 of the pinch-injuries in Malmö happened at the day care centre or school, while 46 occurred at home, and 29 during leisure time. The mean number of children that went to day care centres in Malmö between 1996 and 1999, was 10 870⁴, and the mean number of 1 to 6 year old children living in Malmö was 17 590 (*Statistics Sweden, 1996-1999*). I estimate that only a few children injured their hands at a day care centre, compared to the fact that 62% of all children went to day care centres during our study period. The most probable explanation may be that safety doors are already installed at day care centres and schools in Sweden.

⁴ Information achieved by personal contact with Tarek Borg, Malmö Municipality

GENERAL DISCUSSION

The current thesis presents incidence rates of children with hand injuries referred for treatment in Malmö Municipality, as well as hospitalized children with hand injuries in Sweden. An increase over time was found between 1996 and 2000, and between 1987 and 2001, for unknown reasons. Girls were less likely than boys to suffer from hand injuries. The leading injury types and etiological factors varied across the ages. Fingertip injuries caused by jamming in doors were common in all young ages, and occurred predominantly in home settings. Despite a modest cost per case, their frequency in the population generated large health care costs. In contrast, children with complex injuries caused by machines induced a high cost per case, and a substantial total cost, despite the low number of cases per year. Obtained information may be used to improve prevention strategies, with the purpose to decrease incidences of hand injuries in children.

Strengths and weaknesses

Some strengths and weaknesses of the thesis should be mentioned. First, the fact that Malmö Municipality has only one hospital, and that the private sector is small, make it possible to analyse injury patterns in children from a defined catchment area. Study I, III and IV also include children from other parts of Southern Sweden. This makes the catchment area less defined, but the purpose was to additionally analyze these more severe injuries. Hence, the injury pattern in these studies tends to have preponderance to severe injuries.

Incidence measured in study I and III were based on defined risk populations, as only children from Malmö with hand injuries were compared to the total number of children, in the same ages, in our municipality. The number of patients from Malmö that are treated elsewhere is, due to several reasons, judged to be low, and I did not calculate the cross boundary flow. In addition to the calculated incidences, children with mild injuries may have been treated at home or in the primary health care. Of all children that attend the Emergency Department, many are treated and sent home immediately, with injuries not requiring follow-up. The 340 children registered only at the Emergency Department, with a hand diagnosis during 1996-2000 (study I), were treated for contusions, wounds without complications, closed fractures of finger phalanges, and wrist distortions. I did not retrieve any details from the notes of these patients, nor did I include data from the primary health care. Calculations of total incidence and injury patterns of all children with hand injuries would have required these data.

Lack of data from ambulatory and primary health care in the Swedish Hospital Discharge Register also made it impossible to calculate the total incidence in Sweden between 1987 and 2001. Still, the delimited cohort of Swedish children

during 1987-2001 enabled good quality incidence estimates of all hospitalized children with hand injuries, in a country where the private health-care sector is very small. Furthermore, the fact that almost 10 000 children were included in study I, makes percentages and descriptive statistics safe to rely on.

The retrospective design of the studies did not make classification of severity and outcome possible. The inclusion criteria of treatment referred hand injuries, naturally brings a selection of more severe injuries. Admission of an injury to the hospital indicates further severity. This is, however, uncertain, as different physicians and hospitals may use different criteria when judging if a child needs follow up or admission. Data of outcome have not been presented in the thesis. An additional look through all case notes in study IV showed that eighty four percent of the children were not considered to have any persistent disability at the final examination of a physician. An indication that very few of the patients had any disability is also that few certificates to the insurance companies were written, a common procedure in Sweden if the complaint persists. In previous research, there is little attention given to outcome. One reason for this is probably methodological difficulties, but may also be the fact that the outcome is frequently very good. Children, except for a few severe cases, may have little problems after a hand injury. Outcome is a subject that needs to be further studied, especially in connection with aetiology, and type of injury. Most outcome instruments are developed to evaluate disability in adults with a history of injury, for instance DASH or SF36. Injury specific questionnaires have not been found for children.

Finally, indirect costs were measured as lost production on the labour market. No attempt was made to value potential impact on non-market work or leisure time (study IV). Furthermore, the analysis did not include quality of life issues, and will thus to some extent underestimate benefits of preventive strategies. In principle, the cost to the child in terms of the reduction in opportunities to play etc could also be included, but it was beyond the scope of this thesis to quantify the limitations by type and quantity of activities of the child.

Comparison to previous research

Most of the previous literature on paediatric hand injuries is difficult to relate to studies presented in this thesis. Apart from cultural differences and risk population based differences, the reasons for discrepancy are principally of two kinds: age criteria and selection of patient material. Although no similar earlier research was obtainable, some comparisons of important findings in this thesis to previous literature will be presented, as to incidence, season, location of injury, and circumstances around injuries from doors.

General inclusion criteria

Age criteria in the thesis were chosen in order to study specific patterns in young children. Previous reports on children aged 0 – 18 perhaps benefited because there was a larger pool and pattern of patient material (*Bhende, et al., 1993; Fetter-Zaręka and Joseph, 2002; Mirdad, 2001; Thomas, et al., 1998; Usal and Beattie, 1992*). Unfortunately, this prevents comparison between developmental stages and direction of injury prevention. Sports cause many of the injuries among older children, as well as summer work injuries during adolescence and injuries sustained in school (*Hasserijs and Tufvesson, 1990*).

All children referred to our Department of Hand Surgery from the Emergency Department at Malmö University Hospital were included in study I and III. Generally, previous studies of hand injuries are performed in Emergency Departments with referral rates as for instance 6% (*Usal and Beattie, 1992*) (Table 1). Furthermore, the admission rate was 59% in study I and 65% in study II, in relation to 1%, 3% and 6% reported among children attending Emergency Departments (*Bhende, et al., 1993; Fetter-Zaręka and Joseph, 2002; Usal and Beattie, 1992*) (Table 1). Comparison of hand injury patterns based on such different conditions is impossible. An interesting finding is that the referral rates from our Emergency Department were high: 53% in study I and 57% in study III. Possible explanations may be different age criteria, and different traditions between countries and hospitals to treat small children under general anaesthesia. Our high referral rate may, in addition, be one explanation to the high incidence rate of hospitalized children in Malmö, as compared to the rest of Sweden (study II). Large national database analyses of paediatric hand injuries, as well as studies where only hospitalized children were included, have not been found. Hence, incidences and risk groups identified among Swedish hospitalized children with hand injuries could not be compared to previous literature.

Incidence

The average incidence of hand injuries during 1996 to 2000 in Malmö, Sweden, was 27/10 000 children/y. A study of 0 to 16 year old children with injuries referred to a hand centre in England, reported number of hand injuries in toddlers and preschool children separately (Table 1) (*Vadivelu, et al., 2006*). In United Kingdom, children start school when they are 5 years old and the criteria “preschool children” may therefore result in different patterns in England and Sweden. The population at risk in the study performed by Vadivelu et al. was 42 244 children (0 to 5 years old), and the number of children injured during one year approximately 118. Based on these numbers, I estimated an incidence of both skeletal and soft tissue injuries at 28/10 000 children/y (Table 1). Hence, the incidences in 2006 in Derby, England, and during 1996 to 2000 in Malmö, Sweden, seem to be comparable. The injury patterns were also rather similar, but

Vadivelu et al. report more unspecified soft tissue injuries. A few differences between our studies are, however, worth mentioning. The referral rate to the Hand Centre from their Emergency Department was 35%, which is half as much as the 57% estimated at Malmö University Hospital. In addition, their study was performed between April and September. Hand injuries were more common during the summer in the present thesis (study I and II). Hence, I do not know for certain if their incidence is an overestimation, as the incidence tends to decrease during the winter.

An annual incidence of 13 hand fractures per 10 000 children (0 to 6 years old) per year was found in Malmö, Sweden, between 1975 and 1979 (*Landin, 1983*). Landin counted number of fractures registered and treated in Malmö University Hospital, in contrast to number of children with fractures referred for treatment or follow up at the Department of Hand Surgery. In study I, the number of children with hand fractures between 1996 and 2000 was 127. The risk population during these years decreased from 20 885 in 1996 to 19 659 in 2000. An average annual incidence of children referred for treatment at the Department of Hand surgery, with fractures distal to radius and ulna, could by using these numbers be approximated to 13/10 000 children/y. The incidence of persons in all ages, attending our Emergency Department with a registered hand diagnosis, was estimated to 70/10 000 persons/y in 1997, the population at risk being Malmö Municipality (*Rosberg and Dablin, 2004*). The incidence of persons with hand and forearm injuries referred to the Department of Hand Surgery for treatment was 32/10 000 persons/y. Hence, the incidence is similar in young children, as compared to all ages.

The incidence of hand injuries in general increased in Malmö between 1996 and 2000, but was limited to the ambulatory care (study I). The number of hospitalized children did not tend to increase: the injury pattern rather changed toward mild injuries as wounds. Still, the incidence of hospitalized children with wounds and fractures in Sweden increased as well during 1987 to 2001 (study II). There are many reasons for why the utilization of health-care resources changes over time. Hand and forearm injuries may have become more frequent in the population. Other reasons could be that the diagnostic procedures change and treatment technologies advance. In addition, organisation of the health care system also changes, influenced by political and economic factors. Parents may be more prone to seek health care for mild injuries. The reason for the increase in incidence in Sweden between 1987 and 2001, and in Malmö between 1996 and 2000 was, however, beyond the limit to analyse in retrospective and register studies. One cannot exclude that there is a variation over time, since the incidence of children referred for treatment or follow up in 2002-2003, was somewhat lower (33/10 000 children/y in study III).

Season

A high proportion of admitted children with hand injuries occurred from May to September, similar for all types of injuries, except for burns which occurred more often in January, April and December (study II). No seasonal differences were found among young and old children. Peaks of injury frequencies in May and September, seen in study II, were also reported in a study of children with all kinds of injuries in Gothenburg, the second biggest city in Sweden (*Nathorst Westfelt, 1982*). One reason for these patterns may be that injuries generally occur more often from May to September, but that children go out in the country during the months June, July and August. When an injury occurs during this time, the parents may attend smaller local hospitals, instead of seeing a doctor in their home town. The peaks were not found when hospitalized children from the whole country were analyzed (study II).

Is our home our castle?

The risk for a paediatric hand injury was increased at home, in the evening between 4 pm and 8 pm. The fact that the home is where children often sustain injuries has been shown in a number of previous reports (*Bhende, et al., 1993; Doraiswamy and Baig, 2000; Laflamme and Eilert-Petersson, 1998; Mirdad, 2001*). No literature has, however, been found that relates location of injury to how many hours children spend in different locations during the day. Though it was impossible to calculate exposure rate in day care centres, 73 % of all children went to day care centres in Malmö during 2002. If one assumes that many of these children spend at least 30 hours per week in day care centres, the number of children injured in day care centres in study III (6%) is low. Instead, from study IV, I know that many parents were at home on parental leave, and did not have to stay home from work to take care of the injured child. Hence, the time that young children in Malmö spend at day care centres is difficult to estimate, and percentages may not be sufficient measures.

Several authors have shown that most of the paediatric hand patients present to the Emergency Department from late afternoon (3 pm to 4 pm) to midnight (*Bhende, et al., 1993; Fetter-Zarżeka and Joseph, 2002; Thomas, et al., 1998*). Age criteria in these studies included children up to 16 and 18 years. The most common locations of injury reported were outdoors (including backyard; 42%) and at home (61%; data not shown by Thomas et al.). Locations and causes of hand injury naturally differ a lot between 0 and 18 years. Yet, the time when older children get injured seem to be similar in relation to 0 to 6 year old children included in study III. This may indicate that the common reason is the safe day care centres and schools, as children of all ages often get injured in the evening when they spend time outside these institutions. From this point of view, prevention efforts should now be directed to other locations than day care centres and schools.

When doors slam, fingers jam

Within the home, the location of doors causing finger injuries has been analyzed in children attending an Emergency Department in Scotland (*Doraiswamy and Baig, 2000*). Doors were principally located in the living room and toilet or bath room. Among children referred to our Department of Hand Surgery in study III, the front door in the hall was more of a hazard for fingers than the inner doors. Age criteria and risk population may again be explanations for discrepancies. Fingertip injuries referred to specialized care may in addition present a more severe pattern, possibly caused by other doors? Unfortunately, the severity of isolated finger injuries analyzed by Doraiswamy and Baig was impossible to compare to finger injuries described in study III.

It has been approximated that injuries caused by doors in all ages may amount to 17 000 per year in Sweden, and cause substantial costs (*Björnstig and Björnstig, 1999*). Furthermore, almost half of the injuries occur in children. In contrast to patterns with frequent front doors among young children (study III), Björnstig et al. showed that inner doors caused 63% of all door injuries in 0 to 96 year old persons. Among 0-12 year old children in their report, fingers were jammed about equally on the lock and on the hinge of the door, similar to what I found among 0 to 6 year old children. Among persons older than 12 years, the lock side was a more common site of injury. An increase of the lock/hinge side ratio with age could depend on the size of young children's fingers, which fit perfectly into exciting chinks of doors, in combination with the fact that they do not know that the hinge side of the door is dangerous.

In line with these thoughts, the injured child seldom closed the door itself in study III. Door closers were also reported in a study from The Netherlands (*Venema, 1995*). Jamming in doors in houses was analyzed by using questionnaires distributed to persons of all ages treated in Emergency Departments. Among Dutch children (0-12 years), the door was closed by another person in 75% of the cases. In contrast to study III, where a child often closed the door, the closer was very often a parent. In older Dutch children and adults, half of them closed the door themselves. The estimate that young children jam their fingers on the hinge side, is thus confirmed by the fact that they seldom close the door themselves when an injury occurs. In contrast, when adults close the door themselves, they are injured on the lock side. The number of door cases in our study (n=40) is however low, and further research is needed before statements can be made.

Cost per case or total cost?

The six defined case categories, excluding others, accounted for two thirds of the health care costs for hand injuries in young children. Fingertip injuries caused by

jamming in doors or other pinching causes, as well as complex injuries caused by machines, are both important from a cost point of view. The high impact of these two cases on hand injury costs in children were dependent on a combination of their frequency in the population, and the average cost per case. The relative frequency versus cost per case, however, varied in the two case categories. Though fingertip injuries caused by jamming in doors or other pinching causes were not unreasonably costly per case, it was primarily because of their frequency in the population that they were the most costly paediatric hand injuries overall. In contrast, although complex injuries caused by machines occurred much less frequently than fingertip injuries, they were often severe and caused substantial total costs. From a cost point of view, the ideal preventive efforts would include a mix of interventions that greatly reduce the incidence of fingertip injuries caused by jamming in doors or other pinching causes, but also more directed interventions that reduce the incidence of complex injuries caused by machines.

The costs to society in terms of lost productivity (when parents stayed at home) accounted for 14% of the total cost, and were about equal in magnitude to that of outpatient visits. Previous analyses of adults with tendon, nerve and other hand injuries, showed long periods of sick-leave, implying that the cost of lost productivity accounted for 60 to 87% of total costs (*Rosberg, et al., 2003; Rosberg, et al., 2005; Rosberg and Dahlin, 2004*). This may reflect at least two differences between children and adults. First, the fact children were able to attend the day care centre, and adapt their play to the conditions of the injury. Hence, the injury had less consequence due to adaptable “usual activities”. A few adults in the previous studies had a job where the hand injury caused less impairment, but in the typical case, workers were not able to perform their normal tasks at work, and were thus granted sick-leave. Secondly, eleven (14%) mothers and fathers reported that they were on parental leave at the time of the injury. Thus no additional sick-leave was granted, as the parent was already at home taking care of the injured child and his/her siblings.

Impact on injury prevention

Any child may suffer from a hand injury, and prevention should be directed at all parents and their children. As a complement to this, we now know that boys are more prone to suffer from hand injuries than girls, which is true for all types of injuries. Yet, girls are about as likely as boys to suffer amputations in the young ages, a fact confirmed by a large study of amputations in American children (*Hostetler, et al., 2005*). The preponderance of boys is still accentuated in older children, despite the fact that girls nowadays take part in sports and more and more get injured in the same way as boys. Apart from gender, age was also shown to have an impact on the occurrence of hand injuries, as children in different ages were prone to acquire specific types of injuries. In contrast, hand injuries in general seem to occur independently of national background. This may be

different for certain aetiologies, such as steam roller presses and scalds (*Dahlin, et al., 2008; Freccero, et al., 2000*).

The division of the injuries and mechanisms into seven categories in study IV was an attempt to make the results more easily accessible for preventative work. The number of children in the groups ranged from 6 to 188. The group including other children that did not fit into the selected well defined categories was the second biggest group. From a statistical point of view this may be less satisfying. Yet, cases were selected with experience from my earlier studies, where different patterns and circumstances tended to be repeated or severe. With additional information from previous literature, and from a safety point of view, some further conclusions about the cases may be added.

Jamming in doors causing fingertip injuries was a frequent case in all preschool ages. The most severe such cases resulted in a fingertip amputation, but seemingly maintained function of the hand. The total price label for treating fingertip injuries, caused by jamming in doors or other pinching causes, was EUR 570 000 between 1996 and 2000. A cost saving analysis example of installing doors with safety equipment in the homes, however, called for selective prevention strategies, where safety doors are primarily installed in locations where young children typically stay. Ideal prevention efforts naturally depends on what type of safety equipment exists for doors, how familiar families are with this equipment, and their attitude to buying them?

Safety equipment for doors mentioned in the literature are merely of two types (*Doraiswamy, 1999; Venema, 1995*). One type is changing the shape of the hinges, making the door “unpinchable”. Unpinchable doors are installed in many day care centres in Sweden (Figure 3 in paper III). There are also strips that are permanently installed over the hinge side. The other type of device is designed to prevent the door from being slammed. A door buffer can be permanently installed on the top of the door to prevent it from closing with force. A rubber stop can be placed under the door so that it is out of the way in areas where children play. A similar simple advice is to hang a towel over the door, preventing it from being closed. Familiarity with door safety devices was shown to be generally low among Dutch families (*Venema, 1995*). About one third of the respondents to a questionnaire stated that they had heard of a door buffer or a door stop (38 and 31%, respectively). A door strip was known to 18% of the respondents. The door strip was, however, considered to be effective in preventing the accident that they had suffered by 41% of the respondents. The door buffer and the door stop were considered effective by fewer respondents (23% and 6% respectively). Of all respondents, seventy per cent stated that they were not considering buying a door safety device.

Injuries caused by contact with hot oven plates and oven doors were limited to the youngest children, who were unaware of the danger (*Yanofsky and Morain,*

1984). Already in children 14 months and older, burns are accidental in that children may be pushed or fall against the hot objects. Though there were a substantial number of cases, most of these children were treated as outpatients, and few operations were needed among admitted children. Sequel and complications were limited to only a few more expensive cases.

Fractures were commonly caused by injury mechanisms (falls and hits) that are naturally included in children's every day living. This mechanism is therefore difficult to prevent. The total cost of fractures in these children is low, and the outcome after treatment seems to be excellent. Fractures involving joints or comminute fractures with risk of a poor result (with impaired range of movement) have the same injury mechanism, and are difficult to prevent separately. Costs of hand fractures, in relation to the other types of hand injuries, would perhaps have been substantially higher if children up to 14 years were included, as the incidence rate gradually increased from 0 to 14 years.

A sharp object may cause a laceration. It may be merely a question of degree and luck if the result is a wound, nerve and/or a tendon injury. Falls with glasses, or against stray broken glass, resulted in a third of the tendon and nerve injuries, and a fourth of the complex injuries. This calls for a special direction of prevention against such cases. Jamming in doors and contact burns from the oven are hazards that parents probably have heard of. In contrast, parents may have less knowledge about the effects of laceration injuries and falls on to sharp objects. Carrying glasses, while walking or running, is dangerous and increases the risk of a more complex hand injury. The valuable help of a child doing the washing up may also be dangerous, and should be limited to plastic and wood equipment. From a cost point of view, injury prevention should be directed not only at falls with sharp objects causing complex injuries, but to lacerations in general.

The fact that machines constituted 5% of the injury mechanisms in young Swedish children confirms that such equipment is within young children's reach. Surprisingly, this was true also for rifles, guns, and explosive material among the older children (3%). Complex injuries caused by machines in this thesis occurred in the home. A contributing factor to these injuries may be that laymen, with little experience, use dangerous equipment in the home when children are around. Power saw accidents can be prevented by the Saw Stop system in the United States (*Hostetler, et al., 2005*). It works by recognizing a change in an electrical signal on the saw blade when it contacts a body, and the saw blade disappears within 5 milliseconds, leaving only a scratch on the finger (www.sawstop.com). This work has been rewarding and will hopefully inspire other manufacturers. Substantial health care costs from children with hand injuries, and in some cases probably future lost productivity and Quality of Life losses, may be improved as financing of safer machine designs is evaluated.

Active or passive prevention?

The fact from study III that in 66 of 79 cases, parents were present when the injury occurred, calls for passive prevention where children's environments are changed to areas where risk factors are reduced as much as possible. Different factors have been presented throughout this thesis to have an impact on the occurrence of a hand injury. Indeed, the course of events that finally leads to an injury is complicated.

To achieve passive prevention through installation of safety doors, we would have to recommend all parents to change to safety doors in the home. Applied on the equilibrium mentioned in the background,

$$\mathbf{HP} \Leftrightarrow \mathbf{SE} \quad (\text{Gustafsson, 1977})$$

installation of safety doors in a home would result in a decrease of the **H**azard in that specific area. On the other hand, **E**ducation also decreases, due to less experience from closing pinchable doors and narrow escape occurrences. In addition, **S**upervision decreases, as it is no longer necessary to watch children's fingers or teach them not to slam doors. As stated by previous research, many parents may not consider buying safety doors, and pinchable doors would still exist (*Venema, 1995*). When **S**upervision and **E**ducation decreases within the home, the risk for jamming in doors outside the home may increase, as the **H**azard is unknown to the child. Changing doors and creating a safe environment, apart from not being cost-effective, may even from other aspects not be a satisfactory solution in decreasing fingertip injuries. Active prevention by distributing prevention tips presented in study III is an alternative.

If we instead assume that we recommend all parents to, if possible, only use mincer machines, wood cutters and steam roller presses when children are not around, and switch off the electricity when they have finished, the situation can be improved. **S**upervision is in these cases a very strong factor, and nothing is achieved by near escape experiences. Adults should educate children not to use dangerous machines before the age of 18 years. Passive prevention by excluding dangerous equipments from children's environment or usage of safe machines in the home, as well as during work, is in this example more justified.

In accordance with these thoughts, passive prevention through extraction of dangerous machines from children's fields, or manufacturing of safer machines, is suitable. This could also be true for glasses, other sharp objects, oven plates and oven doors. Active prevention through information and simple tips on how to create a safer environment in the home (Appendix 1 in paper III) may be more suitable to prevent fingertip injuries from doors, as well as fractures caused by

falls and hits. A combination with installation of safety doors in areas where many children spend time could be appropriate.

Conclusion of general discussion

Injury research and prevention work in Sweden has generally relied on the frequency of fatal injuries, and injuries occurring in school and day care centres. Use of mortality data mandates attention to traffic injury and drowning. However, non-fatal injuries to the paediatric hand may well be important to politicians and authorities, when the incidences and costs are considered. Instead fingertip injuries, caused by jamming in doors, and other types of injuries that occur in and around the home, may become important as well. Good quality data of incidences, aetiologies, injury patterns, and costs are now presented, and may be utilized in injury prevention work.

CONCLUSION

- The average incidence was 27 children per 10 000 children per year among young children referred for treatment in Malmö municipality, and 40 children per 100 000 children per year among young children hospitalized with hand injuries in Sweden.
- An increase over time was found between 1996 and 2000, and particularly among wounds and fractures between 1987 and 2001, for unknown reasons.
- While simple wounds, fractures, and burns are frequent in the population, less common flexor tendon and nerve injuries require operation and admission in young children.
- The fingertip is the most injured part of the hand among children with hand injuries referred for treatment or follow up, including nail bed lacerations, fractures, and subtotal or total amputations.
- Even in young children complex injuries such as amputations of several fingers occur.
- Variations in the leading type of injury across age groups suggest it may be suitable to target select prevention toward specific ages.
- Young girls are only 0.64 times as likely as boys to have hand injuries requiring hospitalization, and the predominance of boys is even higher in old children.
- The risk for any type of hand injury is especially high in 1, 2 and 6 year old children. National background has no impact on the occurrence of paediatric hand injuries in general.
- Hand injuries in young children are primarily sustained at home between 4 pm and 8 pm, and only a low percentage of these injuries occur at day care centres.
- Doors, oven plates, sharp objects, falls and hits were shown to cause many hand injuries in the population. Machines used by adults in the home and falls with or against stray broken glass, were shown to cause severe hand injuries with risk for sequel.

- An increasing age is associated with less ward days. A foreign background is associated with more ward days. Gender has no impact on health care costs or number of ward days.
- A high impact on health care costs, arising from fingertip injuries caused by jamming in doors and complex injuries caused by contact with machines, depend on a high frequency in the population, and a high total cost per case. The cost for lost productivity is low (14%).

SUMMARY IN SWEDISH

Populärvetenskaplig sammanfattning

När vi föds är handen i stor utsträckning bara ett instrument för att uttrycka en del av våra reflexer. Redan vid omkring 6 månaders ålder kan dock de flesta av oss sträcka sig efter, gripa tag i och hålla fast vid föremål med hjälp av fingrar och handflata. Vid ett års ålder har handens gripförmåga förbättrats ännu mer, samtidigt som samspelet mellan handen och ögat har utvecklats. Tillsammans med förmåga att krypa och gå gör detta att barn kan utforska omvärlden på ett helt annat sätt än tidigare. Vilja och koncentration är ofta starka när barn i förskoleåldern ska undersöka sin omgivning. Det är emellertid inte alltid som deras utvecklingsnivå svarar mot de färdigheter som krävs för att klippa med sax, duka av bord eller stänga en dörr. Vid sådana tillfällen kan skador på händerna lätt uppstå.

Handen är procentuellt sett den del av kroppen som svenska barn, näst efter huvudet, skadar mest. Trots detta känner vi inte till det årliga antalet barn med handskador i förhållande till alla barn i Sverige (incidens). Över huvud taget finns det sedan tidigare inte så mycket vetenskaplig litteratur skriven om svenska förskolebarn med handskador. Vi vet inte om ålder och kön spelar någon roll för risken att få en handskada eller om utländsk bakgrund har någon betydelse? Var, när och hur skadar barn sina händer? Under vilka omständigheter sker dessa skador? Vilka typer av handskador är vanliga? Vilka skador är allvarliga? Hur uppstår de? Vad kostar det för samhället att ge sjukvård till barn med handskador?

Målsättningen med min avhandling var att söka svar på ovanstående frågor genom att studera barn med handskador, med betoning på förskolebarn i åldern 0 till 6 år. Underlag för studierna är dels journaluppgifter från Handkirurgiska Kliniken i Malmö, dels frågeformulär till föräldrar, dels Socialstyrelsens patientregister över sjukhusvårdade barn i Sverige.

Antalet barn som årligen remitterades för behandling eller uppföljning av handskada på Handkirurgiska Kliniken i Malmö var i snitt 27 per 10 000 i Malmö kommun mellan åren 1996 och 2000. I snitt lades årligen 4 barn med handskada in på sjukhus för behandling per 10 000 barn i hela Sverige under perioden 1987 till och med 2001. Antalet barn med handskador i Malmö och i Sverige ökade av okänd anledning under denna tid.

Risken att få en handskada är hög vid ett års ålder. Pojkar drabbas oftare än flickor. Däremot spelar svensk eller utländsk bakgrund ingen roll. Endast en liten del av skadorna i förskoleåldern uppstår på dagis. Risken att få en handskada är istället högst på kvällen då barnen vistas hemma. Små barn har små fingrar som passar väl in i diverse hål och springor i hemmet. Generellt sett är därmed

finger topparna mest utsatta för skador i förskoleåldern. De vanligaste typerna av handskador och orsakerna därtill, varierar emellertid mellan olika åldrar.

De allra minsta barnen bränner sig ofta genom att lägga händerna på spisplattor, men redan från 4 års ålder är dessa skador sällsynta. Skador på fingertoppar är vanliga i alla förskoleåldrar. De flesta barn som vårdas på Handkirurgiska Kliniken i Malmö för sådana skador har klämt sig i en ytterdörr som oftast stängts av ett barn. Fingrarna kläms i stort sett lika ofta på gångjärnssidan som på låssidan. Frakturer på handens ben är inte vanliga bland de minsta barnen, men en successiv ökning under tillväxten gör dem till den vanligaste typen av handskador i de tidiga tonåren.

Liksom frakturer blir även skärskador på senor och nerver i handen vanligare bland äldre barn, även om de förekommer redan i förskoleåldern. Skärskador kan uppstå då barn får tag i vassa föremål som till exempel knivar. Ofta skadas endast hud och underhuds fett, vilket resulterar i ett relativt lindrigt förlopp. Skadan är dock allvarigare om den drabbar senor eller nerver. I värsta fall kan flera av handens viktiga delar (som senor, nerver, ben och kärl) skadas på samma gång. Exempelvis kan allvarliga skador uppstå om ett barn faller med ett dricksglas, som går sönder, eller om barnet kommer i kontakt med maskiner som är ämnade att användas av vuxna.

Trots en ganska liten kostnad per barn (ca 25 000 SKR) kostade sjukvård för barn som klämt fingertopparna i dörrar mest på grund av det höga antalet skadade. I motsats till fingertoppskadorna var behandlingen för varje allvarlig skada i en maskin dyr (ca 95 000 SKR). Därför orsakade även de här ovanliga skadorna betydande sjukvårdskostnader. Däremot är kostnaden för föräldrar som stannar hemma och tar hand om sitt skadade barn relativt liten. Små barn kan ofta anpassa sina sysslor och gå till dagis även om handen är skadad. Ibland är dessutom mamma eller pappa redan föräldraledig, utan behov om ledighet från jobbet.

Handskador är sällan livsfarliga och de flesta är banala. De medför emellertid risker för försämring av den viktiga handfunktionen. Om skadan uppkommer tidigt i livet kan den i värsta fall få konsekvenser för ett barns framtida utveckling och yrke. Generellt sett har forskning och skadeförebyggande arbete i Sverige betonat skador som är livsfarliga, exempelvis trafikskador och drunkning. Med hänsyn till att handskador är vanliga och därigenom kostnadsalstrande, kan även dessa vara av betydelse. Avhandlingen kan användas vid skadeförebyggande arbete som syftar till att minska förekomsten av handskador hos barn.

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APPENDICES

Appendix 1

Type of injury	ICD No 9	ICD No 10
Wound	881-884(A-B)	S51, S61
Fracture, dislocation and sprain	814-817, 833, 834, 842	S62, S63
Muscle and tendon injury	881-884(C)	S56, S66
Burns	944	T23
Traumatic amputation	885, 886, 887(A-B, E-H)	S58, S68
Nerve injury	955(B-X)	S54, S64
Other injury	903(C-X), 927(B-X), 913-915, 923(B-X)	S55, S57, S59, S65, S67, S69, T11, S50, S60

Appendix 2

External cause	ICD No 9	ICD No 10
Contact with sharp object	920	W25-W27
Caught, crushed, jammed or pinched in or between objects	918	W23
Fall	880-886, 888	W00-W19
Contact with hot substance/ fire or exposure to electric current	890-900, 924, 925	W92, X00-X19
Striking against or struck by object or person	916, 917	W20-W22, W50-W52
Transport accident	< 880	V01-V99
Contact with machinery	919	W28-W31
Injury caused by animal or venomous plant	905, 906	W53-W60, X20-X29
Handgun/firearm discharge or explosion of material	921-923	W32-W40
Miscellaneous	Others	Others

I

HAND INJURIES IN YOUNG CHILDREN

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Four hundred and fifty five young children (0–6 years old) were treated for hand injuries between 1996 and 2000. Boys (61%) were injured more often and a higher number of injuries occurred during May and September. Fingertip injuries were the most common injuries (37%), and were often caused by jamming in doors at home. Fractures were caused by falls and punches and tendon/nerve injuries by sharp objects. The incidence of hand injuries increased from 20.4/10,000/year in 1996 to 45.3/10,000/year in 2000. Only 4% of the children had complex injuries but these placed a high demand on resources. The incidence of injuries was not higher amongst children from immigrant families.

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Keywords: hand injury; children; incidence; aetiology; home accident

INTRODUCTION

Young childrens' hand injuries usually occur in the home. Apart from the head, the hand is the most frequently injured part of the body in young children (Laflamme and Eilert-Petersson, 1998).

A number of investigations of paediatric hand injuries have been performed. Some are clinic-based surveys (Bennett, 1975; Innis, 1995) while others are epidemiological reviews of paediatric hand injuries seen in emergency care services (Bhende et al., 1993). There are a few prospective studies which evaluate patterns of incidence and aetiology (Doraiswamy and Baig, 2000; Mirdad, 2001). There are also reports of accidents due to specific hazards including oven doors (Yen et al., 2001), exercise bicycles (Lehrer et al., 1997) and fireworks (Moore et al., 2000).

Hand injuries in children account for a significant proportion of the emergency care work. Previous research in Sweden on injuries in children has not analysed hand injuries (Gustafsson, 1977; Laflamme and Eilert-Petersson, 1998).

PATIENTS AND METHODS

The Department of Hand Surgery at Malmö University Hospital in Malmö, Sweden, receives all patients with hand injuries from Malmö (250 000 inhabitants) and those with severe injuries from other parts of southern Sweden (1.5 million inhabitants). Each year, about 90 young children (0–6 years) sustain a hand or forearm injury requiring emergency care at our unit. This retrospective study included all children aged less than 7 years old with hand or forearm injuries due to an accident which had occurred between January 1996 and December 2000 and who had been treated as either an inpatient or an outpatient. The children were identified from the diagnostic registers by their ICD no 9 code which was between 800A to 999X (1996–1997) or their

ICD no 10 code which was between S00.0 to T98.3 (1998–2000). Fractures of the distal radius and more proximal bones were not included as they were treated by the Department of Orthopaedic Surgery, but bites and infections were included. There was no limit for the duration between the time of injury and presentation at our unit.

Details, including diagnosis, age at time of injury, sex, date and place of injury, injury localization, aetiology, treatment, inpatient days, national background and number of outpatient and therapy visits were retrieved from the patients' notes. The diagnoses were classified as fingertip injuries, fractures (proximal to the distal interphalangeal joint and distal to radius/ulna), burns, skin and soft-tissue wounds, nerve injuries, tendon injuries, complex injuries, sprains/dislocations, infections, bites and compartment/carpal tunnel syndrome. A complex injury was defined as either an injury to more than one of the anatomical components of the hand (bone, flexor/extensor tendon, joint, nerve and arteries) or total/subtotal amputations through the middle or proximal phalanges. However, a combined tendon and digital nerve injury was considered a tendon injury.

RESULTS

Sex and age

Two hundred and eighty (61%) of the 455 children treated between 1996 and 2000 were boys. The median age in the whole group (Fig 1) was 3.7 (range, 2–83 months) years and 59% required inpatient treatment. Their median stay on the ward was 2 (range, 1–28) days and the median number of outpatient clinic attendances was two (range, 1–38).

Paediatric hand injury incidence

Data from Statistics Sweden (SCB) shows that the number of children under 7 years of age in the District

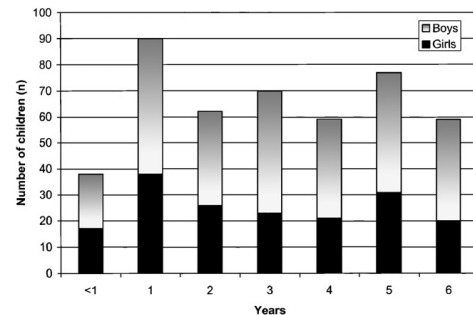


Fig 1 The ages and sexes of young children seen at the Hand Surgery Clinic, Malmö, Sweden (1996–2000).

of Malmö decreased from 17,636 in 1996 to 16,454 in 2000. However, the number of children from Malmö who were treated at the Department of Hand Surgery increased during the study period. Two hundred and seventy-four of the 455 children included in this study were from Malmö and the incidences of injury (children with hand injuries/10,000 children/year) were: 20.4/10,000 in 1996, 25.6/10,000 in 1997, 30.1/10,000 in 1998, 38.3/10,000 in 1999 and 45.3/10,000 in 2000.

Localization of injury

The localization of the injuries is shown in Fig 2. The left and right hands were equally injured and 17 children had bilateral injuries. Among the 110 injuries proximal to the metacarpophalangeal joint and distal to the wrist, 18 were to the dorsal side of the hand, six to both its palmar and dorsal sides and seven were closed fractures. The palmar surface of the hand comprised 79 of the 110 injuries and was the most common site of injury. Injuries to multiple digits were seen in 77 (17%) children (not included in Fig 2).

Injury pattern

Fingertip injuries were the most common (Fig 3). Of the 166 children with fingertip injuries, 30 had a simple soft-tissue injury, 44 had a nail bed injury, 24 had a fracture of the distal phalanx, 28 had a combination of a nail bed injury and a fracture and 40 had suffered subtotal/total amputations of the distal phalanges. The middle finger was most frequently injured and 14 children had multiple fingertip injuries.

Fractures located proximal to the distal interphalangeal joint and distal to radius/ulna were seen in 75 children and a further 52 children had fractures of the distal phalanges. Seventy-two per cent of the 127 fracture injuries were closed and 28% were open. The proximal phalanx of the little finger was the most

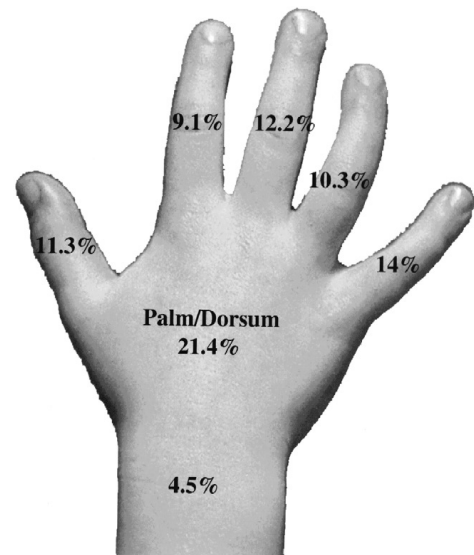


Fig 2 Injury localization (%).

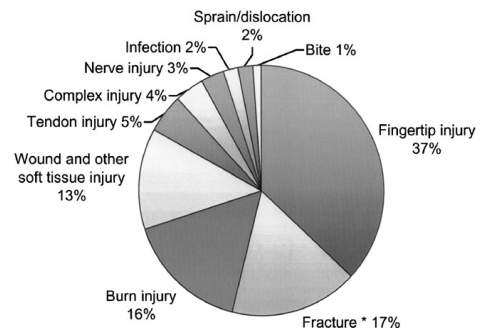


Fig 3 Injury frequency (%). *Proximal to the distal interphalangeal joint and distal to radius/ulna.

fractured bone, followed by the distal phalanges of the middle and ring digit. Fractures to the proximal and distal phalanges were more common than those of the middle phalanx. The little finger metacarpal was mostly commonly fractured metacarpal bone.

Twenty-three children had flexor tendon injuries, of which 15 were in zone 2. Eight of these 15 children also had a digital nerve injury. There were only two cases of extensor tendon injury. The burn injuries were mainly second degree. They involved both the hand and fingers

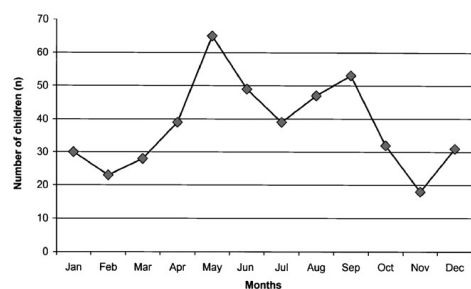


Fig 4 Number of hand injuries according to month of the year.

in 37 of 71 cases, the hand only in 13 and the fingers only in 13 cases. Nineteen of the 455 children, had complex injuries.

A higher number of injuries occurred during May and September (Fig 4), but there was no variation with day of the week. One-fifth of the injuries occurred in 1-year-old children (mainly fingertip and burn injuries sustained at home). Fractures were the most frequent injury in the 6-year-old children and burn injuries were the most common in those under 1-year old. Fingertip injuries were the most frequent injuries in 1–5 year old children.

The most common mechanism of injury was a jamming injury (Fig 5), most frequently in a door (34%), though also in bicycles (4%) or furniture/play tools (4%). Burn injuries usually occurred when the children placed their hands on a hot plate or oven door (11%), though some were scalds (4%). Falls and punches caused many (34%) of the fractures and cutting injuries caused half of the tendon/nerve injuries. Falls when holding, or against, sharp objects caused almost half (43%) of the complex injuries and about a third (36%) of the tendon and nerve injuries. Ten children were involved in mangle accidents. These include two who were treated for compartment syndrome. "Other" mechanisms of injury included animal/children bites, household machine injuries and injuries caused by weapons and tools. Two children had total amputations of multiple fingers due to a mincer machine and a circular saw. One child suffered subtotal amputations of multiple fingers from a saw machine.

Place of injury

Information about place of injury was not available in the notes of 100 children (22%). Home accidents were most frequent in younger children (0–3 years), whereas accidents during leisure activities dominated in 4–6 year old children. Approximately 8% of injuries occurred in childcare centres.

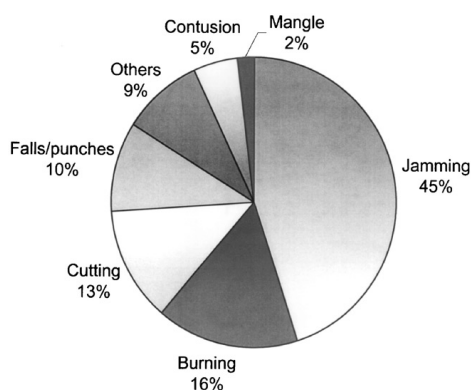


Fig 5 Mechanism of injury (%).

National background

The children were classified according to their names, and divided into those with a Swedish background (first and last name were Swedish), those with a probable immigrant background (first name Swedish but last name foreign) and those with an immigrant background (first and last name of foreign origin). Children who were first or second generation immigrants comprised about 53% of all children less than 7 years old, in Malmö during the last 3 years of the study period (Swedish Statistics, SCB). Of the children from the district of Malmö, who were seen during the last 3 years of the study period, 41% were classified as having an immigrant background. Six per cent were classified as having a probable immigrant background and 53% as having a Swedish background.

DISCUSSION

This study of paediatric hand injuries has shown that boys are more often injured than girls and that most injuries occurred at home, especially for the youngest (0–3 years) children. Injuries sustained during play outside the home were also common in older children.

As well as treating all hand injuries in patients from the city of Malmö, our department treats patients with severe hand and forearm injuries from other parts of southern Sweden. Many children with minor hand injuries, such as simple cuts, are not taken to hospital but are treated at home or in the primary health care. Thus the true incidence of hand injuries is difficult to assess, but if the data for the city of Malmö are assessed (274 patients), the overall incidence of hand injuries which are referred to hospital in young children doubled between 1996 and 2000. We have no explanation as to

why the incidence of hand injuries doubled during the study period: wounds, fractures and fingertip injuries increased, but the other, more major, injuries did not increase.

Earlier studies of hand injuries in children have included children/adolescents aged up to 15 years (Bhende et al., 1993; Mirdad, 2001; Worlock and Stower, 1986), and some have shown that injuries are more common among those aged 5 years or less. Laflamme and Eilert-Petersson (1998) analysed accidents to young children in a Swedish county and found that the incidence of all kinds of injuries was highest in younger children. This is consistent with our findings.

Fingertip injuries, usually caused by shutting doors, were the most common injuries among boys and girls between 1 and 5 years. This is in accordance with previously published studies of finger injuries from other countries (Doraiswamy and Baig, 2000; Macgregor and Hiscox, 1999). We were unable to find out whether the injuries occurred on the hinge or lock side of the door, but it has been reported that most injuries occur on the hinge side and are caused by a child (Doraiswamy and Baig, 2000).

Hand fractures are uncommon among very young children and their incidence increases with age (Worlock and Stower, 1986). In a study of hand fractures and sprains/dislocations at all ages, Packer and Shaheen (1993) showed that almost 70% occurred between the ages of 11 and 40 years (Packer and Shaheen, 1993). Fractures frequently occur during play and sporting activities and in our study most fractures occurred in the older (4–6 years) children. Fractures can be difficult to prevent, as risk factors that suddenly appear during children's play and sporting activities are almost impossible to predict. Isolated fractures due to falls were common and did not cause complications or permanent disabilities. In contrast, the complex injuries in our study were due to dangerous equipment. These injuries, though few, placed a high demand on resources including primary and secondary surgery and rehabilitation. Thus, in children, as in adults, it is a small group of severe injuries that generate substantial costs (Atroshi and Rosberg, 2001; O'Sullivan and Colville, 1993).

Earlier studies of burns to children's hands (Yen et al., 2001), and bodies (Freccero et al., 2000), have shown median ages of between 12 and 24 months. The median age for burn injuries in our study was 20 months, demonstrating that the incidence is high among young children. A retrospective study from the Department of Plastic Surgery in Malmö (Freccero et al., 2000) concluded that burn injuries were more common among immigrant families. In contrast we found no increased incidence of hand injuries amongst immigrants, though we accept that our method of determining immigrant status was imprecise and provided no information on how long the family had been living in Sweden. Seven of

the 10 children involved in mangle accidents had an immigrant background: we have no explanation to this, though many factors may be involved, such as no earlier experience of the equipment and insufficient security measures.

Safety measures are available in Sweden for those who have recently become parents. These are provided when they visit the child welfare centre for vaccination controls. Information and continued improvement of the parents' knowledge of injuries to the hand in young children, one of the most commonly injured parts of the body, is important. Good supervision of the child can help to prevent injuries from dangerous equipment, which cause the most severe injuries with permanent disability. Care with regard to dangerous home constructions (doors), furniture, kitchen equipment and hot objects are important, as young children cannot recognize potential dangers. Furthermore, the distribution of information to producers of home products which are known to cause injuries might reduce the number of injuries. One Danish prospective study of product-related accidents among children has already identified products and home constructions that can cause injuries (Lindblad and Terkelsen, 1991).

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ERRATUM TO: HAND INJURIES IN YOUNG CHILDREN

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This erratum is a correction of our article entitled "Hand injuries in young children" and published in *Journal of Hand Surgery (British and European Volume, 2003)* 28B (4): 376–380. At page 376, the last line, we announced that "the number of children under 7 years of age in the District of Malmö decreased from 17,636 in 1996 to 16,454 in 2000". An error, due to initial misinformation, was made when collecting these data from Statistics Sweden. The correct numbers are that the risk population (mean population (www.ssd.scb.se)) in Malmö decreased from 20,885 in 1996 to 19,659 in 2000. The correct incidences, when

recalculating using the correct risk population, will thereby be:

17.2/10,000 in 1996, 21.8/10,000 in 1997, 25.4/10,000 in 1998, 32.8/10,000 in 1999 and 38.2 per 10,000 in 2000. Our estimate is that these changes affect our results only marginally. The increase of the incidence is nearly the same, but the incidences are approximately 15% less every year than presented in the article.

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Hospitalized Swedish children with hand and forearm injuries: A retrospective review

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Abstract

Aim: To analyse incidences and find risk groups in children hospitalized with hand injuries in a national retrospective study. **Methods:** All children with a primary hand or forearm injury admitted to Swedish hospitals during 1987–2001 were retrieved from the Swedish Hospital Discharge Register and analysed as to incidence and characteristics. **Results:** Among 9855 children included, the median age was 7.0 y and two-thirds were boys. The incidence increased in both younger (0–6 y) and older (7–14 y) children. Wounds and fractures almost doubled, while muscle/tendon injuries decreased. In younger children, wounds and burns were the most frequent diagnoses. In older children, fractures and muscle/tendon injuries were common. Sharp objects caused most of the injuries. University hospitals treated almost half of the children.

Conclusion: The number of children with hand injuries admitted to hospitals in Sweden increased annually. Analyses of causes behind the increase are important to counter this trend.

Key Words: Child, forearm injury, hand injury, incidence, population-based study

Introduction

Children play with their hands every day at home, in day care centres and during school hours, which is necessary for development of both sensory and motor function. Hand injuries are non-fatal, but complications and significant reduction in hand function may have consequences for a child's future development. Apart from suffering for the children, these injuries cause anxiety, feelings of guilt for their parents, and also the need for healthcare.

Hand injuries in children constitute 2–6% of paediatric emergency care in retrospective surveys from Emergency Departments [1–3]. Some of the earlier studies focus on hand fractures [4–6], where boys are more frequently fractured than girls, often in the early teens due to sport. Studies have also been published of aetiological factors and the recommended treatment of different hand injuries in children [7–15]. These former studies may serve as a basis for prevention. A detailed history of children with finger injuries, obtained by questionnaire, indicates that jamming in doors at home is a frequent hazard to fingers [16,17].

In Sweden, there is a tradition of research of injury prevention in children [18–21], but few studies have focused on hand injuries. In a retrospective survey of 274 preschool children from Malmö, Sweden, the incidence of treatment-referred children with hand injuries increased during 1996–2000 [22] this has not been analysed in international studies [23,24]. Such studies can be difficult to apply to a Swedish setting, and large national database analyses of paediatric hand injuries have not been found.

The aim of the present study was to analyse the cohort of Swedish children between the ages of 0 and 14 y old hospitalized during 1987 to 2001 with a traumatic hand or forearm injury, excluding fractures of the radius and ulna, as to incidence and in order to identify risk groups.

Patients and methods

The Swedish Hospital Discharge Register was used to retrospectively find all children (0–14 y old) with a hand or forearm injury, excluding fractures of the radius and ulna, admitted to Swedish hospitals during 1987–2001. The local Ethics Committee at Lund

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University, Sweden, approved the study (LU 731-03). The Discharge Register covers all public inpatient care in Sweden since 1987. No national data of outpatient care are available. The register is essentially population based since the private hospital sector is very small [25].

In addition to a unique personal identification number for all admitted patients, data include information of age, gender, domicile, hospital, department, dates of admission and discharge, length of stay, mode of admission and discharge, primary diagnosis, secondary diagnoses, external cause of injury (E-code), and surgical procedures. The study base consisted of 9855 children with hand and forearm injuries as primary diagnoses.

Diagnoses and external causes of injury (E-codes; available for 95.2%) were coded by the Swedish version of ICD-9 (1987–1996) and ICD-10 (1997–2001). Hand injuries were categorized by the primary diagnosis into seven major types. Wounds were categorized as to localization at the fingers, hand or forearm. Fractures, dislocations and sprains were divided by localization: finger phalanges, metacarpal, carpal bones and interphalangeal, metocarpophalangeal or carpal joints. During 1987–1996, muscle and tendon injuries were categorized according to their localization at the fingers, hand or forearm, and during 1997–2001 by their localization at the flexor or extensor muscles. Burns were classified as being of the first, second or third degree. Traumatic amputations, including both partial and complete amputations, were categorized by localization at the thumb or other fingers. Information of traumatic amputations of multiple fingers was only available during 1997–2001. Nerve injuries were divided into ulnar, radial, median or digital nerve injuries. Twenty-two per cent of all children also had secondary diagnoses, indicating a combined injury. The most common secondary diagnoses were finger nerve injuries.

Statistical methods

The incidence was computed by comparing the children's first admissions for a hand injury to the total number of children at risk. The incidences of different types of injuries were analysed by Poisson regression with calendar year, age and sex as explanatory variables. Statistical differences were assessed by likelihood ratio tests. The total population of boys and girls between the ages of 0 and 14 y old during each year of the study, used as the offset in the analyses, were obtained from Statistics Sweden [26]. The rate is the number of children per 100 000 children per year. Descriptive analysis of patients, diagnoses, external causes and hospitals was performed.

Results

Incidence, age and gender

During the investigated period, the incidence of hospitalized children with hand and forearm injuries between the ages of 0 and 6 y old was 39.6/100 000 persons/y and 42.1/100 000 persons/y in children between the ages of 7 and 14 y old. It increased from 1987 to 2001 both among younger and older children (Figure 1). The incidence of children with wounds and fractures almost doubled (Figure 2). However, the incidence of children with muscle and tendon injuries decreased during the study period, from slightly less than 10 to about 6 children per 100 000 per year. The relative incidence (girls/boys; 95% CI) of children with all types of injuries was 0.64 (0.60–0.68) among the younger and 0.45 (0.43–0.48) among the older children. The median age (interquartile range, IQR) of all children included was 7.0 y (3–11), and two-thirds of the patients were boys (66.5%). The age distribution of different primary diagnoses at the index admission and external causes of injury are shown in Table I.

Wounds

The incidence of children with wounds peaked in 1-y-old children, but then decreased with age (Figure 3). The relative incidence was higher in younger (0.66 (0.59–0.73)) than in older (0.43 (0.38–0.49)) children. Wounds were localized at the fingers (55.1%), hand (20.8%) and forearm (13.8%). These injuries were frequently caused by sharp objects, or the child having been caught, crushed or jammed in or between objects, or by falls (Table II). The median age (IQR)

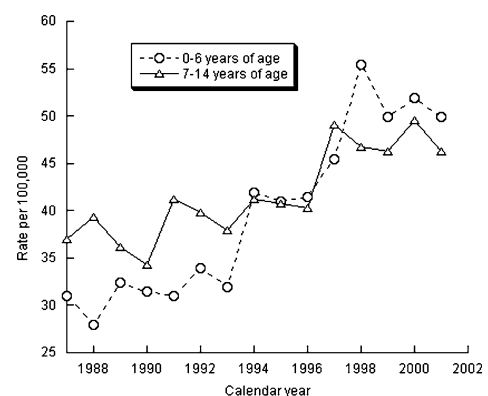


Figure 1. Incidence of younger (0–6 y) and older (7–14 y) children with all hand and forearm injuries as a function of calendar year of occurrence. Incidences are standardized to the age distribution among the younger and older children in the year 2001.

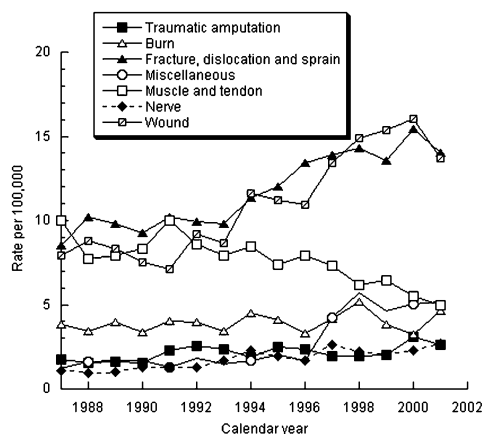


Figure 2. Incidence of children with different types of injuries as a function of calendar year of occurrence. Incidences are standardized to the age distribution in the year 2001.

was 6.0 y (3–10). Seventy-seven per cent of the patients were operated on.

Fractures, dislocations and sprains

The incidence of children with fractures increased steadily from 0 through 14 y of age (Figure 3). Boys fractured more frequently, but the relative incidence

was similar in both age groups (younger 0.64 (0.56–0.74); older 0.56 (0.51–0.61)). The finger phalanges were fractured more frequently (71.1%) than the metacarpal (20.8%) and carpal bones (5.0%). Dislocations and sprains (14% of the category) occurred at the interphalangeal and metacarpophalangeal (81.3%), or the carpal (14.1%) joints. Falls were the most common external causes, but the children were also crushed in or between objects, striking against or struck by an object or a person, or involved in transport accidents (Table II). Median age (IQR) was 10.0 y (6–12), and 87.8% were operated on.

Muscle and tendon injuries

The incidence of children with muscle and tendon injuries increased with the age, but less so than fractures (Figure 3). One girl was injured for every three boys (girls/boys: 0.49 (0.41–0.58) in younger and 0.31 (0.27–0.36) in older children). Main localizations ($n=1295$ (1987–1996)) were the fingers (70.6%), hand (13.9%) and forearm (14.0%). Of the remaining 465 patients (1997–2001), 4.3% had flexor and 1.7% extensor injuries of the forearm, and 59.6% flexor and 26.7% extensor injuries of the wrist or hand. The external cause was primarily contact with sharp objects (Table II). Median age (IQR) was 9.0 y (5–12), and 92.8% were operated on.

Table I. Hospitalized Swedish children with hand and forearm injuries: A retrospective review: distribution of gender, primary diagnosis and external cause by age ($n=9855$).

	Age (y)		Total n (%)
	0–6 n (%)	7–14 n (%)	
Male	2800 (62.3)	3754 (70.0)	6554 (66.5)
Female	1692 (37.7)	1609 (30.0)	3301 (33.5)
<i>Index diagnosis</i>			
Wounds	1540 (34.3)	1194 (22.3)	2734 (27.7)
Fractures, dislocations and sprains	804 (17.9)	1909 (35.6)	2713 (27.5)
Muscle and tendon injuries	584 (13.0)	1176 (21.9)	1760 (17.8)
Burns	817 (18.2)	218 (4.1)	1035 (10.5)
Traumatic amputations	285 (6.3)	243 (4.5)	528 (5.4)
Nerve injuries	110 (2.5)	296 (5.5)	406 (4.1)
Miscellaneous	352 (7.8)	327 (6.1)	679 (6.9)
<i>Injury mechanism</i>			
Contact with sharp object	931 (20.7)	1651 (30.8)	2582 (26.2)
Caught, crushed, jammed or pinched in or between objects	1183 (26.3)	508 (9.5)	1691 (17.2)
Falls	413 (9.2)	1101 (20.5)	1514 (15.4)
Contact with hot substance/fire or exposure to electric current	716 (15.9)	154 (2.9)	870 (8.8)
Striking against or struck by object or person	197 (4.4)	398 (7.4)	595 (6.0)
Transport accidents	129 (2.9)	446 (8.3)	575 (5.8)
Contact with machinery	220 (4.9)	180 (3.4)	400 (4.1)
Injury caused by animal or venomous plant	171 (3.8)	171 (3.2)	342 (3.5)
Handgun/firearm discharge or explosion of material	17 (0.4)	164 (3.1)	181 (1.8)
Miscellaneous	307 (6.8)	330 (6.2)	637 (6.5)
Information missing	208 (4.6)	260 (4.8)	468 (4.7)

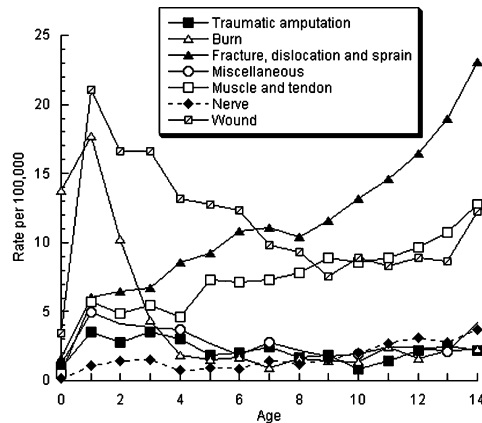


Figure 3. Incidence of children with different types of injuries as a function of age at occurrence. Incidences are standardized to the average incidence over the entire study period.

Burns

Burns was the most common injury type among children younger than 1 y. The incidence of children with burns then decreased rapidly to a low incidence from 4 y of age (Figure 3). The relative incidence changed by increasing age from 0.62 (0.54–0.72) in younger children to 0.35 (0.26–0.47) in older children. The burns were often of the second degree (57.3%), followed by third degree (14.6%) and first (7.7%) degree. Sixteen per cent were not specified as to degree. External causes were contact with hot substance/fire, electric current or handgun/firearm discharge or explosions (Table II). Median age (IQR) was 2.0 y (1–5). Operation was necessary in 23.3% of the cases.

Traumatic amputations

Amputations were uncommon, with no clear age pattern. Girls with amputations were more common in younger (girls/boys: 0.80 (0.63–1.01)) than older (girls/boys: 0.35 (0.26–0.46)) children. The thumb (17.0%), other fingers (73.7%) or multiple fingers (5.1%), and the forearm (3.0%) were amputated. Almost half of these children were caught, crushed or jammed in or between objects. Contact with machines was also common (Table II). Median age (IQR) was 6.0 y (6–10). Eighty-nine per cent of the children were operated on.

Nerve injuries

Nerve injuries were uncommon, with no clear age pattern. The relative incidence was similar in younger (0.51 (0.34–0.76)) and older (0.44 (0.34–0.56))

children. The median nerve was injured more frequently (24.6%) than the ulnar (17.7%) and the radial (3.4%) nerves, while digital nerves constituted 51.0% of the total. Contact with sharp objects was the most common external cause (Table II). Median age (IQR) was 10.0 y (6–12), and operation was necessary in the majority of cases (92.8%). Nerve injury was the most common second diagnosis, reported in 7.5% of all patients included in the study.

Seasonal variation

A high proportion of injuries occurred from May to September, similar for all diagnostic categories, except for burns which occurred more often in January, April and December (data not shown). We found no seasonal differences between younger and older children.

Level of care

Almost half of all children (46.2%) were treated by nine regional university hospitals. The remaining children were treated by county hospitals (29.4%), by district county hospitals (18.0%) and by primary healthcare centres (6.4%). In 24.4% of all admissions, treatment was provided by a Department of Paediatric Medicine. Also common were Departments of Hand Surgery (19.3%), Orthopaedic Surgery (16.5%), Paediatric Surgery (15.9%), General Surgery (12.8%) and Plastic Surgery (10.2%). Median hospital stay (IQR) was 1.0 (1.0–2.0) d with almost no difference between diagnostic categories. Seventy-seven per cent of all children were operated on once, and 29.2% also had a second procedure during the same admission.

Discussion

This study of children admitted for hand and forearm injuries in Sweden has shown that wounds and fractures, dislocations and sprains were the most common types of hand injuries, and their incidences almost doubled from 1987 to 2001. Injuries were more common among boys in all age groups, similar to earlier reports [1,2,7,8,11–13,16,22,27]. The incidence in different age groups showed specific patterns. Most injuries were caused by contact with sharp objects. Hand injuries were more common during the summer, and half of the children were treated by regional university hospitals.

There are limitations in our study. We did not include fractures of the radius and ulna but focused on hand injuries and soft tissue injuries in the forearm, reflecting material representative of a Department of Hand Surgery. The observed frequencies and patterns may have been influenced by the fact

Table II. Hospitalized Swedish children with hand and forearm injuries: A retrospective review: external cause by diagnostic category ($n = 9387$).

	Wound n (%)	Fracture, disl. and sprain n (%)	Muscle and tendon injury n (%)	Burn n (%)	Traumatic amputation n (%)	Nerve injury n (%)	Miscellaneous n (%)	Total n (%)
Contact with sharp object	753 (28.8)	78 (3.0)	1335 (80.1)	0 (0.0)	67 (13.2)	290 (76.7)	59 (9.2)	2582 (27.5)
Caught, crushed, jammed or pinched in or between objects	684 (26.2)	558 (21.6)	68 (4.1)	1 (0.1)	227 (44.7)	7 (1.8)	146 (22.8)	1691 (18.0)
Falls	281 (10.7)	968 (37.4)	89 (5.3)	1 (0.1)	21 (4.1)	31 (8.2)	123 (19.2)	1514 (16.1)
Contact with hot substance/fire or exposure to electric current	13 (0.5)	1 (0.04)	1 (0.1)	849 (85.4)	0 (0.0)	1 (0.3)	5 (0.8)	870 (9.3)
Striking against or struck by object or person	104 (4.0)	399 (15.4)	37 (2.2)	0 (0.0)	13 (2.5)	4 (1.0)	38 (6.0)	595 (6.3)
Transport accidents	128 (4.9)	298 (11.5)	35 (2.1)	5 (0.5)	30 (5.9)	7 (1.8)	73 (11.4)	576 (6.1)
Contact with machinery	113 (4.3)	97 (3.7)	37 (2.2)	21 (2.1)	95 (18.7)	9 (2.4)	28 (4.4)	400 (4.3)
Injury caused by animal or venomous plant	239 (9.1)	23 (0.9)	6 (0.4)	1 (0.1)	12 (2.4)	1 (0.3)	60 (9.4)	342 (3.6)
Handgun/firearm discharge or explosion of material	79 (3.0)	16 (0.6)	5 (0.3)	51 (5.1)	23 (4.5)	2 (0.5)	5 (0.8)	181 (2.8)
Miscellaneous	220 (8.4)	149 (5.8)	54 (3.2)	65 (6.5)	20 (3.9)	26 (6.9)	102 (16.0)	636 (6.8)
Total	2614 (100.0)	2587 (100.0)	1667 (100.0)	994 (100.0)	508 (100.0)	378 (100.0)	639 (100.0)	9387 (100.0)

that only injuries requiring hospitalization were included. Therefore, the lack of data from ambulatory care makes it impossible to calculate the total incidence of children with hand injuries in Sweden.

Previous studies of hand injuries have mainly been performed by Emergency Departments and included all types of injuries in all children [1–3,7,8], thereby making it impossible to calculate the incidence of different types of injuries in a defined population. The total incidence of children with hand injuries treated either as in- or outpatients has only been reported in one study from a defined catchment area of a middle-sized city in Sweden. This study reported the incidence of hand and forearm injuries in children (0–6 y) referred to the Department of Hand Surgery during a 5-y period (27/10 000 persons/y) [22]. The calculations of the incidence in the present study were based on all hospitalized injured children compared to the total population by age group at risk during each calendar year in Sweden. Our average incidence of younger children in Sweden is about four times lower than the incidence of children admitted in the study from Malmö (population 2003: 267 000) [22]. We have no clear explanation for this, but a detailed analysis revealed that the children of Malmö accounted for 6.9% of all admitted children during 1987–2001. The children at risk in Malmö represented only 3.0% of all Swedish preschool children. Presumably, this may indicate that this city had either a high injury incidence, a high propensity to admit these children, or both. The incidence of unintentional hand injuries (age 0–85 y) is 1800 and 3600 per 100 000 inhabitants per year in the Netherlands and in Denmark [23]. The highest incidence was found among 0–14-y-old children. Approximately 2–3% of all patients in these studies were admitted. No similar Swedish data have been reported.

The most common injury type in older children was fractures, dislocations and sprains. The frequency of fractures in the phalanges (71% of all fractures) was similar to that reported in earlier studies (58–80%) [1,6]. In two studies of all types of fractures in children from our catchment area, fractures of the phalanges of the hand and the bones of the carpal and metacarpal region were the second most common [20,27]. The incidences of hand fractures in these studies were much higher compared to our study, probably reflecting the fact that children treated as outpatients were included. Hand fractures are often caused by falls, striking against or being struck by an object or a person, and by transport accidents, and the former may be related to sport activities [1,5,6,11]. Codes indicating injury place of occurrence and type of activities, i.e. sports, are available in the Hospital Discharge Registers from 1997. However, physicians seldom entered this information.

Burns, especially contact burns, afflicted primarily the younger children, a finding in accordance with previous studies [1,12,22]. Younger children were also more likely to be wounded and afflicted by traumatic amputations caused by crushing and pinching in or between objects. Muscle, tendon and nerve injuries caused by contact with sharp objects more often occurred in older children. Muscle and tendon injuries are seldom categorized as a separate type of injury, but are instead included among lacerations or soft tissue injuries [1–3]. Two-thirds of the children with nerve injuries in our study were treated by regional university hospitals. Special techniques and commands at surgery, together with the need for rehabilitation, indicate the more qualified treatment required for these injuries.

Earlier studies have found that hand injuries caused by blunt trauma and crushing injuries were common [1–3,7,22,28]. In our study, contact with sharp objects caused more than a quarter of the hand injuries. The present pattern may be influenced by the fact that jamming injuries during 1987–1996 were not included in the data selection. However, admissions for jamming injuries were uncommon during that period (about 45 per year). Our estimate is that this omission influences our results only marginally.

In conclusion, the incidence of children hospitalized for hand and forearm injuries, excluding fractures of the radius and ulna, in Sweden increased during 1987–2001. The increase was mainly seen in fractures, dislocations and sprains in older children and wounds in younger children. The causes of such development cannot be fully revealed by a register study, but medical records or prospective studies may elucidate contributing factors. A change over time in intervention strategies in different injuries might also be considered. Information of risk factors and risk groups is essential to counter the increase of incidence. The findings have to be communicated to safety prevention authorities at the national and community levels [29,30].

Acknowledgements

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ORIGINAL ARTICLE

Risks for, and causes of, injuries to the hand and forearm: A study in children 0 to 6 years old

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Abstract

Ninety-six children aged 0–6 years with unintentional hand injuries were referred to the Department of Hand Surgery between 2002 and 2003. Either parents, medical staff, or both, completed a questionnaire (response rate 79/96; 82%) about the circumstances of the injury. The incidence of injuries referred for treatment was 33.4/10 000 people/year. Seventy-five percent (59/79) of all injuries occurred at home, and only 8% (6/79) in a day-care centre. The risk was highest between 4 p.m. and 8 p.m. (incidence rate ratio 5.17, 95% confidence interval 2.12 to 17.7) and in 6 year old children (IRR 4.89, 95% CI 1.58 to 37.68). Adults were present when 66/79 children (84%) were injured. Most injuries occurred during play (39/79; 49%). Stuck in front doors (23/79; 29%) (closed by a child) was common. There was no increase in incidence in children with a foreign background (IRR 1.19, 95% CI 0.64 to 2.28). Advice about prevention will be distributed to parents to encourage safer environments in homes.

Key Words: Children, hand, forearm, questionnaire, door

Introduction

Children learn new skills every day to respond to new challenges as they grow up. By using their hands, they develop their cerebral function and organise the motor and somatosensory cortex in the brain. This is necessary for normal development of the hand, arm, and brain, but may result in injuries during play and exploration of the environment [1,2]. Earlier research of hand injuries in children has concentrated on the pattern of injuries seen in emergency departments [3–6] and their treatment [7]. Fractures [8–10] and burns [11] have been studied specifically. Aetiological factors have been explored widely [12–15], but less is known about the immediate circumstances when data are evaluated in questionnaires [16,17].

In Sweden there is a tradition of research into prevention of injuries in children and a long experience in reducing them. However, only one retrospective study of case notes has analysed hand injuries in children [18]. The overall pattern and the

incidence of hand and forearm injuries referred for treatment to the Department of Hand Surgery, Malmö, was studied from 1996 to 2000. Risk factors near the time of the accident are difficult to study retrospectively and it is necessary to analyse the detailed mechanisms that cause such injuries. Our aim was to assess the circumstances associated with injuries to the hand and forearm in young children by using a questionnaire that was answered by the parents just after the accident.

Patients and methods

The study was performed during a year (1 February 2002 – 31 January 2003) at the Department of Hand Surgery, Malmö University Hospital. It was approved by the local Ethics Committee at Lund University (LU 707-01).

Traditionally, nearly all young children in Malmö with an injured hand or forearm, that require admission to hospital, are referred to the Department of Hand Surgery. Children with minor injuries

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are sometimes only treated in the Emergency Department.

All children aged 0 to 6 years with an accidental injury to the hand or forearm during the study period were invited to participate in the study together with their parents. The age criteria were decided to see if there were more specific patterns of injury among young children. Children treated either as inpatients or outpatients were included. Bites and infections were included, but fractures of the radius or ulna were not, as such patients are treated at the Department of Orthopaedics. A questionnaire (Appendix 1) was completed by the children's parents during the stay at hospital, with or without the aid of the medical staff.

All injuries had ICD 10 code (Classification of Diseases and Health problems, Socialstyrelsen, 1997) between S00.0 to T98.3. Details about the injury were retrieved from the patients' case notes. The variables recorded were: date of admission to hospital, referral unit, diagnosis, anatomical site of injury, days in hospital, number of visits for clinics and physiotherapy, date of operation, sex, and age. The statistical methods we used included calculations of incidence rate ratios (IRR), standard descriptive analysis, and 95% confidence intervals (CI) (StataCorp. 2003. Stata Survival Analysis and Epidemiological Tables. Reference Manual Release 8. College Station, TX: Stata Corporation).

Results

In 2002 the population of children (0–6 years) in Malmö municipality was 19 182 (Statistics Sweden (www.ssd.scb.se)). Of the 96 children treated at the Department of Hand Surgery during the study period 64 were officially recorded as citizens of Malmö. The incidence of children with hand and forearm injuries, treated at the Department of Hand Surgery in Malmö, was estimated to 33.4/10 000 persons/year. Seventy-nine of these 96 children (82%), together with their parents, answered the questionnaire and were included in the study. The median age was 4 years (range 1–6 years).

There were no differences between the different seasons, days of the week, or sexes (Table I). The risk increased between noon and 4 p.m. and between 4 p.m. and 8 p.m. The risk was higher in children aged 1, 2, and 6 years.

The child lived with two adults (57/79; 72%) in most of all the families, but some with one (10/79; 13%), or three (8/79; 10%) adults. The mean number of children per family was two, compared to two in Malmö municipality (Statistics Sweden, 2002).

Table I. Risks for, and causes of, injuries to the hand and forearm: a study in children 0 to 6 years old. Questionnaire (Appendix 1) and case note data (population in Malmö 2002: 19 182). No. of children (% of all 79 children) and Incidence Rate Ratios (IRR) with 95% CI.

	No. (%)	IRR (95% CI)
Risk for a hand or forearm injury in different seasons ($n = 79$, question 1)		
March–May	24 (30)	1.00 (reference)
June–August	22 (28)	0.92 (0.49–1.69)
September–November	17 (22)	0.71 (0.36–1.37)
December–February	16 (20)	0.67 (0.33–1.30)
Risk for a hand or forearm injury on different days of the week ($n = 78^*$, question 2a)		
Monday	11 (14)	1.00 (reference)
Tuesday	14 (18)	1.27 (0.54–3.18)
Wednesday	12 (15)	1.09 (0.44–2.81)
Thursday	11 (14)	1.00 (0.39–2.32)
Friday	13 (16)	1.18 (0.49–2.99)
Saturday	11 (14)	1.00 (0.39–2.32)
Sunday	6 (8)	0.64 (0.21–1.88)
Risk for a hand or forearm injury at different times of the day ($n = 78^*$, question 2b)		
6–10 a.m.	6 (8)	1.00 (reference)
10–12 a.m.	15 (19)	2.50 (0.92–9.34)
0–4 p.m.	21 (27)	3.50 (1.37–12.50)
4–8 p.m.	31 (39)	5.17 (2.12–17.7)
8–12 p.m.	5 (6)	0.83 (0.20–4.16)
At night	0 (0)	0.00 (–1.75)
Risk for a hand or forearm injury compared to age ($n = 79$)		
<1 year	4 (5)	1.00 (reference)
1 year	15 (19)	4.42 (1.41–34.51)
2 years	13 (16)	3.83 (1.18–30.84)
3 years	11 (14)	3.29 (0.97–27.61)
4 years	9 (11)	2.71 (0.76–24.08)
5 years	11 (14)	3.29 (0.97–27.61)
6 years	16 (20)	4.89 (1.58–37.68)
Risk for a hand or forearm injury compared to gender ($n = 79$)		
Girl	37 (47)	1.00 (reference)
Boy	42 (53)	1.08 (0.68–1.71)

*The question was not completed in 1 of the 79 cases.

In Malmö municipality children born in a foreign country and children with two parents born in a foreign country are defined as having a foreign background. Thirty-nine percent of the children (0–6 years) in Malmö had a foreign background (Statistics Sweden, 2002). Among the children registered as citizens of Malmö in our study there was no significant difference between Swedish children and children with a foreign background (IRR 1.19, 95% CI 0.64 to 2.28).

Most of the children (59/79; 75%) were injured at home in a flat or house (Figure 1). It was usually in the hall or kitchen, but also in the garden, bedroom, or living room. Eight injuries (10%) occurred in a day-care centre or in school. Among young children (1–5 years) in Malmö 73% were registered on a municipality or a private day-care centre (www.skolverket.se, 2002).

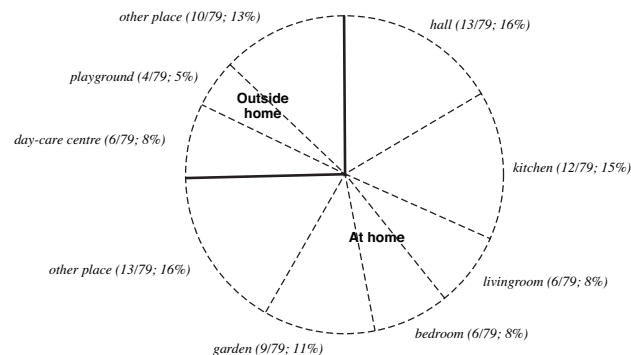


Figure 1. Place where young children with hand and forearm injuries treated at the Department of Hand Surgery, Malmö University Hospital, were injured. Data are based on a questionnaire (Appendix 1) answered by the child and parents at the hospital. The number of children (% of all 79 children) is indicated.

No other children were present when 23 of the children were injured (Table II). Play was the most common activity at the time of injury. This was alone ($n = 11$), or with one ($n = 10$), two ($n = 12$), or more than two children ($n = 6$) (data not shown). Adults were present when 66 children were injured, usually the mother or more than one adult (Table II). The activity of the adult(s) at the time of injury was often cooking, eating, or cleaning up. They were playing or interacting in some other way with 16 of the children (Table II).

Thirteen children were burned (median age 1, range 1–3), of whom five had climbed on the oven or sink. Four children put their hands in hot water or coffee, on heaters ($n = 2$), pulled a flex of an iron that fell on the arm ($n = 1$), or held a firework that exploded ($n = 1$).

The most common mechanism of injury was getting a finger stuck in a door (40/79; 51%). The median age in this group was 4 years (range 1–6). The front door was more of a hazard than the inner doors (Table II). Fingers were often stuck in the lock or hinge. A child, often the child itself or a brother, closed the door more often than an adult. There was no difference in the presence of children (34/40; 85%) and adults (32/40; 80%) at the time of injury (data not shown).

Six patients were injured by falling in the same level ($n = 3$) or from a sofa, toilet, or slide. Of the seven cutting injuries three were caused by knives, and other objects were crushed glass, a washbasin, flint stone, and scissors.

Most of the parents (68/79; 86%) sought medical care on the day of injury. The remaining parents attended hospital the next day (5/79; 6%) or up to eight days after the injury (6/79; 8%). The child was referred from the Department of Orthopaedics

(30/79; 38%), primary health care centres (23/79; 29%), other hospitals in southern Sweden (14/79; 18%), or other departments at Malmö University Hospital (6/79; 8%). Only two children (2%) came to our department directly.

Forty-three of the children (54%) injured the right hand, 34 the left hand (43%), and two children (2%) both hands. The localisation of injury is shown in Figure 2. Fifteen children (18%) had injuries in multiple sites. In 57 of all cases (72%) the parents stated that their child mostly used the right hand, in 11 (14%) the left hand, and in 10 cases (13%) both hands were used equally. This "dominant" hand was injured in 36 cases (45%).

Twenty-eight of the 79 children (35%) had a nail bed injury and eight of these also had a fracture of the distal phalanx. Among the other injuries were wounds (13/79; 17%), closed (7/79; 9%) or open (3/79; 4%) fractures, and subtotal (5/79; 6%) or total (1/79; 1%) amputations. These injuries were on the digits in all but two cases. Single burn injuries (12/79; 15% of all injuries) were at multiple sites on both sides of the hand and fingers (10/79; 13%) or on the forearm (2/79; 2%). All burns were second degree. Two children (2%) had transections of the flexor tendons either combined with transection of the median nerve or a digital nerve injury. The series also included three cases (4%) with compartment syndrome, infection, and dislocation. Five children (6%) had multiple diagnoses.

Fifty-one of the 79 patients (65%) were admitted to hospital and the median hospital stay was two days (range 1–20). The median number of visits to a physician was three (range 0–7) and for physiotherapy one (range 1–10). Fifty-four children (68%) were operated on. They were operated on within 12 hours of injury ($n = 25$; 32%) or between 12 and 24

Table II. Risks for, and causes of, injuries to the hand and forearm: a study in children 0 to 6 years old. Frequencies based on questionnaire data (Appendix 1). Number of children (%).

	No. (%)
Frequency of injured children compared to other children present ($n=78^*$, question 4)	
No children	23 (30)
2 children	20 (25)
1 brother	13 (17)
> 2 children	9 (12)
1 sister	8 (10)
1 friend	5 (6)
Frequency of injured children compared to activity of the injured child ($n=78^*$, question 6)	
Playing	39 (50)
Passing door	17 (22)
Other activity	9 (12)
Cycling	5 (6)
Cooking/eating	4 (5)
Going in the car	4 (5)
Frequency of injured children compared to adults present ($n=78^*$, question 5)	
Mother	25 (32)
> 1 adult	25 (32)
No adult	12 (15)
Father	8 (10)
1 other adult	8 (10)
Frequency of children compared to the activity of adults present ($n=65^*$, question 7)	
Playing [†]	16 (25)
Cleaning up	12 (18)
Other activity	12 (18)
Cooking/eating	10 (15)
Reading/talking	9 (14)
Passing door	6 (9)
Frequency of children that was injured in different jamming objects ($n=51$, question 12)	
Front door	23 (45)
Other object	11 (22)
Other door	9 (18)
Inner door	8 (16)
Frequency of children being stuck in different sides of a door ($n=40$, question 13)	
Lock side	20 (50)
Hinge side	15 (37)
Other side	5 (13)
Frequency of children compared to door closer ($n=40$, question 14)	
Injured child	9 (23)
Other	8 (20)
Brother	7 (17)
Adult	7 (17)
Spontaneously	6 (15)
Sister	3 (7)

*The question was not completed in 1 case. [†]Play or other activity together with the injured child.

hours ($n=15$; 19%) afterwards. Nine children (11%) were operated on 2 to 11 days after injury. In six cases (8%) this information was missing.

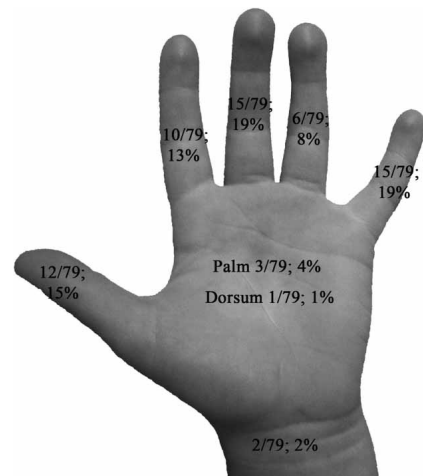


Figure 2. Localisation of hand and forearm injuries in young children treated at the Department of Hand Surgery, Malmö University Hospital. The number of children (% of all 79 children) is indicated.

Discussion

In the present study of 79 young children aged 0–6 years we analysed risk factors for a hand or forearm injury with a questionnaire answered by the parents immediately after the injury. There have been several reports on the epidemiology of hand injuries in children and similar patterns seem to occur in different countries and geographic areas [3,5,7,17, 18]. Most of the studies were retrospective, and did not analyse the circumstances surrounding the injuries. If aetiological research is to guide interventions, we need to look at interactions between the individual children and their environment (family, home, and social culture) to devise risk groups [19]. Our aim was to see what the dangers of hand injuries were, and where safety factors were missing.

We found a much higher risk of injury in the late afternoon, consistent with earlier studies [20,21]. One explanation could be that children stay at day-care or school late and become tired. Few children were injured at a day-care centre.

It has previously been concluded that burns are more common among families with a foreign background in Malmö municipality [22]. We found no increase in frequency of hand and forearm injuries among children with a foreign background. Of 13 children with burns, only three came from a foreign background. Seventeen of the 96 children (18%) treated in our department during the study period did not participate in the study. Thirteen of these were from Malmö and eight (61%) probably had a

foreign background (from their names). To explore the sensitivity of our results, we included the latter 13 children. The IRR was then 0.86 (95% CI 0.51 to 1.47) and did not change our main conclusion.

Half the children in the study were playing when they were injured. Playing includes many different activities and this answer may have been used in the questionnaire when the activity was not clear. It has been previously defined as the most common activity during which children get injured [23]. The home environment was the most common place of injury. Previous reports of hand injuries have suggested that outdoors was the most common setting [3,5]. The age criteria in our study could explain the difference in setting, and the small sex difference we found compared with previous studies of injuries in children.

Contact burns of the hand with irons and oven doors are common among young infants, whereas electrical and flame injuries are with older children [11]. Injuries to the palm in children have a good prognosis with a low incidence of complications, illustrated by the fact that only 4 of 13 children with burns needed revision. Yen et al. have published Oven Door Burn Prevention Tips for Parents [12].

Doors have been previously defined as a hazard for children's fingers [3,7,16,17]. The cause of finger injuries in 283 children aged less than 14 years old in Scotland has been studied [3]. A common location of the door for such finger injuries was the living room (32%) and toilet/bathroom (20%). The front door was a less important site (9%) in contrast to our study. Children closed the door and adults were often not responsible for the injury, consequent with our study.

The frequency of children who required admission to hospital (65%) was high compared with the 3.4% and 1.4% shown in previous studies of hand injuries in children [3,5]. Many children with minor hand injuries are not taken to a Department of Hand Surgery but are treated in the primary health care. We searched in the register at Malmö University Hospital for children with hand or forearm diagnoses treated at other departments. About 75 children were treated by the Emergency Department and 10 at the Department of Orthopaedics. The incidence of 33.4/10 000 persons/year (the same as previously reported [18]) is the incidence of injuries that are referred to hand surgery care. If the true incidence of all these injuries could be calculated, the hospitalisation rate would be less in our study.

There are limitations in our study. The correct answers in a questionnaire about injuries to children are sometimes modified. The parents may remember the wrong answers or write the answers that they think are expected, because of feelings of guilt.

The effects of a safety promotion strategy will depend on several factors, including both parents' and the child's compliance with safety procedures. In a study of young children's knowledge of safety rules, 4 to 6 year old children recalled about half of their parents' rules for home safety [24]. No correlations were found between the injury history of the child and the number of rules he or she remembered. Adults were present at the injury moment in 66 of totally 79 cases in our study. Our estimate is that passive prevention through safer home environments is an effective way to prevent hand and forearm injuries.

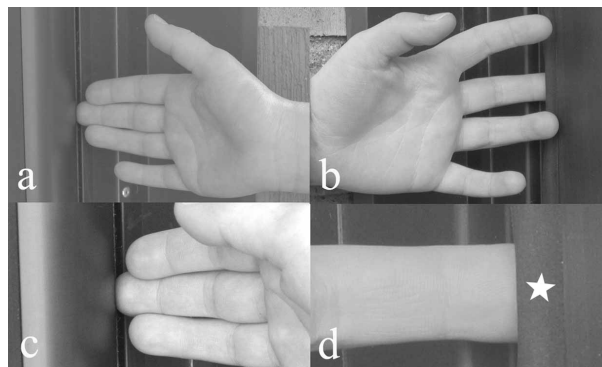


Figure 3. Two examples of constructions of hinges of front doors that avoid pinching finger tips. On the left (*a, c*), the hinge is formed as a long cylinder attached at the bottom and top to the frame, where there is almost no space between the door and the frame, thereby making it impossible to squeeze a fingertip. On the right (*b, d*) the hinges are hidden at the top and the bottom of the door. There is a rubber membrane (white star) between the door and the frame, so avoiding crushing of the finger even if it is put between the door and the frame. The lower pictures (*c, d*) are details of *a* and *b*.

Doraiswamy brought up suggestions of door safeguards in a previous study [16]. Doorstoppers and/or a safe design of the hinge side are alternatives that can decrease the number of fingers stuck in doors (Figure 3). Similar constructions are installed at many day-care centres and schools in Sweden, indicated by the low number of injuries occurring at these places. Front doors in ordinary houses can be provided by a safe design of the hinge side. We present 10 tips to avoid hand injuries (Appendix 2) based on risk factors shown in this study and our previous studies [18,25]. This information can be used to increase the knowledge of risks for, and causes of, hand and forearm injuries among parents to young children.

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Appendix 1

Traumatic hand injuries in preschool children

No _____

Questionnaire

It is important that you complete the questionnaire as carefully as possible. If you have any questions or are in doubt about anything, please contact the person who gave you the questionnaire. *Circle the answer of your choice, or fill in an alternative choice on the line.*

1. On what date did the injury occur? _____

2. a) On what day of the week? b) At what time of the day?

a) Monday Tuesday Wednesday Thursday Friday Saturday Sunday

b) 6-10 a.m. 10-12 a.m. 0-4 p.m. 4-8 p.m. 8-12 p.m. at night

3. In which room/place was the child injured?

kitchen bathroom livingroom bedroom playing room garden day-care centre

school playground other place _____

4. Were there any other children around? How many?

brother __ sister __ playmate __ other __

5. Were there any adults around?

mother father grand-mother grand-father day-care staff other _____

6. In what activity was the child involved at the moment of injury?

playing eating cycling going in the car sleeping bathing

other activity _____

7. In what activity were any adults involved at the moment of injury?

cooking eating sleeping playing with the child building washing ironing
washing up reading driving the car gardening sauna renovating

other activity _____

8. Was there any object(s) involved in the accident?

Yes, which one? _____ No

9. Please describe *how* the object caused the injury _____

10. If it is a burn injury, what caused it?

water coffee/tea oil soup fire coal oven plate
oven door iron element chemicals other object _____

11. Did any specific person cause the injury?

Yes, which one? _____ No, it appeared spontaneously

12. If it is a jamming injury, where was that?

inner door front door gate car door boot balcony terrace door
cupboard under the under a
door TV stone other place _____

13. If the child was stuck in a door or gate, where about on the door did it happen?

hinge side lock side floor side roof side

14. Did any person in particular close the door?

brother sister playmate father mother other _____

15. If the child fell, where from was that?

table chair sofa bicycle ladder swing climbing
tree
peram- rocking
bulator horse other object _____

16. Which one is the child's dominant hand, i. e. the hand he or she uses the most?

right left both are used equally

17. In which country was the child born? _____

18. In which country were you (parents) brought up (0-16 years old)?

21. How many brothers does the child have? 1 2 3 4 or more

Appendix 2

- 1) Hand injuries occur independently of sex and nationality.
- 2) Three quarters of all hand injuries occur at home.
- 3) Be extra observant in the afternoon between 4 p.m. and 8 p.m.
- 4) Adults are often present at the time of injury. Children are safe only when they are under direct supervision.
- 5) The dexterity of the hand is not fully developed until the age of 6 years. To close a door or carry a glass is difficult, even if the child is willing.
- 6) Don't let children handle sharp objects. A fall with a glass or a bottle can cause serious injuries.
- 7) Tips for prevention of burns:
 - Be extra observant when the child is about a year old.
 - Protect the oven.
 - Keep hot fluids out of reach.
 - Don't put the children on the sink.
 - Use a kitchen gate.
- 8) Tips for preventing injuries from getting stuck:
 - Injuries to fingers are common among children 2 to 6 years old.
 - Be extra observant in the hall.
 - Keep the front door shut when no one is going in or out, even in summer.
 - Use protection devices on front doors.
 - Use a rubber stopper or put a towel over inner doors.
 - Fingers can get stuck on both sides of the door.
 - The door is often closed by the child itself, or another child, causing injury.
- 9) Young children may not remember rules for safety.
- 10) A safe environment is good protection.



Research article

Open Access

Cost per case or total cost? The potential of prevention of hand injuries in young children – Retrospective and prospective studies

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Abstract

Background: Health-care costs for hand and forearm injuries in young children are poorly documented. We examined costs in 533 children injured years 1996–2003.

Methods: Health-care costs and costs for lost productivity were retrospectively calculated in children from three catchment areas in Sweden. Seven case categories corresponding to alternative prevention strategies were constructed.

Results: Over time, diminishing number of ward days reduced the health-care cost per case. Among children, the cost of lost productivity due to parental leave was 14 percent of total cost. Fingertip injuries had low median costs but high total costs due to their frequency. Complex injuries by machine or rifle had high costs per case, and despite a low number of cases, total cost was high. Type of injury, surgery and physiotherapy sessions were associated with variations in health-care cost. Low age and ethnic background had a significant effect on number of ward days.

Conclusion: The costs per hand injury for children were lower compared to adults due to both lower health-care costs and to the fact that parents had comparatively short periods of absence from work. Frequent simple fingertip injuries and rare complex injuries induce high costs for society. Such costs should be related to costs for prevention of these injuries.

Background

Hand and forearm injuries in young children range from simple wounds, burn injuries and fractures to nerve and tendon injuries. Even in children severe complex injuries may occur. The most frequent injury among children, caused by jamming indoors, is a fingertip and nail bed injury with or without fracture. Recent research reports a substantial increase in incidence of children admitted with hand and forearm injuries in Sweden 1987–2001 [1,2]. The reasons for the increase are unknown. Health-care utilization of hand and forearm injuries in children is

poorly documented [3-9]. In adults, the costs for a hand injury vary with type of injury and are influenced by several factors including the length of sick leave [10-12]. From a policy point of view it is useful to relate the cost of health-care utilization to the cost for prevention, not the least since many of the injuries in children probably can be avoided [3,13,14]. The information should be presented to politicians and authorities in view of the reported observed increased incidence. Our idea is that if injuries are to be prevented, the injury mechanisms behind different common or severe diagnoses must be

identified. With experience from our earlier studies [1,2,15], we have created seven case categories, typical for hand and forearm injuries in children. In this study we quantify how much these different cases cost in relation to each other. With this information, injury prevention may be more effective and directed against the important cases from a cost point of view.

Methods

The information about health-care resource use for hand and forearm injuries in children was collected during two previous studies [2,15]. Between 1996 and 2000 [2] we retrospectively included all young children (0–6 years old) with an unintentional hand or forearm injury ($N = 455$) that were treated as outpatients or hospitalized at the Department of Hand Surgery, Malmö, Sweden. The children were identified from the diagnostic registers by the Swedish Version of the International Classification of Diseases, Ninth Revision (ICD-9) during 1996–1997 (800A–999X) and Tenth Revision during 1998–2003 (S00.0–T98.3). Children with fractures of the radius and ulna or more proximal bones were not included, as they were treated at the Department of Orthopaedic Surgery. Children with bites and infections, due to trauma, were included.

During one year (February 2002 to January 2003), all children ($N = 96$) referred to the Department of Hand Surgery, Malmö, Sweden, were invited to a prospective study where a questionnaire was completed by the parents at the hospital (response rate 78/96:81%) [15]. From the questionnaires we had information on if, and for how long, each of the parents was absent from paid work as well as their normal profession and occupation. The cost of lost productivity was calculated from the number of days the parents stayed at home to take care of their injured child using the human capital approach [16]. The projects were carried out in compliance with the Helsinki Declaration and after approval by the Ethical Committee in Lund, Sweden (LU 707-01, LU 451-03; verbal and written informed consent).

We also compare the cost of health-care to the cost of prevention using an illustrative example of fingertip injuries caused by jamming in doors and prevention by installing doors with safety arrangements. The calculations were based on the Malmö catchment area where we had a complete coverage of hand injuries.

The costs within the health care sector were calculated using the fees paid by a referring hospital for patients registered outside the region of Skåne and included overhead cost using year 2000 prices. The fees were EUR 868 per emergency ward day, EUR 414 per elective ward day, EUR 231 per emergency operative minute, EUR 12 per elective

operative minute, EUR 154 per physician visit and EUR 62 per visit to a physiotherapist or occupational therapist (annual average exchange rate year 2000: 1 EUR = 8.4465 SEK).

Details of health-care costs were retrieved from the patient's notes. In addition to this, we collected information about national background, age at the time of injury, sex, date and place of injury, aetiology and diagnosis. Data were also divided by the catchment area, i.e. Malmö municipality (all types of injuries referred to our department), county Skåne excluding Malmö municipality (at time of data collection more severe injuries referred to our department) and southern part of Sweden excluding Skåne (more severe injuries referred to our department).

Based on the diagnoses and the mechanisms of injury, and with experience from our earlier studies, we constructed seven case categories that correspond closely to alternative prevention strategies. These were; A) burn injuries caused by hot objects, B) fingertip injuries caused by jamming in doors or other pinch objects, C) fractures, dislocations and sprains caused by falls or hits, D) tendon and nerve injuries and wounds caused by sharp objects, E) complex injuries (an injury to more than one of the anatomical components of the hand or total or subtotal amputation through the middle or proximal phalanges) caused by falls with sharp objects, F) complex injuries caused by machines and rifles and G) other injuries (which include burn injuries not caused by hot objects, fingertip injuries caused by sharp objects and falls or hits, complex injuries and fractures caused by pinch or crush objects, infections and bites). The study includes all 533 children from 1996–2000 and 2002–2003.

Initial analyses of data showed a linear association between health-care cost and length of stay, but with an increasing variation around the mean trend. Separate cost functions were therefore estimated for three subsamples, following the length of hospital stay: no ward days, 1–3 ward days and 4 or more ward days.

Statistical analyses

Data is described using median with 25th and 75th percentiles for the total sample and by catchment area. Multiple regression analysis [17] was used to analyse what factors were associated with the variation in costs. Regression analyses are used to describe the statistical associations between a dependent and one or more independent variables. The estimated coefficient of a variable is then the partial effect of that variable on the dependent variable holding all other variables constant. The distribution of health-care costs was skewed to the left with a tail of high-cost observations and the cost equations were estimated using the logarithmic transformation on cost [17]. The

Table 1: The health-care cost per child, in EUR, of treating hand and forearm injuries in 533 young children at Department of Hand Surgery, University Hospital, Malmö, Sweden by catchment area.

	Malmö (N = 323)	Skåne ¹ (N = 168)	Southern Sweden ² (N = 42)	Total (N = 533)
Gender:				
	<i>Number of children (%)</i>			
Boys	201 (62)	98 (58)	22 (52)	321 (60)
Girls	122 (38)	70 (42)	20 (48)	212 (40)
Age:				
	<i>Median age in months (25th to 75th percentile)</i>			
	45 (24–66)	38 (20–62)	40 (19–56)	42 (22–63)
Cost data:				
	<i>Median cost in EUR (25th to 75th percentile)</i>			
Length of stay	868 (0–1736)	2743 (0–2604)	2584 (1736–4341)	1282 (0–2150)
Surgery	188 (0–656)	563 (0–1061)	908 (352–1852)	351 (0–882)
Physician visit	308 (154–616)	462 (308–616)	308 (154–616)	308 (154–616)
Total health care cost	1280 (308–2814)	2743 (1049–4560)	3754 (2478–6486)	2102 (462–3606)

Data are presented as median with 25th and 75th percentile.

¹ Malmö excluded.

² Malmö and Skåne excluded

estimated coefficients then show in percentage terms how much higher or lower health-care costs were associated with different characteristics, holding everything else constant, i.e. the marginal effects. For instance, from Table 2 column (1), children with no ward days who had utilised physiotherapy during the health-care episode cost on average 56 percent more than other children with no physiotherapy, all else equal. As both dependent variable cost and independent variable length of stay were logged in the cost equations, the coefficient was an elasticity. For instance, from Table 2, column (2) the coefficient of length of stay is 0.70, which means that when length of stay increased by 10 percent, the cost increased by 7 percent, all else equal. Below each regression table we have listed the characteristics of the reference person. A reference person is a "baseline person" or a statistical construction used to make comparisons, but the study population does not necessarily contain a child with the listed characteristics.

The negative binomial regression model was used in the analysis of factors associated with the variation in length of stay. The incidence rate ratios (IRR) from the estimation show the relative effect of a characteristic holding other factors constant. An IRR equal to one means the same relative incidence and IRR less (greater) than one means a relatively lower (higher) incidence.

All analyses started by including all the available variables that were hypothesised to have an influence on costs. The least significant variable was then excluded and the model

rerun. This procedure continued until only variables significant at the 5% level remained (reduced model) [11,12].

Results

Annual median cost and length of stay

A total of 533 children with an age up to 7 years were included in the study, consisting of 212 girls (40%) and 321 boys (60%). The distribution of health-care cost among the children by catchment area is shown in Table 1. The annual health-care cost for all injuries decreased during the study period from EUR 398,762 (1996) to EUR 247,540 (2000), and was EUR 192,624 for the 12 month period February 2002 – January 2003 by year 2000 prices of resource use. The number of patients during the years varied, i.e. the highest number of treated patients were 2000 and the lowest 1996 and 2002–2003, with a median number of patients of 86 per year. The annual distribution of median cost per patient and length of hospital stay divided by Malmö municipality, Skåne (Malmö municipality excluded) and southern part of Sweden (excluding Skåne) is shown in Fig 1. Generally, the cost was higher and the length of stay longer among the patients from the area outside Skåne, compared to the patients from Malmö, during the entire period.

The main contributor to the total health-care cost was ward days followed by surgical sessions and physician visits. Only 12% of the children used physiotherapy (<1% of the costs; not included in Table 1). The median cost of surgical sessions was higher for patients from Skåne, and par-

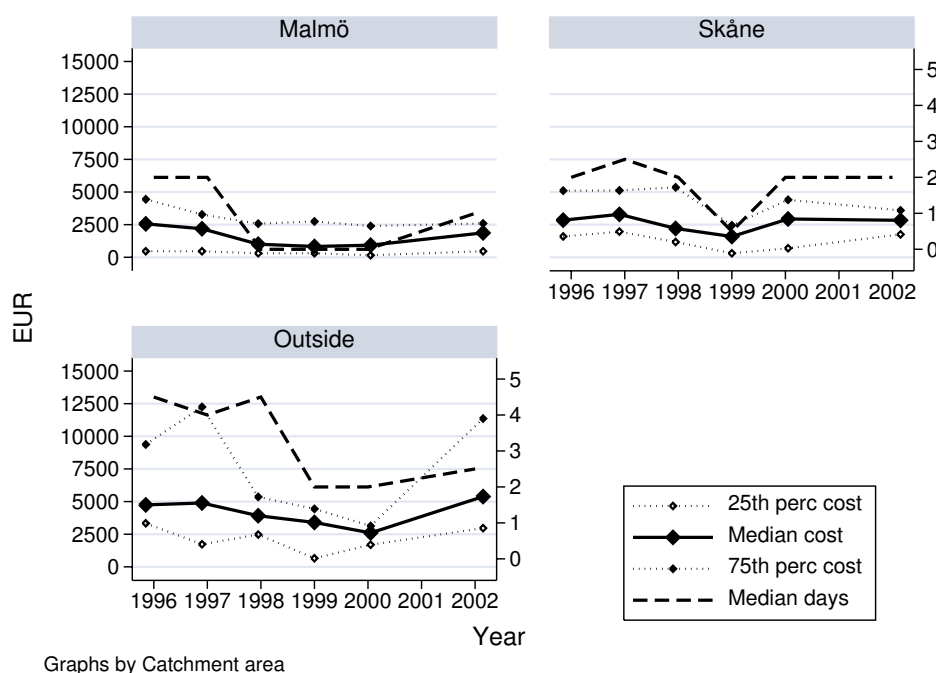


Figure 1
Annual median total health-care cost in EUR (left hand side scale) with 25th and 75th percentiles and number of ward days (right hand side scale) per patient 1996–2003.

ticularly for patients from southern Sweden. This was largely explained by the fact that only major hand injuries were referred to the Department of Hand Surgery in Malmö, while the less severe injuries were treated at the local hospital. The impact of catchment area from the regression analysis is reported below.

In the subsample of children admitted in 2002–2003 and residents in Malmö ($N = 51$), we found that the cost of lost productivity was only 14 percent of the total cost, whereas the cost of surgical sessions amounted to 20 percent and other health-care costs to 65 percent (Fig 2).

A. Burn injuries caused by contact with hot objects

The median cost per patient among burn injuries ($N = 82$) caused by contact with hot objects was low. A few children were admitted, needing multiple dressings and treatment with antibiotics, reflected by the number of outliers (Fig

3). The total health-care cost was therefore higher than for cases with fractures, dislocations and sprains caused by falls or hits (C) and complex injuries caused by falls with sharp objects (E); (Fig 4). The children were often admitted after more than one day (Fig 5).

B. Fingertip injuries caused by jamming in doors or other pinch objects

The median cost for a fingertip injury ($N = 188$), caused by a door or any other pinch object, was in the middle compared to the other cases (Fig 3). In contrast, the total health-care cost for these cases was the highest, because of their frequency (Fig 4). More than 70% of these children were admitted to the department on the same day as the injury occurred (Fig 5). A patient with a fingertip injury, treated more than 4 ward days, had a low health-care cost compared to the reference case (Table 2).

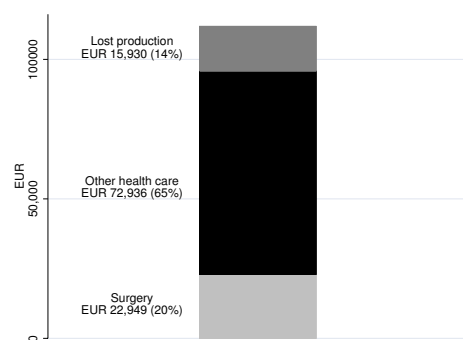


Figure 2
Total cost (EUR) for hand and forearm injuries in 51 children from the Malmö catchment area for 12 months 2002–2003 by sources of cost (surgery, other health-care cost, including ward days; lost productivity when parents were absent from paid work due to the child's injury).

C. Fractures, dislocations or sprains caused by falls or hits

A fracture, dislocation or sprain ($N = 47$), caused by a fall or hit, had the lowest median cost (Fig 3). Thus, the total health-care cost for these cases was the second lowest of all categories, despite their high frequency (Fig 4). Almost 90% were admitted to the department two or more days after they were injured, since such injuries generally were not associated with open wounds (Fig 5). Outpatients and children treated more than 4 days were associated with low health-care costs, compared to the reference case (Table 2). The children were treated in about half the number of ward days as the reference case, probably since no operation was required (Table 3).

D. Tendon and nerve injuries or wounds caused by contact with sharp objects

The median cost for a tendon/nerve injury or a wound caused by a sharp object ($N = 55$) was higher than for many other cases, but few cases were really expensive (Fig 3). The total health-care cost was about the same as for burn injuries caused by contact with hot objects (A), but not so high compared to complex injuries caused by machines or rifles (F) or to fingertip injuries (B; Fig. 4). The health-care cost was substantially lower for such a case not hospitalized (Table 2), including for instance a simple wound that did not need further treatment. Among admitted patients treated less than 4 days, the cost was high compared to the reference case, which may be reflected by the tendon and nerve injuries and not wound per se (Table 2). These cases were admitted early after the

injury occurred (Fig 5), and were not associated with any significant change in length of stay (Table 3).

E. Complex injuries caused by falls with sharp objects

The median cost of a complex injury caused by a fall with a sharp object ($N = 6$) was the second highest (Fig 3). These cases were few and, in contrast, the total health-care cost was the lowest when compared to all other cases (Fig 4). Two thirds were admitted the same day as they were injured (Fig 5). The cost analysis showed that the health-care cost was high compared to the reference case, if the patient was admitted less than 4 days (Table 2).

F. Complex injuries caused by machines or rifles

A complex injury caused by a machine or a rifle ($N = 12$) entailed a high cost per case (Fig 3). Despite the low number of injuries, this group had the second highest total health-care cost of the defined categories [excluding the category Others (G)] (Fig 4). These children were admitted to the Department within one day after the injury (90%; Fig 5), often with an urgent transport by ambulance. In the cost analysis, the cost for such a case was substantially high compared to the reference case, among admitted patients (Table 2). These cases were not associated with any change in length of stay (Table 3).

G. Other injuries

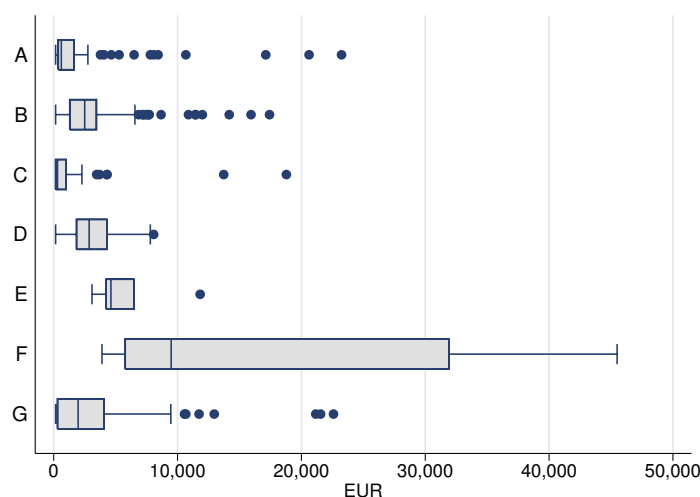
This category consisted of 143 patients, each with different injuries to the hand or forearm (see Methods). These cases were too few each to be separately included in the analyses. Generally, these heterogeneous cases had low median costs but with a few outliers with high costs. The health-care cost was low compared to the reference case, if the patient was not admitted (Table 2).

Age, gender and national background

An increasing age was associated with less ward days (Table 3), but age had no significant effect on the health-care cost. We found no difference between girls and boys considering health-care costs or length of stay. Having an immigrant background was associated with more ward days (Table 3), but had no significant effect on health-care cost.

Surgical sessions, physiotherapy, time before admittance and catchment area

Additional surgical and physiotherapy sessions were associated with higher health-care costs, mostly so for children treated as outpatients (Table 2). For example, compared to the reference person, having one additional surgical session was associated with a 102 percent higher cost [column (1)] and more ward days (Table 3).

**Figure 3**

Box plot of health-care cost (EUR) by type of case, sorted by median cost. Seven case categories that closely corresponded to alternative prevention strategies were constructed: A) burn injuries caused by hot objects, B) fingertip injuries caused by jamming in doors or other pinch objects, C) fractures, dislocations and sprains caused by a fall or hit, D) tendon and nerve injuries and wounds caused by sharp objects, E) complex injuries (an injury to more than one of the anatomical components of the hand or total or subtotal amputation through the middle or proximal phalanges) caused by falls with sharp objects, F) complex injuries caused by machines and rifles, and G) other injuries.

Cost of health-care and cost of prevention

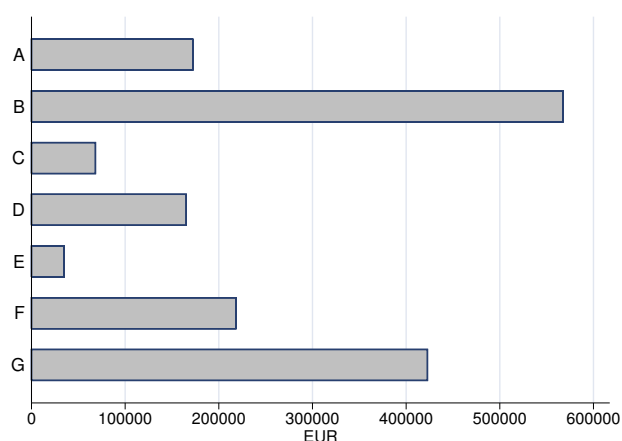
In the light of impact on the use of health-care resources, we further explored the cost of prevention of fingertip injuries as an example. Based on communications with two manufacturers of doors, information was obtained on the additional cost of doors equipped with safety arrangements on the hinge side to prevent children from accidentally crushing their fingers. The additional cost ranged from EUR 85 to EUR 167 per door (prices Jan 2007). If all fingertip injuries could be avoided through installation of safer doors, treating 188 children at our department is equivalent to the additional cost of 3400 to 6680 doors with safety arrangements.

Continuing our example, we restrict the sample to Malmö municipality, where we were certain that all pinch injuries were transferred to our department. Assume that we wanted to avoid the 115 pinch-cases whose health-care costs were EUR 320 000 and using the less costly safety door at the addition cost per door of EUR 85, we would get 3765 doors for the same price. Malmö municipality had 133 000 households in 2003, and assuming that an average household has at least 5 doors, 665 000 doors

would have to be replaced counting doors only in private homes. This calls for selective prevention strategies where safety doors are primarily installed in places where young children typically stay.

In our sample, house doors were by far the most common mechanism, but 13 of all children were injured in car doors. Hence, full prevention need to extend beyond houses. Alternative strategies could be closer surveillance of young children, temporary removal of doors indoors where children play, etc, or putting a towel on the top of the door thereby preventing the children to fully close the door [15]. Intervention programs by home visits can reduce the total costs of care [13].

In our data, 12 of the pinch-injuries in Malmö happened at the day care centre or school, while 46 occurred at home and 29 during leisure time. The mean number of children that went to day care centres in Malmö, between 1996 and 1999, was 10 870 [18], and the mean population in Malmö was 17 590 children (1–6 years old; <http://www.scb.se>). Our estimate is that only a few children with hand injuries were injured at a day care centre, com-

**Figure 4**

Bar plot of health-care cost (EUR) by type of case, sorted by total costs for all patients. Seven case categories that closely corresponded to alternative prevention strategies were constructed: A) burn injuries caused by hot objects, B) fingertip injuries caused by jamming in doors or other pinch objects, C) fractures, dislocations and sprains caused by a fall or hit, D) tendon and nerve injuries and wounds caused by sharp objects, E) complex injuries (an injury to more than one of the anatomical components of the hand or total or subtotal amputation through the middle or proximal phalanges) caused by falls with sharp objects, F) complex injuries caused by machines and rifles, and G) other injuries.

pared to the fact that 62% of all children went to day care centres during our study period. One explanation may be that safety doors are already installed at day care centres and schools in Sweden.

Discussion

The main sources of health-care cost for 533 young children with hand and forearm injuries, treated at the Department of Hand Surgery, Malmö, Sweden, were ward days (59%) and surgery sessions (26%). In the subsample of 77 children, treated during the last year of the study (2002–2003), we had additional information on consequences of the injury measured by parents' days of absence from work due to the child's injury, a factor not previously considered [4,6,19]. The cost to society in terms of lost productivity, when parents stayed at home, accounted for 14% of the total cost and was about equal in magnitude to that of outpatient physician visits. Previous analyses on adults with tendon, nerve and other hand and forearm injuries from our department, showed long periods of sick-leave, implying that the cost of lost productivity accounted for 60–87 percent of total costs [11,12,20].

This may reflect at least two differences between children and adults. First, the fact children were able to attend the day care centre and adapt their play to the conditions of the injury. Hence, the injury had less consequence due to adaptable "usual activities". A few adults in the previous studies had a job where the hand injury caused less impairment, but in the typical case, workers were not able to perform their normal tasks at work and were thus granted sick leave. Secondly, eleven (14%) mothers and fathers reported that they were on parental leave at the time of the injury and thus no additional sick-leave was granted, as the parent was already at home taking care of the injured child and his/her siblings. As we measured lost market productivity, potential limitations in the family's activities were not included in the valuation. Only eight children (1.5%) were classified to have a major impairment with *potential* influence on future labour-market consequences, but we do not have further follow-up data on these children and hence we refrain further quantification in terms of costs or future lost quality of life. The analysis did not include quality of life issues, and will thus to some extent underestimate benefits of preventive strategies. In principle, the cost to the child in terms of the reduction in opportunities to play etc could also be included, but it was beyond the scope of this study to

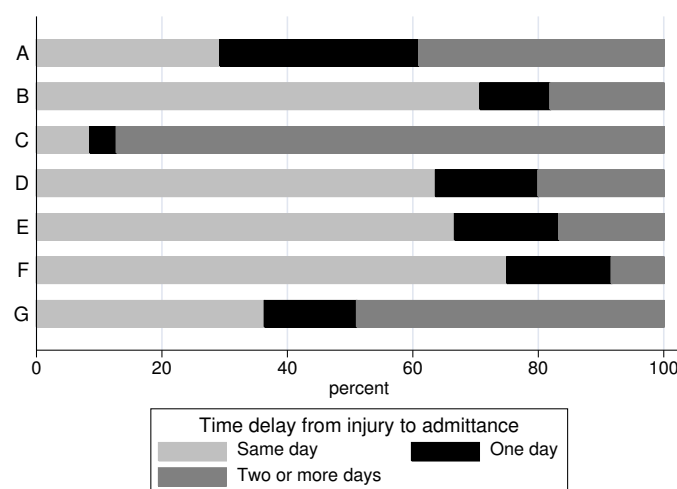


Figure 5

Bar plot of distribution of time from injury to admittance by type of case sorted by percent admitted the same day, after one day and after two or more days. Seven case categories that closely corresponded to alternative prevention strategies were constructed: A) burn injuries caused by hot objects, B) fingertip injuries caused by jamming in doors or other pinch objects, C) fractures, dislocations and sprains caused by a fall or hit, D) tendon and nerve injuries and wounds caused by sharp objects, E) complex injuries (an injury to more than one of the anatomical components of the hand or total or subtotal amputation through the middle or proximal phalanges) caused by falls with sharp objects, F) complex injuries caused by machines and rifles and G) other injuries.

quantify the limitations in terms of type and quantity of activities of the child.

Our data covered a seven year long time period, and we found that length of stay has varied over time with a possible long-term downward trend (Fig 1) in spite of an increased incidence of hand and forearm injuries [1,2]. In particular, there was a dip in 1998–2000 for patients from the town of Malmö and in 1999 for patients from other parts of the region of Skåne. The decrease in length of stay for patients from other parts of southern Sweden dipped in 1999, but seemed to remain at the new level thereafter. Notably over the whole study, 42 patients were admitted from other county councils and the first year included 16 of these.

Fig 1 also illustrates the close relationship between length of stay and cost, which was consistent with our finding that ward days were the major source of cost for most patients (Table 2). We have used the price per ward day and other resource use from year 2000 paid by other county councils, which includes overhead costs. Over the

period 1996–2003, the routines or criteria for admittance to or discharge from our department have not changed for health-care reasons. However, the organization of the health-care delivery changed when the Region Skåne was formed Jan 1 1999, merging the two county councils and one municipality formerly responsible for providing health-care. This coincided with the mentioned dip in length of stay for children with a hand or forearm injury, while the impact on median total health-care costs was smaller. Interestingly, from Fig 1 we also note that the patterns of change differ somewhat between the three catchment areas covered by the Department of Hand Surgery in Malmö. The median length of stay for children from Malmö and from the area outside Skåne decreased by two days implying an administrative decrease of length of stay, which did not seem to be true for children from Skåne (excluding Malmö). For all years but 1999, the distribution of length of stay and of cost per episode was not equal for patients from Malmö compared to the two other catchment areas by the Mann-Whitney test of equality of distribution. Patients from outside Skåne were not equal to patients from Skåne excluding Malmö in year 1996,

Table 2: Ordinary least squares regression results of the logarithm of health-care costs on case categories, demographic and treatment characteristics.

Variable	(1) ^{a)} No ward days Coefficient	(2) ^{b)} 1–3 ward days Coefficient	(3) ^{c)} 4+ ward days Coefficient
Fingertip injury caused by door or other pinch object			-0.10*
Fracture, sprain or dislocation caused by fall/hit	-0.56***		-0.16*
Tendon or nerve injury or wound caused by sharp objects	-0.75***	0.09*	
Complex injury caused by fall with a sharp object		0.32**	
Complex injury caused by machine or rifle		0.36*	0.28**
Other injuries	-0.39***		
Number of surgical sessions	1.02***	0.13**	0.04*
Number of physiotherapy sessions	0.56***	0.21***	0.18**
Logarithm of length of stay		0.70***	0.79***
Constant	5.99***	7.24***	7.29***
Number of individuals	213	218	102
Adjusted R ²	0.35	0.69	0.89
F	23.83***	82.40***	179.89***
Akaike's information criterion	368.71	-87.08	-35.50

Separate regressions by length of stay: No ward days, 1–3 ward days and 4 or more ward days. Estimated coefficients denote percentage change in cost.

Note: Significance levels indicated by stars: * $p < 0.05$; ** $p < 0.01$ and *** $p < 0.001$.

Initial model controlled for age, gender, ethnicity, all case categories, physiotherapy, place of injury, catchment area, admitted on weekend, admitted later than the same day, surgery and length of stay. Insignificant variables were omitted from the final model.

^{a)} Reference person was a child with a burn injury or finger tip injury (categories A and B), no physiotherapy and no operation session.

^{b)} Reference person was a child from categories A, B, C or G, no physiotherapy, no operation session and zero ward days.

^{c)} Reference person was a child from categories A, D, E or G, no physiotherapy, no operation session and zero ward days.

while the lack of significance for years 1997 and onwards in this case was probably also related to the lack of statistical power as the number of patients from outside Skåne was below 10 these years. In the latter group, the number of actual nights in hospital may be overestimated for patients living in Malmö, who during the episode needed multiple re-dressings performed during anaesthesia, but otherwise were on leave from the hospital. Using a unit price per ward day the total health-care cost of these patients will be overestimated to some degree.

In a sensitivity analysis, we re-estimated the cost and length of stay equations, restricting the sample to only Malmö patients consisting of 61 percent of the total sample. We found, in essentials, the same factors to be associated with the variation in cost and length of stay. Neither did the magnitude of the coefficients change for central variables including the case categories.

It seems unlikely that changes in the administrative price per se during the observed period would have affected the

Table 3: Negative binomial regression of factors associated with the variation in number of ward days. All patients.^{a)}

Variable	IRR	95 % confidence interval
Fracture, sprain or dislocation caused by fall/hit	0.45**	0.27–0.75
Age	0.99***	0.99–1.00
Immigrant background	1.23*	1.00–1.51
Number of surgical sessions	3.46***	2.96–4.06
Admitted day after injury	0.77*	0.58–1.01
Admitted two or more days after injury	0.78*	0.63–0.98
Patient from Malmö city	0.58***	0.48–0.71
Alpha	0.53	0.41–0.67
Number of observations	533	
Pseudo R ²	0.18	

Note: Significance levels indicated by stars: * $p < 0.05$; ** $p < 0.01$ and *** $p < 0.001$. IRR = incidence rate ratio.

^{a)} Reference person was a newborn child from categories A, B, D, E, F, G; from outside Malmö city and with Swedish background, admitted the same day as the injury and no operation session.

incentives for referral and/or discharge. There have been no relative changes in the administrative price, only an increase by index. We cannot rule out, that constrained budgets of referral departments may have induced a reduced probability to refer children with less severe injuries, and rather treat them at home. Furthermore, the number of ward days for all patients, irrespective of age, has steadily decreased 1992 to 2006 by 1.0 day with no obvious dip. Hence the general trend seems to have affected also the number of ward days for young children and in some cases more so.

Our goal in the analysis has been to identify and quantify the cost to the health sector, and to society, of hand and forearm injuries in young children. Information on sources of cost and its magnitude is necessary for the selection of efficient prevention strategies, besides knowledge about the efficacy and other aspects of alternative interventions [3,4,21]. The cost of illness methodology used here is typically used in exploratory phases, where the aim is to develop and choose between different lines of development. For us this was also the motive behind defining case categories, rather than merely performing the analyses by diagnosis. As defined, the case categories are associated with the mechanism of injury, and thus possible preventive strategies.

In fingertip injuries caused by jamming in doors or other pinch objects (category B), the median was lower than tendon and nerve injuries and wounds, but a high number of treated patients implied that treatment of these fingertip injuries accounted for the single largest source of cost. The total health-care cost was EUR 568 000 for 188 patients. In comparison, the less common complex injuries caused by a machine or a rifle (category F), had substantial median cost per case but as there were only 12 patients over the entire period, the total health-care cost remained at EUR 218 000. This reflects the dilemma of prevention – cost per case or total costs [19].

Contact with sharp objects is the second most common (21%) injury mechanism in Swedish children (0–6 years) admitted for hand injuries [1]. In our cost analysis, patients with tendon/nerve injuries and wounds or complex injuries caused by sharp objects were associated with 9% and 32%, respectively, higher health-care costs for children treated 1–3 ward days. Such objects cause injury to important either single (tendon/nerve) or multiple (complex) anatomical structures. The health-care cost for complex injuries caused by machines or rifles was higher for children admitted 1–3 days (36% higher) and 4 or more days (28% higher). Among 10,000 Swedish children (0–6 years old) injured during 15 years, five percent of the injuries were caused by contact with machinery and

0.4% by contact with handgun/firearm discharge (severity unknown) [1].

Statistics from the National Board of Health and Welfare in Sweden (2003–2004) show that among children (0–17 years old) that applied for health-care at Emergency Departments or General Practitioner centrals, at hospitals, because of an injury, one fourth (23%) had injuries to the hand and wrist <http://www.socialstyrelsen.se>. Only injuries to the head were more common (25%). Separate information is not available for 0–6 year old children. The average incidence of hospitalized hand and forearm injuries among children 0–6 years was 40/100,000 persons/year during 1987–2001 and increased during this period [1]. The hand must be looked upon as a frequently recurrent part of the body in accidents among Swedish children. The cost point of view that we now have introduced is one way to bring the problem to general notice.

Conclusion

In conclusion, health-care costs for treating hand and forearm injuries in young children have not been considered previously. When cases were sorted by mechanism and type of injury, fingertip injuries caused by jamming doors or other pinch objects were associated with the highest total health-care cost. Second highest total health-care cost, among the defined categories, were complex injuries caused by machines or rifles. Even though only 0.4–5% of the population, these cases induced a high cost for treatment of the individual child. Lost productivity was much less than observed in adults. In designing prevention strategies considering both the cost savings in the health care sector, and perhaps more importantly the avoided pain and suffering for the child, the results in this study indicate that two important groups are fingertip injuries (high total cost for the group) and complex injuries (high cost per case). Therefore, the costs for prevention should be considered in view of the question: "Cost per case or total cost?"

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors have contributed equally to the article.

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