Epidemiology and etiology of childhood fractures in southern Sweden

Lempesis, Vasileios

2018

Document Version:
Förlagets slutgiltiga version

Link to publication

Citation for published version (APA):
Lempesis, V. (2018). *Epidemiology and etiology of childhood fractures in southern Sweden*. [Doktorsavhandling (sammanläggning), Ortopedi - klinisk och molekylär osteoporosforskning]. Lund University: Faculty of Medicine.

Total number of authors:
1

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Epidemiology and Etiology of Childhood Fractures in Southern Sweden

Vasileios Lempesis

DOCTORAL DISSERTATION

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To be defended at:

Ortopedens Föreläsningssal, Inga Marie Nilssons gata 22, Malmö

May 11, 2018 at 09.00.

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Karolinska Institutet

Organization
LUND UNIVERSITY
Clinical and Molecular Osteoporosis Research Unit
Dept of Clinical Sciences, Dept of Orthopedics
Skåne University Hospital, Malmö

Document name
DOCTORAL DISSERTATION

Date of issue
April 19, 2018

Author: Vasileios Lempesis

Sponsoring organization

Title and subtitle:
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Abstract

Background: As much as 40–50% of children are expected to sustain fractures during growth. A childhood fracture is also associated with high risk of fractures in adult life. Previous research has shown that fracture incidence has not been stable and some studies suggest that this has also continued during recent decades.

Aims: The aim of this thesis was therefore to describe fracture epidemiology and etiology in children in Malmö, Sweden, in 2005–2006. We also wanted to make historical comparisons, to be able to estimate fracture time trends in the pediatric city population, and investigate time trends in the epidemiology of pediatric distal forearm fractures in the county of Skåne.

Methods: In papers I, III, IV we identified fractures in children (age<16 years) in the city of Malmö during the years 2005–2006 through the diagnosis registry, medical charts and radiographic archives of the hospital. We then calculated crude and age-standardized fracture rates and made comparisons with previously collected and published pediatric fracture data from 12 sample years during the period 1950 to 1994. In Paper II we used data from the SHR, an official database of in- and outpatient care episodes in the county of Skåne, Sweden, to ascertain distal forearm fractures in children (<17 years of age) that occurred between 1999 and 2010.

Results: In paper I, we found that the rate of pediatric fractures in the city of Malmö in 2005–2006 was 1832 per 10^5 patient years (2359 in boys and 1276 in girls). Fractures were more common in boys than in girls (age-adjusted fracture RR 1.8; 95% CI 1.6 to 2.1) and the most common fracture types were the distal forearm (31%), the phalanges of the digits (15%), and the metacarpals (10%). Fractures in which the etiology could be determined occurred most often during sports, playing or in traffic. The age- and gender-adjusted incidence in children in 2005–2006 did not differ significantly from 1993–1994 (RR 0.9; 95% CI 0.8 to 1.03).The age-adjusted incidence in girls was however lower (RR 0.8; 95% CI 0.7 to 0.99) with no evident change in boys (RR 1.0; 95% CI 0.9 to 1.1). In paper II, the rate of pediatric distal forearm fractures in the county of Skåne, Sweden, 1999–2010 was 634 per 10^5 person years (750 in boys and 512 in girls), with a significant increase of 2.2% (95% CI 1.7 to 2.6) per 10^5 persons per year during the period of observation ((RR 2.0%; 95% CI: 1.5 to 2.6) in boys and (RR 2.4%: 95% CI: 1.7 to 3.1) in girls). In paper III, we found that the pediatric distal forearm fracture incidence in the city of Malmö in 2005–2006 was 564 per 10^5 person years (719 in boys and 401 in girls). The age- and gender-adjusted incidence in children in 2005–2006 did not differ significantly from 1993–1994 (RR 1.1; 95% CI 0.9 to 1.3), neither in boys (RR 1.2; 95% CI 0.98 to 1.6) nor in girls (RR 0.8; 95% CI 0.6 to 1.1). In paper IV, we found that the pediatric hand fracture incidence in the city of Malmö in 2005–2006 was 448 per 10^5 person years (639 in boys and 247 in girls). The age- and gender-adjusted hand fracture incidence in children in 2005–2006 did not differ significantly from 1993–1994 (RR 1.0; 95% CI 0.7 to 1.1), neither in girls (RR 0.8; 95% CI 0.5 to 1.1) nor in boys (RR 0.9; 95% CI 0.7 to 1.2)

Conclusion: The incidence of pediatric fractures in Malmö in 2005–2006, was higher in boys than in girls and the overall incidence in children was no different in 2005–2006 compared to 1993–1994. The incidence of pediatric distal forearm fractures in the county of Skåne, Sweden, is increasing, which may lead to an increased number of fractures in adults in the future.

Key words
Children, boys, girls, epidemiology, etiology, fractures, trends, distal forearm, hand, phalanges, metacarpals,

Classification system and/or index terms (if any)

Supplementary bibliographical information

Language: English

ISSN and key title:
1652-8220

ISBN:
978-91-7619-613-7

Recipient’s notes

Number of pages

Price

Security classification

Signature ________________________________Date 20180404______

The Epidemiology and Etiology of Childhood Fractures in Southern Sweden

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Cover photo by Vasileios Lempesis

Figures 1 and 2 by Pontus Andersson

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Faculty of Medicine, Lund University, Sweden

ISBN 978-91-7619-613-7

ISSN 1652-8220

Printed in Sweden by Media-Tryck, Lund University

Lund 2017

MADE IN SWEDEN

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Table of Contents

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List of papers

I. **Time trends in pediatric fracture incidence in Sweden during the period 1950–2006**

Lempesis V, Rosengren BE, Nilsson JÅ, Landin L, Johan Tiderius C, Karlsson MK.

Acta Orthopaedica. 2017 Aug;88(4):440–445

II. **Increasing wrist fracture rates in children may have major implications for future adult fracture burden. A registry study involving 2.8 million patient years based on the Skåne region of Sweden, 1999–2010**

Jerrhag D, Englund M, Petersson I, Lempesis V, Landin L, Karlsson, MK, Rosengren, BE

Acta Orthopaedica 2016; 87(3): 296–300.

III. **Time trends in childhood distal forearm fracture epidemiology during six decades in Malmö, Sweden**

Lempesis V, Jerrhag, D, Rosengren BE, Landin L, Tiderius CJ, Karlsson MK

Submitted

IV. **Hand fracture epidemiology and etiology in children –time trends in Malmö, Sweden during Six Decades**

Lempesis V, D, Rosengren BE, Landin L, Tiderius CJ, Karlsson MK

Submitted

Abbreviations

ALF	Avtal om Läkarutbildning och Forskning (Agreement on Compensation for Medical Education and Research
BMD	Bone Mineral Density
BMI	Bone Mass Index
CI	Confidence Interval
DXA	Dual-energy X-ray Absorptiometry
FoUU	Forskning Utveckling och Utbildning (Science Development and Education
ICD	International Classification of Disease
PY (py)	Person Years
RR	Rate Ratio
SD	Standard Deviation
SHR	Skåne Healthcare Register
SPSS	Statistical Package for the Social Sciences
WHO	World Health Organization

Introduction

Bone

Definition

The human skeleton supports the weight of the human body, and provides a stable attachment for tendons and muscles, thereby enabling mobility. It also protects the most important organs and functions as storage of minerals. The main component of the skeleton is bone tissue.

Bone tissue occurs in two forms, 80% cortical and 20% trabecular bone. Cortical bone, also known as compact bone, is found in the periphery of bones and has a compact and rigid structure. Trabecular bone, also known as cancellous bone, is found in the interior of bones, especially in the metaphysis, is more vascularized than compact bone and is composed of a sponge-like network of bone rods. The surface of a bone is lined by the periosteum, a thin membrane that is rich in blood vessels and nerves, and that participates in bone growth and fracture repair.

Bone tissue consists of an abundant extracellular matrix and dispersed cells. The extracellular matrix is composed of about 15% water, 30% collagen fibers and 55% crystalline salts. Crystalline salts form when calcium phosphate reacts with calcium hydroxide to form hydroxyapatite. The cell types found in bone tissue are osteogenic cells, osteoblasts, osteocytes and osteoclasts. Osteogenic cells are stem cells found in bone marrow and the periosteum and have the ability to mature into osteoblasts. Osteoblasts produce collagen fibers and salts, eventually become enclosed in the calcified matrix in spaces called lacunae, and further mature into osteocytes. The function of osteocytes is to facilitate bone metabolism by maintaining the mineral content and exchange of nutrients to blood. Osteoclasts are derived from macrophages and their function is to break down bone. Osteoclasts line the interior surface of compact bone called endosteum. The osteon or Haversian unit is the cylindrical structural unit of compact bone. It is composed of a central longitudinal canal, which contains blood vessels and nerves. Circumferential layers of calcified collagen matrix called lamellae surround the central canal. Between the lamellae lie osteocytes in their respective lacunae. The osteocytes communicate with each other and receive nutrients through small canals called canaliculi. There are also larger perforating canals (Volkmann’s canals) that facilitate the connection of the central canals with penetrating vessels and nerves originating from the periosteum or endosteum (Figure 1).

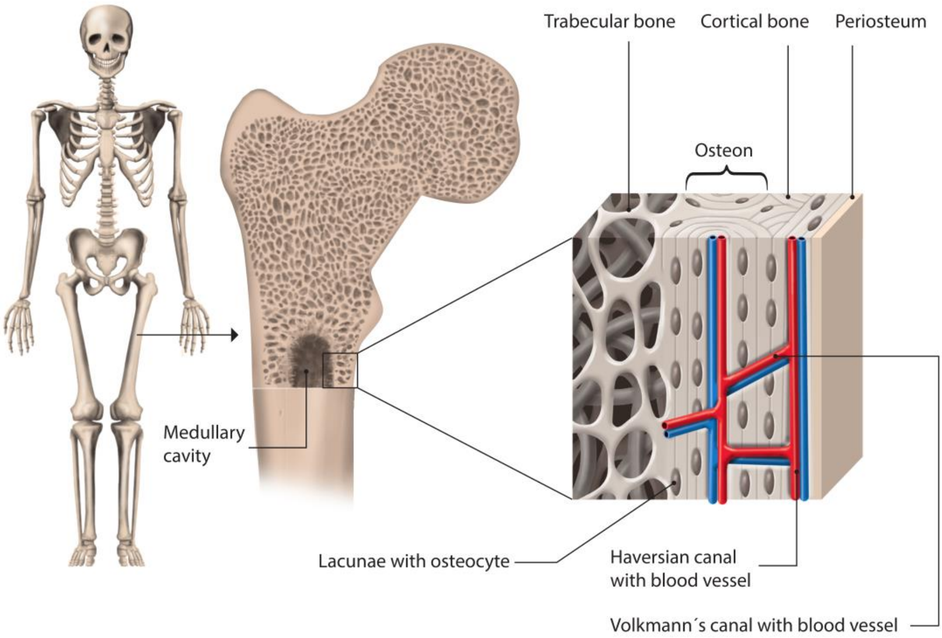


Figure 1. Bone Tissue. Trabecular and cortical bone. Illustration: Pontus Andersson.

Bone modeling and remodeling

Bone is in a state of continuous renewal. This is achieved by the process of bone remodeling (a metabolic process in bone tissue in which the bone rebuilds but does not change the size or shape of the skeleton)(Parfitt 1988). Remodeling is the sum of two parallel processes, bone resorption, the removal of old bone by osteoclasts, and bone deposition, the production of new bone by osteoblasts. This process allows for the repair of fractures, repair of micro fractures and allows the skeleton to adapt to load. The rate of remodeling is very high after birth and 100% of the skeleton is replaced during the first year of life but remodeling slows down and in adults is only about 10% per year. In contrast, the process of bone modeling (a metabolic process in bone tissue in which the skeleton changes in size and shape) occurs by the deposition of new bone without a parallel resorption of old bone. Besides growth, bone modeling allows for adaptation of bone strength and form according to mechanical loads (Teitelbaum 2000, Clarke 2008, Wang et al. 2008, Tortora et al. 2012)

Bone growth, mineralization and peak bone mass

At birth, the bones of the skeleton are mostly composed of soft cartilage. With increasing age, the bones grow in diameter and length and the mineral content increases. Bone growth during childhood occurs through both appositional growth and axial growth. Appositional growth, the increase in bone diameter, is facilitated by deposition of bone at the periosteum. Growth in length of the long bones, also called axial growth, occurs in the epiphyseal plates, the growth zones located near joint areas. As the child enters puberty, axial growth accelerates. This leads to accumulation of more fragile bone in the area around the growth plates. The epiphyseal plates close at the end of puberty and axial growth then stops (Wang et al. 2008).

During young adulthood, appositional growth continues while bone resorption in the medullary canal slows down and the total mass of bone in the body continues to increase. Total bone mass continues to increase up to roughly 10 years after puberty where peak bone mass is achieved, the highest total bone mass during life. Later in life, an increased rate of resorption in relation to deposition leads to widening of the medullary canal and lower total bone mass (Figure 2) (Clarke 2008, Wang et al. 2008, Tortora et al. 2012).

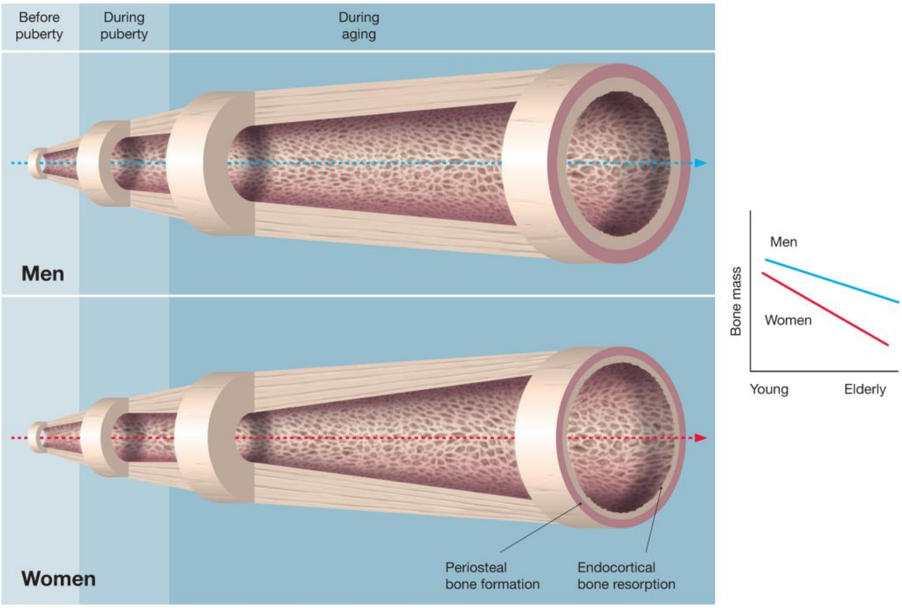


Figure 2. The figure on the left demonstrates cortical thickness in long bones in men and women before and during puberty and during aging. The figure on the right demonstrates changes in bone mass from young to old age. Illustration: Pontus Andersson

Fractures, bone strength and measurements

In order to support the weight of the body and facilitate mobility, bones must be able to withstand and transfer force. When the mechanical load applied to a bone increases, past the point of failure, a fracture occurs. Bone strength, the ability to withstand trauma and fractures, is related to the quality and quantity of bone. Bone quality depends on several traits such as bone geometry, the degree and quality of mineralization and the composition of the organic components. Bone strength can be measured by invasive methods and therefore, in clinical practice, it is most commonly instead correlated to Bone Mineral Density (BMD). Dual-energy X-ray Absorptiometry (DEXA) is the method used to estimate the BMD (g/cm^2), through measurement of Bone Mineral Content (BMC) (g) and bone size (cm^2), most usually at the hips and lumbar spine. BMD correlates well with fracture risk and is expressed either in absolute values, or more usually as T- and/or Z-scores. Z-score is then the deviation in standard deviations (SD) in relation to the mean BMD of healthy individuals of the same gender and age, while T-score is the deviation compared to young individuals of the same sex. According to the WHO, osteoporosis in adults is defined as a BMD lower than 2.5 SD below the mean in young individuals of the same sex (the original definition included only women and BMD estimated by DEXA) (Table 1).

Table 1. Definition of osteoporosis by the WHO according to T-score (World Health Organization 1994).

T-score	Bone Mineral Density stage
Over –1 SD	Normal
Between –1 and –2.5 SD	Osteopenia
Below –2.5 SD	Osteoporosis
Below –2.5 SD and ≥ 1 osteoporosis related fracture	Severe or established osteoporosis

Fractures in children

The bones in children are different from those in adults. The periosteum is thicker and the mineral content lower. Bones of children are weaker in the area around the epiphyseal plate, due to the deposition of new bone that is not yet completely mineralized. This property is accentuated during the pubertal growth spurt. These attributes mean that bones of children can deform and bend like a branch of a tree. In cases of complete fractures, the bone fragments can be held together by the periosteum, or be totally displaced. Fractures can also occur in connection with the growth plates, often defined according to the Salter-Harris classification (Figure 2) (Salter et al. 1963).

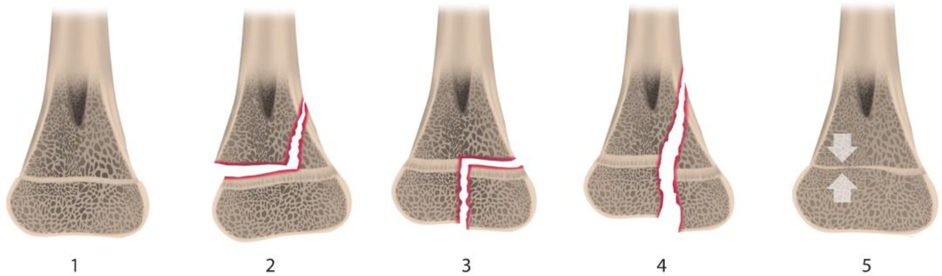


Figure 2. The Salter Harris classification of fractures involving the growth plate. Type 1, a fracture through the growth plate only. Type 2, a fracture through the growth plate that also involves the metaphysis. Type 3, a fracture through the growth plate that also involves the epiphysis.Type 4, a fracture that crosses the growth plate and involves both the metaphysis and epiphysis. Type 5, a crush injury of the growth plate. Illustration: Pontus Andersson

Epidemiology of fractures in children

Epidemiology

Epidemiology is defined as “The study of the occurrence and distribution of health-related events, states, and processes in specified populations, including the study of the determinants influencing such processes, and the application of this knowledge to control relevant health problems” (Porta et al. 2014).

Historical aspects

Buhr was a pioneer in fracture epidemiology when in 1959 he published data on fracture epidemiology regarding Oxford and reported on the incidence of various fracture types in both adults and children. The authors reported results as age-specific incidences in 10-year groups. The study, however, utilized population data for the entire UK, not only from Oxford, for estimation of age-specific rates (Buhr et al. 1959). In 1962 Alffram et al. studied the epidemiology and etiology of distal forearm fractures in children and adults in the city of Malmö, Sweden. This study reported, apart from a high incidence in the elderly, an almost equally high incidence in children aged 10–19 years (Alffram et al. 1962). The authors used official population data for the calculation of the age-specific incidence, and chose to report the age-specific incidences in 5-year groups instead. Landin later reported on the epidemiology and etiology of pediatric fractures in Malmö, Sweden, during 10 different years spanning from 1950 to 1979. Incidences were then reported in 2-year age strata, an approach that set the standard for pediatric epidemiological studies that followed (Kopjar et al. 1998, Tiderius et al. 1999, Lyons et al. 2000, Cooper et al. 2004, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010, Hedstrom et al. 2012, Randsborg 2013, Clark 2014).

Current knowledge

Factors that affect pediatric fracture incidence

Age

The age-specific fracture incidence in children increases with increasing age, with a more abrupt increase coinciding with the growth spurt at puberty, after which the fracture incidence decreases (Figure 3) (Landin 1983, Lyons et al. 1999, Cooper et al. 2004, Hedstrom et al. 2010, Mayranpaa et al. 2010, Clark 2014, Moon et al. 2016).

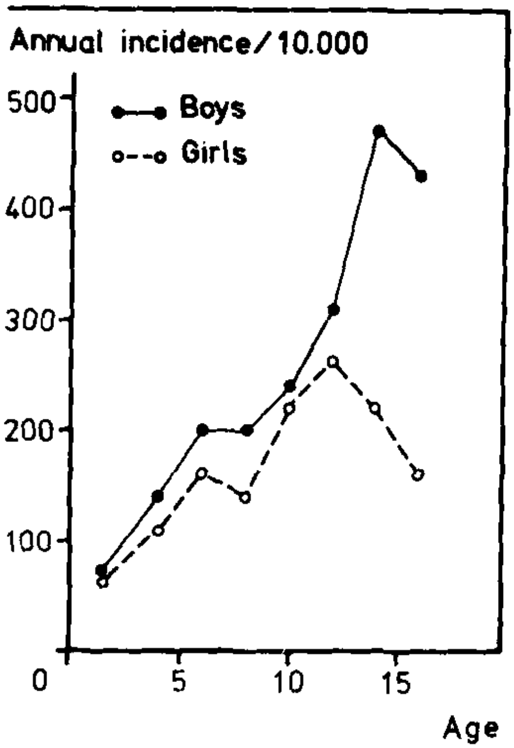


Figure 3. The age- and sex-specific incidence of fractures in children in Malmö, Sweden, 1975–1979. Published with permission from the author Lennart Landin.

But the overall fracture incidence is, of course, the sum of many age-specific incidences of different types of fractures. The age-specific incidences of distal forearm fractures, phalangeal fractures and proximal humerus fractures follow a similar pattern, with a late peak around puberty, while the incidence of supracondylar humerus fractures instead demonstrates an early peak incidence

(Landin 1983, Rennie et al. 2007, Mayranpaa et al. 2010). As the combined incidence of distal forearm fractures, phalangeal fractures and proximal humerus fractures constitutes almost 50% of the overall pediatric fracture incidence, these three types of fracture affect the overall age-specific fracture incidence to a large extent. Examples of the age-specific incidence of different fractures are presented in figure 4.

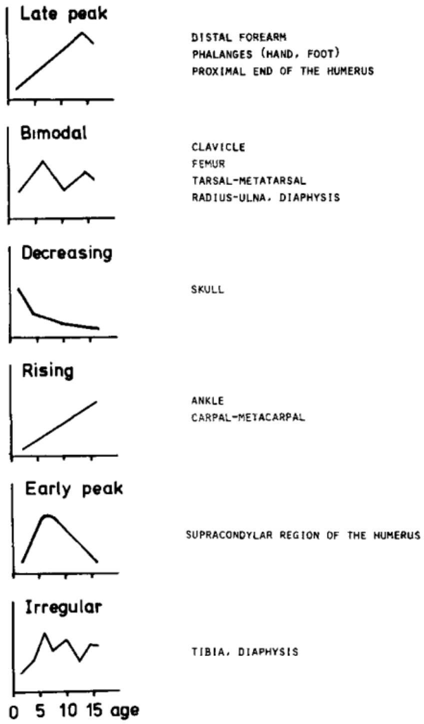


Figure 4. The age- and sex-specific incidence of various fracture types in children in Malmö Sweden, 1975–1979. Different patterns of distribution according to Landin (Landin 1983). Published with permission from the author Lennart Landin.

As the fracture incidence also varies with age, the distribution of children in the different age groups within the population at risk will affect the overall fracture incidence. For example, in a population with more children in the older age groups the overall fracture incidence will be higher.

Gender

Multiple studies have reported a higher incidence of fractures in boys than in girls (Hanlon et al. 1954, Landin 1983, Lyons et al. 1999, Tiderius et al. 1999, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010, Moon et al. 2016). The age-specific incidence in girls increases in the same manner as in boys with increasing age, but girls reach their peak fracture incidence 1–2 years before boys. (Landin 1983, Tiderius et al. 1999, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010, Moon et al. 2016).

Ethnicity, race and socioeconomic class

Ethnicity, race and socioeconomic class are factors that are often reported to affect fracture risk. A UK study, for example, found more than twice as high fracture rate in white children compared to black children (Moon et al. 2016), supported by South African data (Thandrayen et al. 2009). In Scotland, children in low socioeconomic class had approximately 40% higher fracture risk than children in higher classes (Ramaesh et al. 2015). A similar study from Wales, however, found no such association (Lyons et al. 2000).

Geographic differences, urban/rural

Studies have also reported different fracture rates in different countries (Lyons et al. 2000) but also within the same country. For example, a UK study reported a higher incidence in children in rural than in urban areas (Cooper et al. 2004).

Common fractures, side preponderance

Pediatric fractures more often involve the extremities than the axial skeleton, and the upper more often than the lower extremity (Landin 1983, Tiderius et al. 1999, Cooper et al. 2004, Mayranpaa et al. 2010, Hedstrom et al. 2012). The most common of all types of pediatric fractures is usually reported to be the distal forearm fracture, followed by fractures of the hand, fractures of the clavicle and fractures of the distal humerus (Hanlon et al. 1954, Landin 1983, Lyons et al. 1999, Cooper et al. 2004, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010). Extremity fractures also occur more often in the left than in the right side (Hanlon et al. 1954, Landin 1983), although the side preponderance seems to be different for different fracture types (Hanlon et al. 1954, Landin 1983). For example, fractures in the metacarpals are much more common in the right than in the left hand (Landin 1983).

Time trends

Few studies have evaluated time trends in pediatric fracture incidence. A study by Landin is one of these. He found that the incidence of pediatric fractures in Malmö, Sweden, was twice as high in the second half of the 1970s compared to the 1950s (Landin 1983). Concerning more recent time trends, one study from Finland reported lower pediatric fracture incidences in 2005 compared to 1983 from the same area(Mayranpaa et al. 2010) while another study from 1998–2007 in Sweden found a similar incidence to that in Malmö, Sweden, during the 1970s (Hedstrom et al. 2010).

Etiology of fractures in children

Types of studies

Early pediatric fracture epidemiology studies that included data on fracture etiology, initially documented the mechanism that caused the trauma leading to the fracture, the environment where the fracture occurred and the activity during which the fracture occurred (Hanlon et al. 1954, Landin 1983). This classification provided background data for fracture prevention.

Recent studies evaluating fracture etiology utilize more structured classifications (Lyons et al. 2000, Hedstrom et al. 2012). Examples of such classifications are the International Statistical Classification of Diseases and Related Health Problems, where the latest version is the tenth revision (ICD-10) and the Nordic Medico-Statistical Committee (NOMESCO) classification of External Causes of Injury (NCECI), where the latest version is the fourth revision (World Health Organization, NOMESCO Working Group for Classification for Accident Monitoring 2007). These classification systems allow registration of injury-related codes, providing a rationale for low-cost collection of injury data.

The most common injury mechanism of a pediatric fracture seems to be a fall (Landin 1983, Kopjar et al. 1998, Tiderius et al. 1999, Hedstrom et al. 2010, Mayranpaa et al. 2010). Specific activities that are commonly associated with fractures are playing and sports activities and transport accidents (Landin 1983, Kopjar et al. 1998, Tiderius et al. 1999, Hedstrom et al. 2010, Mayranpaa et al. 2010).

Injury prevention in Sweden

Etiology data for injuries is of the utmost importance for creating preventive strategies. In 1954, a study in the Department of Pediatrics in Uppsala found that around 400 children died every year in Sweden due to accidents. In boys between

5 and 9 years of age accidents were the predominant cause of death (Bejerot et al. 1955, Bejerot et al. 1955, Bejerot et al. 1955, Berfenstam et al. 1955, Berfenstam 1995). The findings of this report necessitated an injury prevention initiative than continued for decades. The Child Accident Prevention Committee (CAPC) was formed by the pediatrician Ragnar Berfenstam, the pediatrician and pediatric surgeon Theodor Ehrenpreis, and the administrator Ulla Bonde. The committee was active until 1980, when it was replaced by the National Child Environment Council (in Swedish "Barnmiljörådet"), which in turn was replaced by the "Ombudsman for Children" 1993. The preventive work by the CAPC focused initially on information campaigns aiming to inform parents and teachers about the risk of accidents, increase safety at home, school and in traffic and increase the knowledge of accident prevention. As an example of successful pediatric fracture work, the following section covers the history of interventions in traffic environment in Sweden. Table 1 summarizes the introduction of various traffic safety measure, laws and regulations in Sweden over the years, and table 2 the number of circulating vehicles and number of deaths in traffic. The apparent success of injury prevention in traffic, a process initiated due to epidemiological studies, highlights the importance of injury epidemiology data and the need for continuous updates.

In 1935, the National Society for Road Safety was started (in Swedish "Nationalföreningen för trafiksäkerhetens främjande" (The National Society for Road Safety), with the aim of improving traffic behavior and increasing traffic safety. At this time, there were no speed limits at all in Swedish traffic. Trying to reduce the number of deaths then led to the introduction of traffic education in schools in 1938. During the Second World War, the number of cars in circulation fell. In 1944, the NTF held a conference titled "Post-war traffic safety problems" (in Swedish "Efterkrigstidens trafiksäkerhetsproblem"). The focus was once again on spreading information and increasing awareness amongst politicians and drivers. During the 1950s to 1970s, the number of cars in circulation increased, as did the number of deaths, reaching in 1970 the highest number of deaths in traffic ever recorded in Sweden. Following these horrendous numbers, the Swedish Transport Safety Administration (in Swedish "Trafiksäkerhetsverket" (TSV) was initiated in 1968 and the Swedish Road and Transport Research Institute in 1971 (The National Society for Road Safety , The Swedish Road Administration 2008, Brüde 2013). In 1988 and 1989 the NTF started campaigns to increase bicycle helmet usage ("Hjälm88" and "Hjälm 89"), coupled in 1990 to a WHO global initiative to increase bicycle helmet usage (Svanstrom et al. 2002). In 1997 the Swedish Government adopted the "Vision Zero" road traffic safety project (Vizion Zero). The initiative focuses on the need to consider human fallibility when designing road safety systems. The goal of these systems involving road and vehicle design is to avoid accidents and minimize death and serious injury when accidents occur. At the same time the Swedish Traffic Accident Data Acquisition (STRADA) database was started (Swedish Traffic Accident Data Acquisition), combining police and hospital reports and recording the outcomes of non-fatal injuries. During the 2000s, circulating vehicles kept increasing, while the number of fatalities kept decreasing. The focus stayed on systemic changes to improve road and vehicle safety. From 2003 to 2006, the percentage of new motor vehicles with seat belt reminders and stability systems increased from zero to 80% and from 15% to 91% respectively. In single-lane undivided highways, the use of centerline continuous shoulder rumble strips expanded. Bicycle helmet usage in children (6–15 years old) had increased from around 5% in 1988 to 45% in 2005 and to 64% in 2011(Svanstrom et al. 2002) (The National Society for Road Safety , The Swedish Road Administration 2008, Brüde 2013).

Table 1. Examples of traffic safety measures, laws and regulations introduced in Sweden.

Year	Measures, laws and regulations
1930	Speed limits removed from inhabited areas
1938	Traffic education incorporated in school
1954	Traffic education in schools revised
1955	Reintroduction of speed limits in all urban and some rural areas
1955	Mandatory speedometers for cars
1963	Swedish Car Inspection (in Swedish “Bilprovningen”) started
1967	Mandatory periodic car inspections
1968	Sweden switches from left- to right-hand drive
1968	Minimum tire depth
1968	Mandatory seatbelts for cars entering circulation
1975	Mandatory seatbelt usage for front passengers
1977	Vehicles in operation required to have their lights turned on at all times
1978	Mandatory helmet usage when operating a motorcycle
1986	Mandatory seatbelt usage for rear passengers older than 15 years
1986	Mandatory seatbelt usage for rear passengers regardless of age
1990	The limit for driving under the influence of alcohol (DUI) reduced to 0.02%.
1990	Driving license requirements updated
1990	Automatic camera surveillance (ATK)
1990	Cable dividers combined with 2+1 roads
1994	DUI limit further reduced to 0.01%
1998	Mandatory cycle lighting when cycling in the dark
1999	Mandatory usage of winter tires during the winter
2005	Mandatory bicycle helmet usage for children younger than 15 years

Table 2. Number of cars in circulation and number of deaths in traffic in Sweden.

Year	*Cars in circulation*	*Number of deaths in traffic*
1935	159,000	311
1936	–	420
1939	249,000	568
1940s	83,000	283
1950	345,000	595
1960	1,300,000	1036
1970	2,400,000	1307
1980	3,100,000	848
1990	3,900,000	772
2000	4,400,000	564
2012	Approx. 5,000,000	286

Aims

The aims of this thesis were:

To describe the overall epidemiology and etiology of pediatric fractures as well as specific pediatric fractures, in Malmö, Sweden, during 2005–2006 (Papers I, III, IV).

i. To compare these data with previously collected and published data from the same region from 12 evaluated periods from 1950/1955 to 2005–2006

ii. To evaluate time trends in epidemiology, both crude fracture incidences and fracture incidences adjusted for changes in demographics in the population at risk, during the evaluated years

To describe epidemiology and time trends of pediatric distal forearm fractures in the Skåne Region during the years 1999–2010 (paper II) and make comparisons with historical reports.

To make predictions about future fracture burden based on distal forearm fracture epidemiology in the Skåne Region during the years 1999–2010.

Patients and methods

Papers I, III, IV

Summary

These papers describe the epidemiology of all fractures (Paper I), distal forearm fractures (Paper III) and hand fractures (Paper IV) in children (<16 years old), in the city of Malmö, Sweden, during the years 2005 and 2006. We also compared these fracture data with previously published similar data regarding earlier years. Data were collected through medical records, referrals and radiographs.

Population at risk

The city of Malmö is located in the southernmost part of Sweden and is the third largest city in the country. In the year 2005, the city population was 271,271 inhabitants (45,910 <16 years of age) and in the year 2006, 276,244 inhabitants (46,492 <16 years of age). The emergency department at the only city hospital provides trauma care for city residents.

Data collection 2005–2006

In 2001, the city hospital switched to digital radiographs and a digital archive was set up to include all digital radiographs obtained within the healthcare system in the southern region of the country. The radiographs in this database are not archived according to the diagnosis but according to date, anatomical location and the patient-specific 10-digit patient personal number. For this reason, it was no longer possible to collect data in the same way as in the previous studies. We instead identified fracture cases through the hospital in- and outpatient diagnosis database. This database includes the diagnostic codes (ICD-10) recorded during in- and outpatient visits, the patient's unique personal identity number, name, and current as well as previous addresses. During registration in this database, the patients name, gender and address are automatically retrieved from the Swedish Tax Agency (Skatteverket), thereby minimizing the possibility of errors.

We conducted a search for the records of city residents <16 years of age for visits in 2005 and 2006 at the Departments of Emergency, Orthopedics, Hand Surgery and Otorhinolaryngology with the diagnoses S02.3–S02.4, S02.6–S02.9, S12.0–S12.2, S12.7, S22.0, S32.0–S32.8, S42.0–S42.9, S52.0–S52.9, S62.0–S62.8, S72.0–S72.9, S82.0–S82.9 and S92.0–S92.9. This search identified 4599 visits with a fracture diagnosis. Of these 1143 were due to a distal forearm fracture and 1548 due to a hand fracture. For each case, we reviewed the medial records, referrals and X-ray reports. For hand and forearm fracture cases, all relevant radiographs were reviewed by one orthopedic surgeon (VL), while for the remaining cases radiographs were only reviewed when there was uncertainty about the diagnosis. If there was still uncertainty after reviewing the X-ray, a senior specialist in orthopedic surgery (LL) was consulted.

Validation

In order to validate the ascertainment method of cases in Papers I, III, IV, the author reviewed all the pediatric skeletal radiographs of city residents produced from January 1, 2005, to February 28, 2005. This review, which was meant to simulate the ascertainment system used in previous studies, revealed 103 fractures. A search in the hospital diagnosis database and subsequent review of medical records, referrals and X-ray reports identified 103 fractures. The two methods together identified 106 fractures while only 100 fractures were identified by both methods.

Other collected variables

We utilized the same protocol as in previous studies and for each fracture recorded the age and gender of the patient, the type of the fracture, the affected side (when applicable) and the etiology of the fracture (Landin 1983, Tiderius et al. 1999). The protocol can be found in Appendix 1. Multiple fractures were handled in the same manner as in previous studies. This means that in general we recorded multiple fractures as separate fractures. This also includes bilateral fractures of the same bone and fractures on the same bone on the same side on different occasions.

Simultaneous fractures of both bones of the forearm were however registered as one fracture. In addition, multiple fractures of the digital phalanges were counted as one fracture, as were multiple metacarpal fractures and combinations of carpal-metacarpal fractures (excluding the scaphoid).

Previous studies (Landin 1983, Tiderius et al. 1999) included patients aged <17 years. During processing of the material (Landin 1983) we discovered a possible error in the manner we included patients aged 16 years. We therefore chose to include only patients <16 years old and subsequently removed fractures in patients older than 15 years from the previously collected material.

In paper IV, the aims were to describe the epidemiology of hand fractures in Malmö, Sweden, and make comparisons with previous studies from the same geographical area but also to provide more detailed information about the distribution of hand fractures per specific bone. To allow this we therefore collected more detailed information about the fractures and registered multiple phalangeal and metacarpal fractures separately. For the estimation of fracture rates and differences in rates over time, the registered information was aggregated so that it followed the same protocol as in previous studies where multiple phalangeal fractures on the same hand were counted as one fracture, as were multiple metacarpal fractures and combinations of fractures of carpal-metacarpal bones on the same hand (excluding the scaphoid) (Landin 1983, Tiderius et al. 1999).

Historical data 1950 to 1994

All medical records, reports and radiographs have been stored in the hospital archives for a century (Herbertsson et al. 2005). Until 2001, physical radiographs were stored in this archive and organized according to date, anatomical location and diagnosis. Previous studies have utilized this radiological archive for the collection of pediatric fracture data in city residents during 12 separate years. These were 1950, 1955, 1960, 1965, 1970, 1975, 1976, 1977, 1978, 1979(Landin 1983), 1993 and 1994 (Tiderius et al. 1999). These studies utilized a common protocol for recording fracture data, the same as we utilized for 2005–2006.

Population data

Official data regarding the population of Malmö for the years included in the papers were available in one-year classes through Statistics Sweden (Statistiska Centralbyrån SCB). SCB is a government agency in Sweden. According the official website of the Government of Sweden:

> "The main task of Statistics Sweden is to supply customers with statistics for decision making, debate and research. Besides producing and communicating statistical data, Statistics Sweden are tasked with supporting and coordinating the Swedish system for official statistics."

Statistics

We used Microsoft Excel® 2010 for database management and statistical calculations. In order to make comparisons, data from the previously evaluated years were grouped into 6 periods. These were set to 1950/1955, 1960/1965, 1970/1975, 1976–1979 and 1993–1994. Incidence rates are presented as number of fractures per 100,000 (10^5) person years. The age-adjusted and (when applicable) age- and gender-adjusted rates were calculated through direct standardization. As the standard population, we chose the average pediatric population of Malmö for the period 1950–2006. We used the chi^2 distribution to calculate rate ratios when comparing incidence rates. We considered a $p<0.05$ as statistically significant and we present 95% confidence intervals (CI) to describe uncertainty.

Paper II

In paper II we describe the epidemiology of distal forearm fractures in children (≤16 years old) in the Skåne Region of Sweden, during 1999–2010, which corresponded to 2.8 million person years at risk. The Skåne Region, located in the southern part of Sweden, had a population of 1.3 million in 2017 (272,000 children ≤16 years old) and included the city of Malmö (the site for studies I, III, IV). Data were extracted from the Skåne Healthcare Register (SHR). In the SHR, the diagnostic codes from visits within the healthcare system in the Skåne region have been continuously registered since 1998. Entries include the patient's unique 10-digit personal identity number, address, date of visit and ICD-10 diagnostic code. From the personal identity number it is possible to extract information about date of birth and gender. No information on the side (left/right) is however included in the records and it is therefore not possible to identify patients with bilateral fractures. The SHR has been validated against medical charts concerning distal forearm fracture data and shown to have a sensitivity of 90% and a positive predictive value (PPV) of 94% (Rosengren et al. 2015).

We extracted data from the SHR concerning visits of patients <17 years old that occurred from 1999 to 2010 with a distal forearm fracture diagnosis (ICD-10 diagnostic codes S52.50, S52.51, S52.60, S52.61). Multiple visits due to the same fracture are registered in the SHR as separate entries. In order to avoid multiple counting of the same fracture we chose to apply a washout period of one year (365 days) on the extracted data. A new distal forearm fracture on the same patient during the washout period would therefore not be registered as a fracture. This is the reason why we started with the year 1999. We consequently retrieved data also for 1998 to serve as a basis for washouts in 1999.

We obtained population data in 1-year classes through Statistics Sweden. As the population at risk for each year, we used the average of the population at the end of that year and the population at the end of the previous year. The population at risk for the estimation of the fracture incidence for the whole period of observation in person years was calculated as the sum of the population at risk of all included years. We calculated age-standardized rates through direct standardization against the average annual population of all included years. We used Microsoft Excel® 2010 and Statistical Package for the Social Sciences (SPSS® 12) for database management and statistical calculations. The Poisson regression was utilized to calculate time trends of incidence rates and Poisson interaction between curves to compare age-rate distribution between periods.

Ethics

The study was approved by the ethics committee, Lund University (Reference number 2010/191 for papers I, III–IV and 2011/432 for paper II) and was conducted in accordance with the Declaration of Helsinki.

Funding

Financial support was provided by ALF, Herman Järnhardts Foundation, Greta and Johan Kocks Foundation, Region Skåne FoU and the Faculty of Medicine at Lund University. The funding sources were not involved in the design, conduct, or interpretation of the study, or in the writing of the submitted work.

Summary of papers

Paper I

Time trends in pediatric fracture incidence in Sweden during the period 1950–2006

Introduction: The aim of this study was: i) to describe the epidemiology and etiology of fractures in children (<16 years) in the city of Malmö, Sweden, during the time period 2005–2006, ii) to make comparisons with fracture data collected previously from the same region during 12 different years spanning from 1950 to 1994, and iii) to evaluate whether previously reported changes in epidemiology were affected by demographic changes.

Results: During the period 2005–2006 we found 1,692 fractures (1,119 in boys and 573 in girls) which corresponded to a fracture rate of 1,832 fractures per 10^5 person years (2,359 in boys and 1,276 in girls). The age- and gender-adjusted fracture rate in children was not significantly different than in 1993–1994 (Rate Ratio (RR) 0.9; 95% CI 0.8 to 1.03). There was a lower rate in girls (RR 0.8; 95% CI 0.7 to 0.99) but not in boys (RR 1.0; 95% CI: 0.9 to 1.1). Demographic changes were found to have affected the previously reported decrease in unadjusted fracture incidence from 1976–1979 to 1993–1994 as age-adjusted rates did not differ significantly (RR 1.0; 95%CI 0.9 to 1.1).

Conclusion: The incidence of pediatric fractures in Malmö in 2005–2006 compared to 1993–1994 was lower in girls but similar in boys. Demographic changes affected previously reported changes in fracture incidence.

Paper II

Increasing wrist fracture rates in children may have major implications for future adult fracture burden

A registry study involving 2.8 million patient years based on the Skåne region of Sweden, 1999–2010

Introduction: The aim of this paper was to describe the epidemiology of pediatric distal forearm fractures in children (<17 years old) in the county of Skåne in Sweden during 1999–2010, to make comparisons with historical reports and to estimate the vector of fragility fracture risk in the future.

Results: During 1999–2010 the incidence of distal forearm fractures was 634 per 10^5 person years, 50% higher compared to the 1950s. During the period of observation, we found increasing rates in children (+2.2% per 10^5 persons and year (1.7–2.6), boys (+2.0% (95% CI 1.5–2.6)) and girls (+2.4% (1.7–3.1)).

Conclusion. The incidence of distal forearm fractures in children is increasing and is now 50% higher than in the 1950s. The reasons for this increase are unclear and may be attributed to changes in lifestyle with a lower level of physical activity. The possible link between pediatric distal forearm fractures and an increased risk of fragility fractures in old age combined with a projected increase in life expectancy indicate that fragility fractures may be more common in the future.

Paper III

Time Trends in Childhood Distal Forearm Fracture Epidemiology during Six Decades in Malmö, Sweden

Introduction: The distal forearm fracture is the most common fracture in children. This type of fracture has been associated with future high adult fracture risk. The aim of this study was: i) to describe the epidemiology and etiology of pediatric distal forearm fractures in children (<16 years of age) in the city of Malmö, Sweden, during 2005–2006, ii) to compare these data with published Malmö pediatric distal forearm fracture data previously collected during 12 different years spanning from 1950 to 1994 and iii) to evaluate if current or previously reported changes in epidemiology are affected by changes in demography.

Results: During 2005–2006 we found 521 fractures of the distal forearm (341 in boys and 180 in girls) which corresponded to an unadjusted fracture rate of 564 fractures per 10^5 person years (719 in boys and 401 in girls). The age-adjusted incidence of distal forearm fractures in children 2005–2006 was 44% higher than in 1950/1955 (RR 1.4; 95% CI 1.2 to 1.8) while it did not differ significantly compared to 1993–1994 (RR 1.1; 95% CI 0.9 to 1.3). Gender-specific comparisons between 2005–2006 and 1993–1994 identified no significant differences in the age-adjusted fracture rate in boys and girls, but in 2005–2006 a tendency to a higher incidence in boys (RR 1.2; 95% CI 0.98 to 1.6) and a tendency toward lower incidence in girls (RR 0.8; 95% CI 0.6 to 1.1). In 2005–2006, the etiology of the distal forearm fractures could be determined in 75% of cases. Of the fractures with known etiology cases, 41% were the result of sports accidents, 32% of playing accidents, 11% of accidents at school and 11% of traffic accidents.

Conclusion: The incidence of distal forearm fractures in children in 2005–2006 was higher than in 1950/1955. Comparing 1993–1994 to 2005–2006, we found no significant differences in fracture incidence in children, only indications were found of possible opposing changes in fracture incidence in the two genders (higher incidence in boys and lower in girls). Distal forearm fractures in children usually occur during sports or playing activities.

Paper IV

Hand Fracture Epidemiology and Etiology in Children

Time Trends in Malmö, Sweden, during Six Decades

Introduction: Fractures are common in children, and fractures of the bones of the hand are the second most common type of pediatric fracture after fractures of the distal forearm. The aim of this study was to describe the epidemiology and etiology of hand fractures in children (<16 years old) in the city of Malmö, Sweden, during 2005–2006 and make comparisons with previously published pediatric hand fracture data collected in the same city during 12 different years spanning from 1950 to 1994.

Results: In 2005–2005 we found 414 hand fractures (303 in boys and 111 in girls), corresponding to an unadjusted pediatric hand fracture rate of 448 per 10^5 person years (639 in boys and 247 in girls). Of these, 247 (60% of hand fractures) affected the phalanges of the fingers, 140 (34%) the metacarpals or carpal bones (except the scaphoid) and 27 (6%) the scaphoid bone. Boys had a 2.5 times higher age-adjusted hand fracture incidence (RR 2.5; 95% CI 1.8 to 3.5). The age- and gender-adjusted incidence of hand fractures was more than twice as high in 1976/1979 as in 1950/1955 (RR 2.4; 95% CI 1.9 to 3.1) while we found no significant difference in 2005–2006 compare to 1976–1979 (RR 0.8; 95% CI 0.7 to 1.01). In 2005–2006, the etiology of hand fractures could be determined in 70% of cases. Of these cases, 42% occurred during sports, 20% during fights, and 13% due to traffic accidents. By comparison, in 1950/1955 the etiology could be determined in 42% of cases, 27% of which were due to sports accidents, 10% due to fights and 21% due to traffic accidents.

Conclusion: Hand fractures are more common in boys than in girls and often occur due to sports fights, traffic and school accidents. The incidence of hand fractures in children the second half of the 1970s was more than twice as high as in the first half of the 1950s. There also seem to have been changes in hand fracture etiology during the evaluated years.

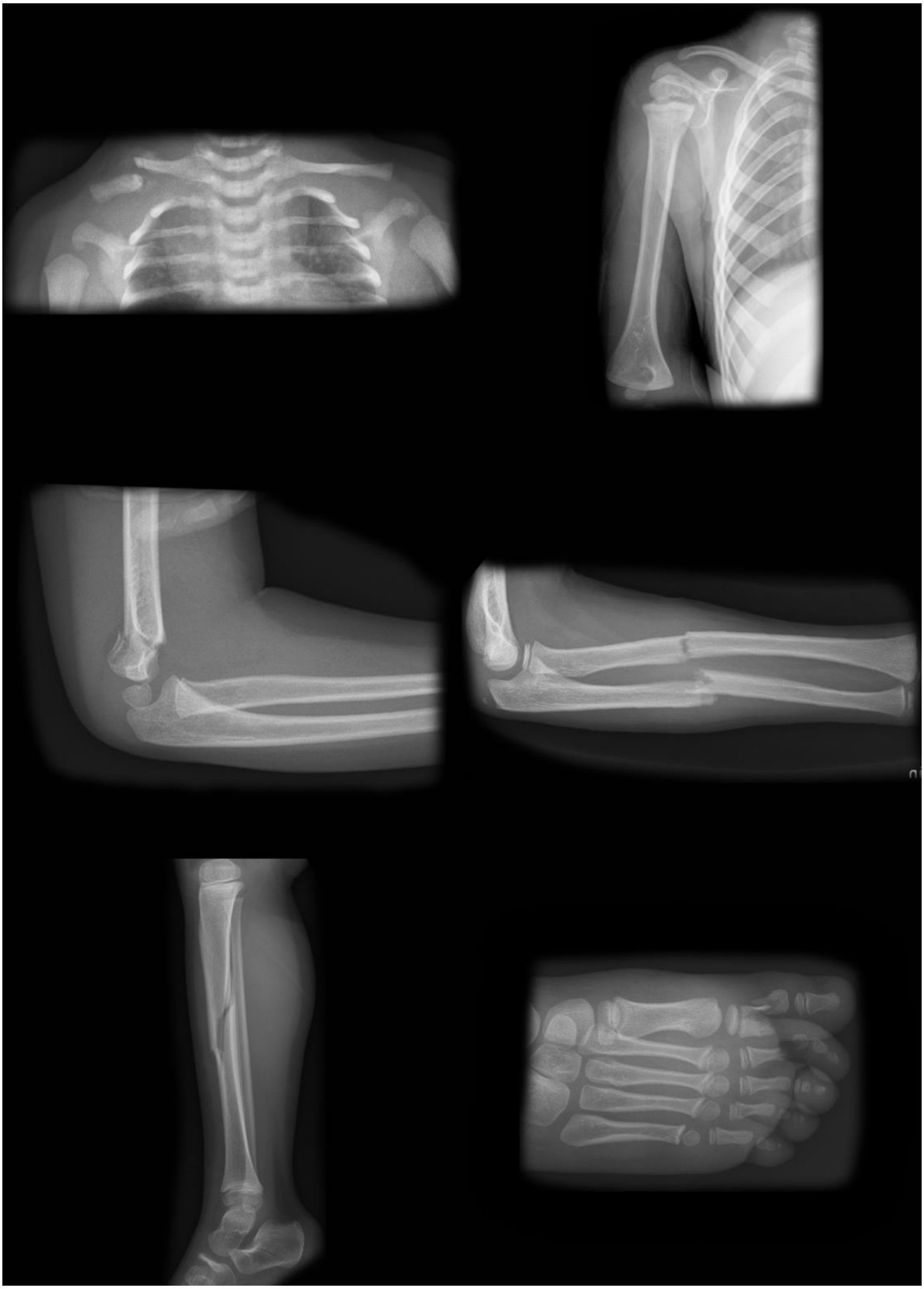


Figure A1. X-Rays showing examples of the various pediatric fractures covered in this section. Top left, a fracture of the right clavicle. Top right, a compression fracture of the proximal humerus. Middle left, a fracture of the distal humerus. Middle right, a forearm fracture involving the diaphysis of the radius and ulna. Low left, a fracture of the diaphysis of the tibia. Low right, a foot fracture involving the proximal phalanges of the first and second toes.

Additional results

The following sections includes unpublished epidemiology and etiology data from Malmö on fracture types in children (<16 years), in which we found more than 50 fractures during the period 2005–2006. We also present these results in relation to those for previously reported periods (Landin 1983, Tiderius et al. 1999).

For each fracture type, we report summarized fracture data in the text and five graphs that show:

i. The age-specific fracture rate in boys and in girls in Malmö, Sweden, during 2005–2006

ii. The crude fracture rate in boys and in girls (<16 years) in Malmö, Sweden, in the different periods from 1950/1955 to 2005–2006

iii. The age-adjusted, fracture rate in boys and in girls in Malmö, Sweden, in the different periods from 1950/1955 to 2005–2006.

iv. The age-specific fracture rate in boys during 1950/1955, 1976–1979 and 2005–2006

v. The age-specific fracture rate in girls during 1950/1955, 1976–1979 and 2005–2006.

We also present three tables that show:

i. Number of fractures as well as crude and age-adjusted fracture rates in children, in boys and in girls during the different evaluated periods.

ii. Time differences in epidemiology of fractures in children and in boys and girls separately, presented as comparisons of the crude and age-adjusted fracture rates between study start (1950/1955), the period with the highest overall fracture rate (1976–1979), the most recently evaluated and published period (1993–1994) and finally the latest evaluated period 2005–2006.

iii. Fracture etiology data in the different periods presented as a proportion of all fractures with known etiology.

At the end of the chapter, we present a table describing data for all fractures, also for the more unusual fractures (less than 50 during the two years 2005–2006).

Fractures of the clavicle in Malmö, Sweden, 1950/1955 to 2005–2006

During 2005–2006, we found 114 fractures of the clavicle (75 in boys and 39 in girls), accounting for 7% of all fractures (7% in boys and 7% in girls). The crude fracture rate for fractures of the clavicle in 2005–2006 was 123 per 10^5 person years (158 in boys and 87 in girls). The age- and gender-adjusted fracture rate was 124 per 10^5 person years (158 in boys and 87 in girls) (Table A1).

Fractures of the clavicle were more common in boys than in girls, with a significant boy-to-girl age-adjusted fracture rate ratio (RR 1.8; 95%CI 1.2 to 2.7).

Of all fractures of the clavicle, 60 occurred on the left side (38 in boys and 22 in girls). Concerning side preponderance, we found no significant left-to-right fracture rate ratio in children (RR 1.1; 95%CI 0.8 to 1.6), in boys (RR 1.0; 95%CI 0.6 to 1.6) or in girls (RR 1.3; 95%CI 0.7 to 2.6).

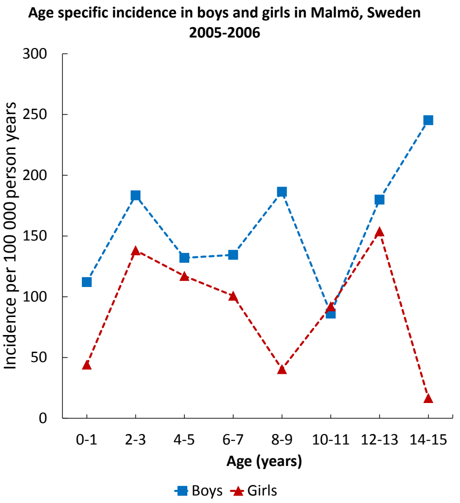
Of all evaluated periods, the highest absolute age- and gender-adjusted incidence was found in 1976–1979 and the lowest in 2005–2006. The age- and gender-adjusted incidence of fractures of the clavicle in children in 2005–2006 compared to 1976–1979 was significantly lower in all children (RR 0.7; 95% CI 0.5 to 0.9) and in girls (RR 0.6; 95% CI 0.3 to 0,997) but not in boys (RR 0.7; 95% CI 0.5 to 1.2) (Additional Table B1).

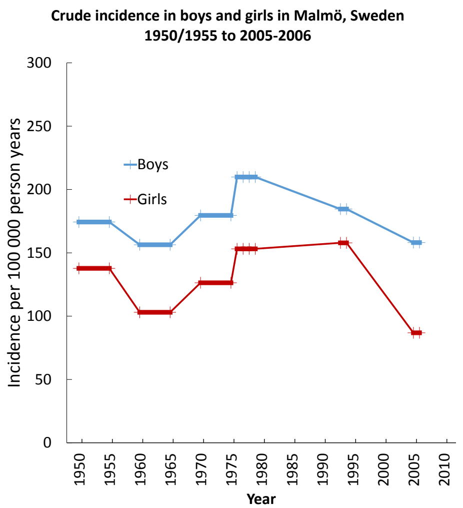
The etiology of fractures of the clavicle in 2005–2006 could be determined in 65% of cases compared to 36% in 1950/1955. In 2005–2006, most fractures occurred due to accidents during sports (43% of clavicle fractures with known etiology), playing (22%) and accidents in traffic (15%). The proportion of fractures due to sports accidents in 2005–2006 was higher than all previously evaluated years. In 2005–2006, fractures due to home accidents represented 2.7%, the smallest percentage of all periods (Additional Table C1).

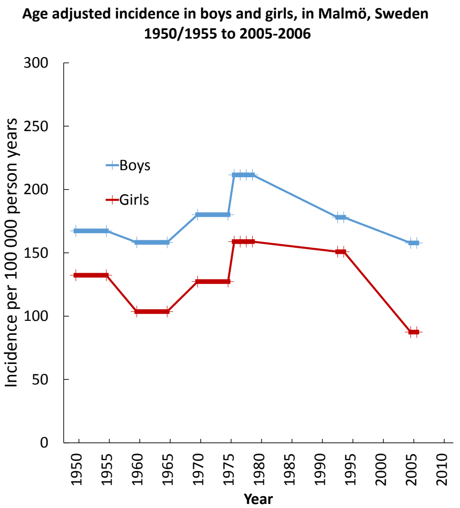
It should be noted that our ascertainment system for 2005-2006 did not include the diagnosis codes for birth fractures, which possibly affected registration of fractures of the clavicle (see section "*General Discussion, Fracture ascertainment in Malmö, papers I, III and IV").*

Fractures of the clavicle

Gender specific incidence in relation to age in 2005–2006 (first chart), gender-specific crude and age-adjusted incidences during the different evaluated time periods (second and third charts) and gender-specific incidence in relation to age in different time periods (fourth and fifth chart).







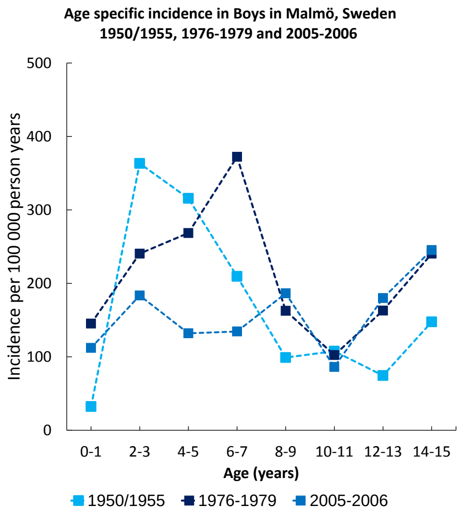


Table A1. The number, incidence and age-adjusted incidence (per 10^5 person years) of fractures of the clavicle in all children, in boys and in girls separately in Malmö, Sweden, during different evaluated periods.

Fractures of the clavicle in Malmö, Sweden, 1950/1955 to 2005–2006

		1950/55	1960/65	1970/75	1976–79	1993–94	2005–06
Number of fractures	All children	146	135	147	293	141	114
	Boys	83	83	88	173	78	75
	Girls	63	52	59	120	63	39
Crude Incidence	All children	156	130	154	182	172	123
	Boys	174	156	180	210	185	158
	Girls	138	103	126	153	158	87
Age-adjusted Incidence	All children	150	132	154	186	165	124
	Boys	167	158	180	212	178	158
	Girls	138	103	126	153	158	87

Table B1. Time differences in unadjusted and age-adjusted incidence of clavicle fractures clavicle in boys and girls in Malmö, Sweden. Comparisons between 1950/1955, 1976–1979, 1993–1994 and 2005–2006 are presented as rate ratios with 95% CI in parentheses.

	Denominator	1950/1955			1976–1979		1993–1994
	Nominator	1976–1979	1993–1994	2005–2006	1993–1994	2005–2006	2005–2006
	All children	1.2 (0.95 to 1.4)	1.1 (0.9 to 1.4)	0.8 (0.6 to 1.01)	0.9 (0.8 to 1.2)	0.7 (0.54 to 0.8)	0.7 (0.6 to 0.9)
Unadjusted	Boys	1.2 (0.9 to 1.6)	1.1 (0.8 to 1.4)	0.9 (0.7 to 1.2)	0.9 (0.7 to 1.15)	0.8 (0.6 to 0.99)	0.9 (0.6 to 1.2)
	Girls	1.1 (0.8 to 1.5)	1.1 (0.8 to 1.6)	0.6 (0.4 to 0.9)	1.0 (0.8 to 1.402)	0.6 (0.4 to 0.8)	0.6 (0.4 to 0.8)
	All children	1.2 (0.9 to 1.7)	1.1 (0.8 to 1.5)	0.8 (0.6 to 1.2)	0.9 (0.6 to 1.2)	0.7 (0.5 to 0.9)	0.7 (0.5 to 1.1)
Age-adjusted	Boys	1.3 (0.8 to 2)	1.1 (0.7 to 1.7)	0.9 (0.6 to 1.5)	0.8 (0.5 to 1.3)	0.7 (0.5 to 1.2)	0.9 (0.5 to 1.4)
	Girls	1.2 (0.7 to 2)	1.1 (0.7 to 1.95)	0.7 (0.34 to 1.2)	0.9 (0.6 to 1.6)	0.6 (0.3 to 0.997)	0.6 (0.3 to 1.1)

Table C1. The etiology of fractures of the clavicle in the different evaluated periods. Data are presented as proportions of all fractures where the etiology could be determined.

Environmental factors		**1950/55**	**1960/65**	**1970/75**	**1976–79**	**1993–94**	**2005–06**		
				All children			**All children**	**Boys**	**Girls**
Known		**36.3%**	**51.1%**	**59.9%**	**56.7%**	**54.0%**	**64.9%**	**70.7%**	**53.8%**
Unknown		**63.7%**	**48.9%**	**40.1%**	**43.3%**	**46.0%**	**35.1%**	**29.3%**	**46.2%**
Home		**24.5%**	**31.9%**	**29.5%**	**22.3%**	**25.3%**	**2.7%**	**3.8%**	**0.0%**
Day nursery		**1.9%**	**0.0%**	**3.4%**	**2.4%**	**2.7%**	**2.7%**	**1.9%**	**4.8%**
School		**3.8%**	**0.0%**	**3.4%**	**4.2%**	**2.7%**	**4.1%**	**3.8%**	**4.8%**
Work		**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Traffic accidents		**26.4%**	**29.0%**	**17.0%**	**22.3%**	**17.3%**	**14.9%**	**17.0%**	**9.5%**
	Bicycle accidents	18.9%	5.8%	10.2%	15.7%	13.3%	8.1%	11.3%	0.0%
	Pedestrian hit by vehicle	5.7%	15.9%	2.3%	4.8%	1.3%	2.7%	3.8%	0.0%
	Moped, motorcycle	0.0%	2.9%	2.3%	0.6%	0.0%	4.1%	1.9%	9.5%
	Car passenger	1.9%	1.4%	2.3%	1.2%	0.0%	0.0%	0.0%	0.0%
	Other	0.0%	2.9%	0.0%	0.0%	2.7%	0.0%	0.0%	0.0%

Playing accidents		**26.4%**	**26.1%**	**17.0%**	**16.3%**	**26.7%**	**21.6%**	**17.0%**	**33.3%**
	Playground	3.8%	11.6%	4.5%	2.4%	13.3%	9.5%	7.5%	14.3%
	In-lines, skateboard	1.9%	0.0%	0.0%	0.0%	1.3%	4.1%	3.8%	4.8%
	Sledge, other “snow”	3.8%	4.3%	0.0%	2.4%	5.3%	0.0%	0.0%	0.0%
	Other play accidents	17.0%	10.1%	12.5%	11.4%	6.7%	8.1%	5.7%	14.3%
Sports accidents		**17.0%**	**11.6%**	**18.2%**	**20.5%**	**20.0%**	**43.2%**	**45.3%**	**38.1%**
	Ball-game	0.0%	2.9%	2.3%	4.8%	6.7%	27.0%	28.3%	23.8%
	Ice-hockey, skating	3.8%	5.8%	6.8%	4.2%	0.0%	4.1%	5.7%	0.0%
	Gymnastics and athletics	0.0%	0.0%	0.0%	0.6%	1.3%	0.0%	0.0%	0.0%
	Horse accidents	7.5%	1.4%	4.5%	4.2%	6.7%	4.1%	0.0%	14.3%
	Wrestling, boxing, etc.	3.8%	1.4%	3.4%	6.6%	5.3%	2.7%	3.8%	0.0%
	Skiing	1.9%	0.0%	0.0%	0.0%	0.0%	5.4%	7.5%	0.0%
	Other	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Fights		**0.0%**	**1.4%**	**2.3%**	**0.0%**	**4.0%**	**10.8%**	**11.3%**	**9.5%**
Other		**0.0%**	**0.0%**	**9.1%**	**12.0%**	**1.3%**	**0.0%**	**0.0%**	**0.0%**

Fractures of the proximal humerus in Malmö, Sweden, 1950/1955 to 2005–2006

During 2005–2006, we found 52 fractures of the proximal humerus (24 in boys and 28 in girls), accounting for 3% of all fractures (2% in boys and 5% in girls). The crude fracture rate for fractures of the proximal humerus in 2005–2006 was 56 per 10^5 person years (51 in boys and 62 in girls) (Table A2). The age- and gender-adjusted fracture rate was 57 per 10^5 person years (50 in boys and 65 in girls).

We found no difference in the age-adjusted incidence of fractures of the proximal humerus between boys and in girls, with no significant boy-to-girl age-adjusted fracture rate ratio (RR 0.8; 95%CI 0.5 to 1.4).

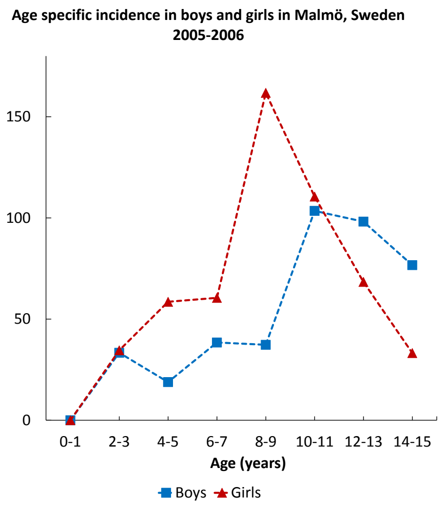
Of all fractures of the proximal humerus, 23 occurred on the left side (13 in boys and 10 in girls). Concerning side preponderance, we found no significant left-to-right fracture rate ratio in children (RR 0.8; 95%CI 0.4 to 1.4), in boys (RR 1.2; 95%CI 0.5 to 3.0) or in girls (RR 0.6; 95%CI 0.2 to 1.3).

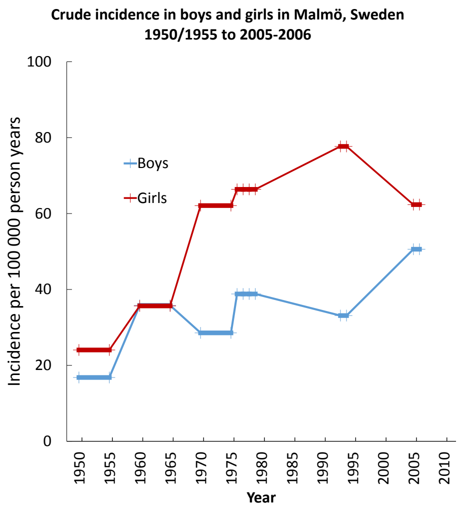
Of all evaluated periods, the highest age- and gender-adjusted incidence in absolute numbers was found in 2005–2006 and the lowest in 1950/1955. The age- and gender-adjusted incidence of fractures of the proximal humerus in children in 2005–2006 compared to 1950/1955 was significantly higher in children (RR 2.8; 95% CI 1.6 to 4.9) while changes in boys and in girls were not statistically significant (Table B2).

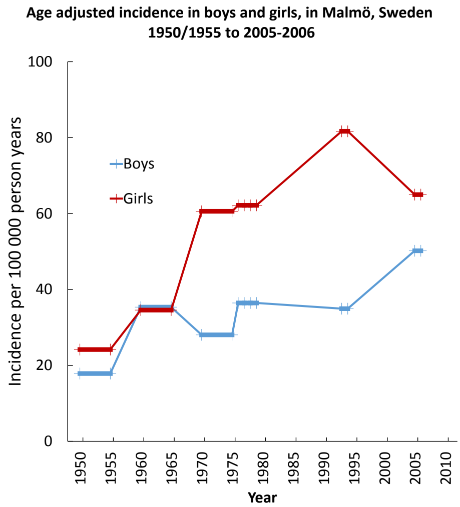
The etiology of fractures of the proximal humerus in 2005–2006 could be determined in 79% of cases compared to 53% in 1950/1955. In 2005–2006, most fractures occurred due to accidents during sports (46% of fractures with known etiology), playing (34%) and accidents at school (7%). The proportion of fractures due to traffic accidents in 2005–2006 was 4.9%, the lowest of all previously evaluated periods (Table C2).

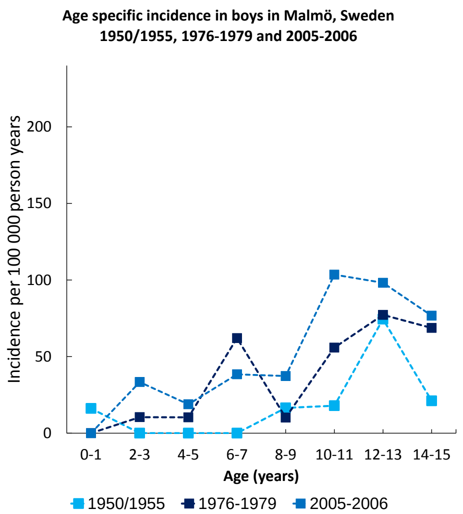
Fractures of the proximal humerus

Gender-specific incidence in relation to age in 2005–2005 (first chart), gender-specific crude and age-adjusted incidences during the different evaluated time periods (second and third chart) and gender-specific incidence in relation to age in different time periods (fourth and fifth chart).









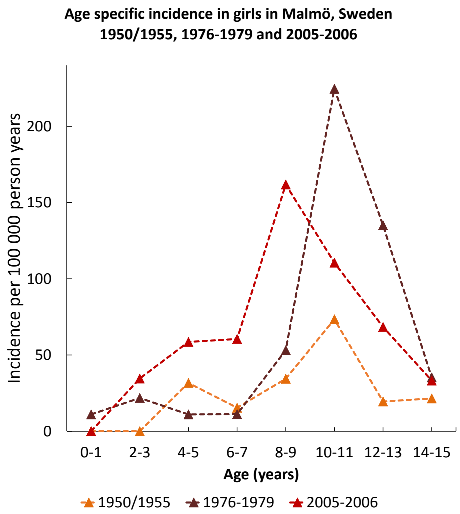


Table A2. The number, incidence and age-adjusted incidence (per 10^5 person years) of fractures of the proximal humerus in children, in boys and in girls in Malmö, Sweden, during the different evaluated periods.

Fractures of the proximal humerus in Malmö, Sweden, 1950/1955 to 2005–2006

		1950/1955	1960/1965	1970/1975	1976–1979	1993–1994	2005–2006
Number of fractures	All children	19	37	43	84	45	52
	Boys	8	19	14	32	14	24
	Girls	11	18	29	52	31	28
Crude Incidence	All children	20	36	45	52	55	56
	Boys	17	36	29	39	33	51
	Girls	24	36	62	66	78	62
Age-adjusted Incidence	All children	21	35	44	49	58	57
	Boys	18	35	28	36	35	50
	Girls	24	36	62	66	78	62

Table B2. Time trends in the unadjusted and the age-adjusted incidence of fractures of the proximal humerus in boys and girls in Malmö, Sweden. Comparisons between 1950/1955, 1976–1979, 1993–1994 and 2005–2006 are presented as rate ratios with 95% CI in parentheses.

Denominator		1950/1955			1976–1979		1993–1994
Nominator		1976–1979	1993–1994	2005–2006	1993–1994	2005–2006	2005–2006
	All children	2.6 (1.6 to 4.4)	2.7 (1.5 to 4.8)	2.8 (1.6 to 4.89)	1.0 (0.7 to 1.5)	1.1 (0.8 to 1.5)	1 (0.7 to 1.6)
Unadjusted	Boys	2.3 (1.04 to 6.1)	2 (0.8 to 5.8)	3 (1.3 to 8.2)	0.9 (0.4 to 1.6)	1.3 (0.7 to 2.3)	1.5 (0.8 to 3.2)
	Girls	2.8 (1.4 to 5.9)	3.2 (1.6 to 7.2)	2.6 (1.25 to 5.8)	1.2 (0.7 to 1.8)	0.9 (0.6 to 1.5)	0.8 (0.5 to 1.4)
	All children	2.3 (1.03 to 6.1)	2.8 (1.2 to 7)	2.7 (1.2 to 7)	1.2 (0.6 to 2.2)	1.2 (0.6 to 2.2)	1.0 (0.5 to 1.8)
Age-adjusted	Boys	2 (0.5 to 28.4)	2 (0.5 to 27.8)	2.8 (0.8 to 35.1)	1 (0.3 to 3.3)	1.4 (0.5 to 4.3)	1.4 (0.5 to 4.7)
	Girls	2.6 (0.9 to 12.5)	3.4 (1.2 to 15.6)	2.7 (0.9 to 12.9)	1.3 (0.6 to 3)	1 (0.5 to 2.5)	0.8 (0.4 to 1.7)

Table C2. The etiology of fractures of the proximal humerus in the different evaluated periods. Data are presented as percentages of all fractures where the etiology could be determined.

Environmental factors		1950/55	1960/65	1970/75	1976–79	1993–94	2005–06		
		All children					All children	Boys	Girls
Known		**52.6%**	**56.8%**	**76.7%**	**77.4%**	**62.2%**	**78.8%**	**83.3%**	**75.0%**
Unknown		**47.4%**	**43.2%**	**23.3%**	**22.6%**	**37.8%**	**21.2%**	**16.7%**	**25.0%**
Home		**40.0%**	**14.3%**	**0.0%**	**4.6%**	**7.1%**	**2.4%**	**5.0%**	**0.0%**
Day nursery		**0.0%**	**0.0%**	**0.0%**	**0.0%**	**3.6%**	**2.4%**	**5.0%**	**0.0%**
School		**10.0%**	**0.0%**	**0.0%**	**9.2%**	**0.0%**	**7.3%**	**10.0%**	**4.8%**
Work		**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Traffic accidents		**10.0%**	**23.8%**	**15.2%**	**7.7%**	**21.4%**	**4.9%**	**5.0%**	**4.8%**
	Bicycle accidents	10.0%	14.3%	12.1%	3.1%	10.7%	4.9%	5.0%	4.8%
	Pedestrian hit by vehicle	0.0%	0.0%	0.0%	0.0%	10.7%	0.0%	0.0%	0.0%
	Moped, motorcycle	0.0%	4.8%	3.0%	3.1%	0.0%	0.0%	0.0%	0.0%
	Car passenger	0.0%	4.8%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%
	Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Playing accidents		**20.0%**	**33.3%**	**45.5%**	**23.1%**	**32.1%**	**34.1%**	**30.0%**	**38.1%**
	Playground	0.0%	9.5%	12.1%	6.2%	14.3%	22.0%	15.0%	28.6%
	In-lines, skateboard	0.0%	0.0%	3.0%	0.0%	3.6%	0.0%	0.0%	0.0%
	Sledge, other “snow”	0.0%	4.8%	0.0%	1.5%	3.6%	2.4%	5.0%	0.0%
	Other play accidents	20.0%	19.0%	30.3%	15.4%	10.7%	9.8%	10.0%	9.5%
Sports accidents		**20.0%**	**28.6%**	**39.4%**	**53.8%**	**35.7%**	**46.3%**	**45.0%**	**47.6%**
	Ball-game	0.0%	0.0%	3.0%	3.1%	0.0%	17.1%	25.0%	9.5%
	Ice-hockey, skating	0.0%	0.0%	0.0%	3.1%	7.1%	2.4%	5.0%	0.0%
	Gymnastics and athletics	10.0%	0.0%	0.0%	4.6%	0.0%	2.4%	0.0%	4.8%
	Horse accidents	10.0%	23.8%	36.4%	41.5%	17.9%	14.6%	0.0%	28.6%
	Wrestling, boxing, etc.	0.0%	4.8%	0.0%	0.0%	7.1%	2.4%	5.0%	0.0%
	Skiing	0.0%	0.0%	0.0%	0.0%	0.0%	7.3%	10.0%	4.8%
	Other	0.0%	0.0%	0.0%	1.5%	3.6%	0.0%	0.0%	0.0%
Fights		**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**2.4%**	**0.0%**	**4.8%**
Other		**0.0%**	**0.0%**	**0.0%**	**1.5%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Fractures of the distal humerus in Malmö, Sweden 2005–2006

During 2005–2006, we found 104 fractures of the distal humerus (63 in boys and 41 in girls), accounting for 6% of all fractures (6% in boys and 7% in girls). The crude fracture rate for fractures of the distal humerus in 2005–2006 was 113 per 10^5 person years (133 in boys and 91 in girls) (Table A3).The age- and gender-adjusted fracture rate was 117 per 10^5 person years (139 in boys and 94 in girls).

Fractures of the distal humerus were no more common in boys than in girls, with no significant boy-to-girl age-adjusted fracture rate ratio (RR 1.5; 95%CI 0.97 to 2.2).

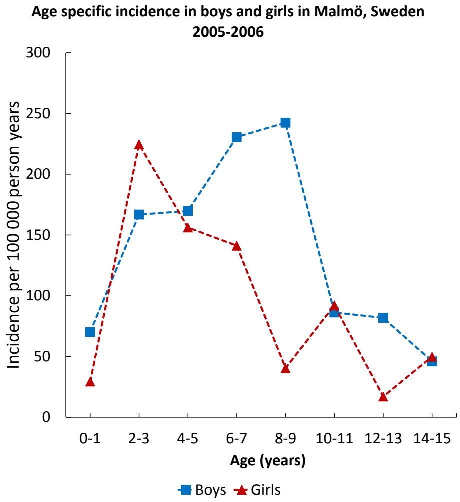
Of all fractures of the distal humerus, 58 occurred on the left side (39 in boys and 19 in girls). Concerning side preponderance, we found no significant left-to-right fracture rate ratio in children (RR 1.3; 95%CI 0.8 to 1.9), in boys (RR 1.6; 95%CI 0.95 to 2.8) or in girls (RR 0.9; 95%CI 0.4 to 1.7).

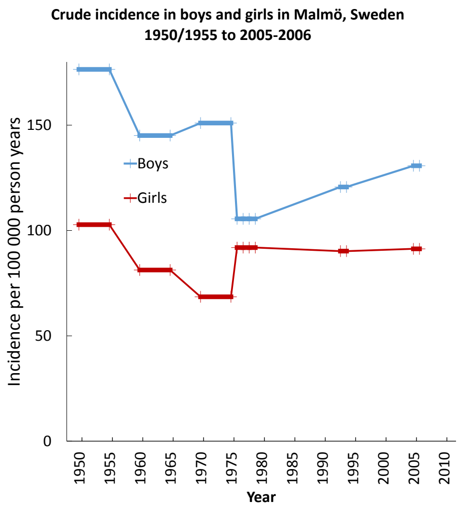
Of all evaluated periods, the highest age- and gender-adjusted incidence in absolute numbers was found in 1950/1955 and the lowest in 1976–1979. When we compared 2005–2006 to 1950/1955 and to 1976–1979, we found no significant change in the age- and gender-adjusted incidence of fractures of the distal humerus in children (Table B3).

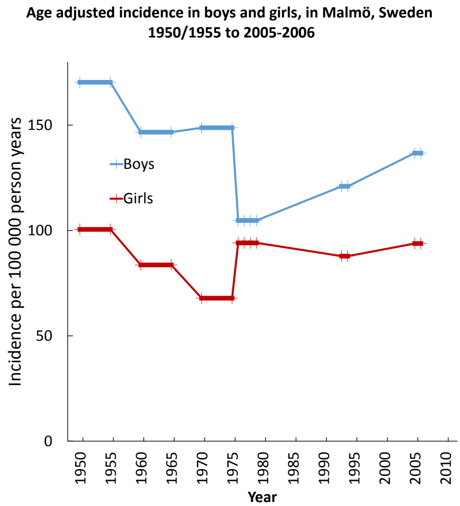
The etiology of fractures of the distal humerus in 2005–2006 could be determined in 68% of cases compared to 45% in 1950/1955. In 2005–2006, most fractures occurred due to accidents during playing (50% of distal humerus fractures with known etiology), sports (20%) and accidents at school (13%). The proportion of fractures due to accidents during playing, sports and at school in 2005–2006 was the highest of all previously evaluated periods. In 2005–2006, the proportion of distal humerus fractures due to home accidents was 5.7%, the lowest of all previously evaluated periods (Additional Table C3).

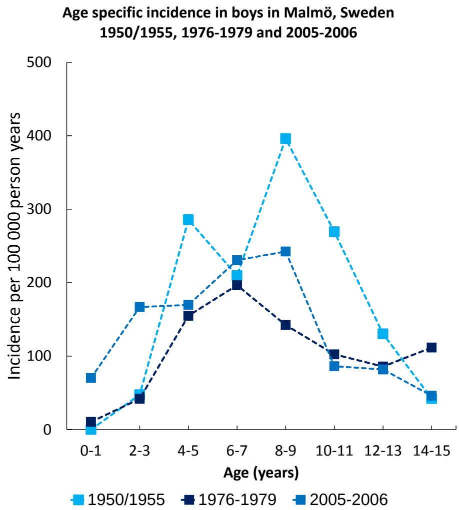
Fractures of the distal humerus

Gender-specific incidence in relation to age in 2005–2005 (first chart), gender-specific crude and age-adjusted incidences during the different evaluated time periods (second and third chart) and gender-specific incidence in relation to age in different time periods (fourth and fifth chart).









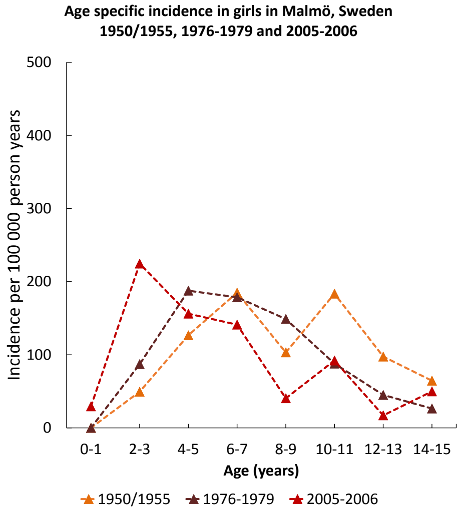


Table A3. The number, incidence and age-adjusted incidence (per 10^5 person years) of fractures of the distal humerus in children, in boys and in girls in Malmö, Sweden, during the different evaluated periods.

Fractures of the distal humerus in Malmö, Sweden, 1950/1955 to 2005–2006

		1950/1955	1960/1965	1970/1975	1976–1979	1993–1994	2005–2006
Number of fractures	All children	131	118	107	160	89	104
	Boys	84	77	75	88	51	63
	Girls	47	41	32	72	38	41
Crude Incidence	All children	140	114	112	100	108	113
	Boys	176	145	153	107	121	133
	Girls	103	81	69	92	95	91
Age-adjusted Incidence	All children	136	116	110	100	107	117
	Boys	170	147	151	106	121	139
	Girls	103	81	69	92	95	91

Table B3. Time trends in the unadjusted and the age-adjusted incidence of fractures of the distal humerus in boys and girls in Malmö, Sweden. Comparisons between 1950/1955, 1976–1979, 1993–1994 and 2005–2006 are presented as rate ratios with 95% CI in parentheses.

Denominator		1950/1955			1976–1979		1993–1994
Nominator		1976–1979	1993–1994	2005–2006	1993–1994	2005–2006	2005–2006
	All children	0.7 (0.6 to 0.9)	0.8 (0.6 to 1)	0.8 (0.6 to 1.04)	1.1 (0.8 to 1.4)	1.1 (0.9 to 1.5)	1.1 (0.8 to 1.4)
Unadjusted	Boys	0.6 (0.4 to 0.8)	0.7 (0.5 to 1)	0.7 (0.5 to 1.05)	1.1 (0.8 to 1.6)	1.2 (0.9 to 1.7)	1.1 (0.7 to 1.6)
	Girls	0.9 (0.6 to 1.3)	0.9 (0.6 to 1.4)	0.9 (0.6 to 1.4)	1.0 (0.7 to 1.5)	1.0 (0.7 to 1.5)	1.0 (0.6 to 1.5)
	All children	0.7 (0.5 to 1.1)	0.8 (0.5 to 1.2)	0.8 (0.6 to 1.3)	1.1 (0.7 to 1.6)	1.2 (0.8 to 1.8)	1.1 (0.7 to 1.6)
Age-adjusted	Boys	0.6 (0.4 to 1.1)	0.7 (0.4 to 1.2)	0.8 (0.5 to 1.3)	1.2 (0.6 to 2.1)	1.3 (0.7 to 2.3)	1.1 (0.7 to 2.0)
	Girls	0.9 (0.5 to 1.8)	0.9 (0.5 to 1.8)	0.9 (0.5 to 1.8)	0.9 (0.5 to 1.9)	1.0 (0.5 to 2.0)	1.0 (0.5 to 2.1)

Table C3. The etiology of fractures of the distal humerus in the different evaluated periods. Data are presented as percentages of all fractures where the etiology could be determined.

Environmental factors		1950/55	1960/65	1970/75	1976–79	1993–94	2005–06		
				All children			All children	Boys	Girls
Known		**45.0%**	**46.6%**	**57.9%**	**61.3%**	**65.2%**	**67.3%**	**63.5%**	**73.2%**
Unknown		**55.0%**	**53.4%**	**42.1%**	**38.8%**	**34.8%**	**32.7%**	**36.5%**	**26.8%**
Home		**8.5%**	**14.5%**	**12.9%**	**11.2%**	**15.5%**	**5.7%**	**5.0%**	**6.7%**
Day nursery		**0.0%**	**0.0%**	**0.0%**	**2.0%**	**3.4%**	**0.0%**	**0.0%**	**0.0%**
School		**5.1%**	**5.5%**	**6.5%**	**9.2%**	**3.4%**	**12.9%**	**17.5%**	**6.7%**
Work		**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Traffic accidents		**20.3%**	**21.8%**	**16.1%**	**19.4%**	**5.2%**	**5.7%**	**5.0%**	**6.7%**
	Bicycle accidents	18.6%	16.4%	12.9%	19.4%	5.2%	5.7%	5.0%	6.7%
	Pedestrian hit by vehicle	0.0%	3.6%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%
	Moped, motorcycle	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%
	Car passenger	1.7%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Playing accidents		**47.5%**	**45.5%**	**45.2%**	**42.9%**	**41.4%**	**50.0%**	**45.0%**	**56.7%**
	Playground	11.9%	14.5%	27.4%	17.3%	20.7%	35.7%	27.5%	46.7%
	In-lines, skateboard	0.0%	0.0%	0.0%	2.0%	3.4%	4.3%	5.0%	3.3%
	Sledge, other “snow”	1.7%	0.0%	0.0%	2.0%	0.0%	2.9%	5.0%	0.0%
	Other play accidents	33.9%	30.9%	17.7%	21.4%	17.2%	7.1%	7.5%	6.7%
Sports accidents		**15.3%**	**12.7%**	**19.4%**	**14.3%**	**31.0%**	**20.0%**	**20.0%**	**20.0%**
	Ball-game	1.7%	1.8%	4.8%	4.1%	10.3%	7.1%	10.0%	3.3%
	Ice-hockey, skating	6.8%	3.6%	4.8%	3.1%	1.7%	2.9%	5.0%	0.0%
	Gymnastics and athletics	1.7%	0.0%	1.6%	1.0%	8.6%	4.3%	2.5%	6.7%
	Horse accidents	1.7%	1.8%	6.5%	5.1%	5.2%	2.9%	0.0%	6.7%
	Wrestling, boxing, etc.	0.0%	5.5%	1.6%	1.0%	3.4%	0.0%	0.0%	0.0%
	Skiing	0.0%	0.0%	0.0%	0.0%	1.7%	1.4%	0.0%	3.3%
	Other	3.4%	0.0%	0.0%	0.0%	0.0%	1.4%	2.5%	0.0%
Fights		**1.7%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**5.7%**	**7.5%**	**3.3%**
Other		**1.7%**	**0.0%**	**0.0%**	**1.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Diaphyseal forearm fractures in Malmö, Sweden, 1950/1955 to 2005–2006

During 2005–2006, we found 87 diaphyseal forearm fractures (60 in boys and 27 in girls), accounting for 5% of all fractures (5% in boys and 5% in girls). The crude fracture rate for diaphyseal forearm fractures in 2005–2006 was 94 per 10^5 person years (126 in boys and 60 in girls) (Additional Table A4). The age- and gender-adjusted fracture rate was 98 per 10^5 person years (131 in boys and 62 in girls).

Diaphyseal forearm fractures were twice as common in boys as in girls with a significant boy-to-girl age-adjusted fracture rate ratio (RR 2.1; 95%CI 1.3 to 3.4).

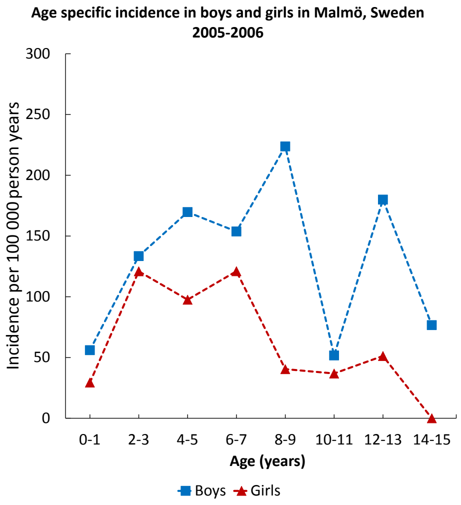
Of all diaphyseal forearm fractures, 38 occurred on the left side (27 in boys and 11 in girls). Concerning side preponderance, we found no significant left-to-right fracture rate ratio in children (RR 0.8; 95%CI 0.5 to 1.2), in boys (RR 0.8; 95%CI 0.5 to 1.4) or in girls (RR 0.7; 95%CI 0.3 to 1.6).

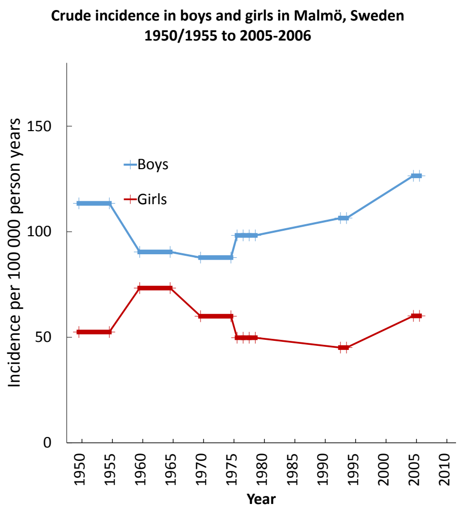
Of all the evaluated periods, the highest age- and gender-adjusted incidence in absolute numbers was found in 2005–2006 and the lowest in 1976–1979. When we compared 2005–2006 to 1976–1979, we found no significant change in the age- and gender-adjusted incidence of diaphyseal forearm fractures in children (Table B3).

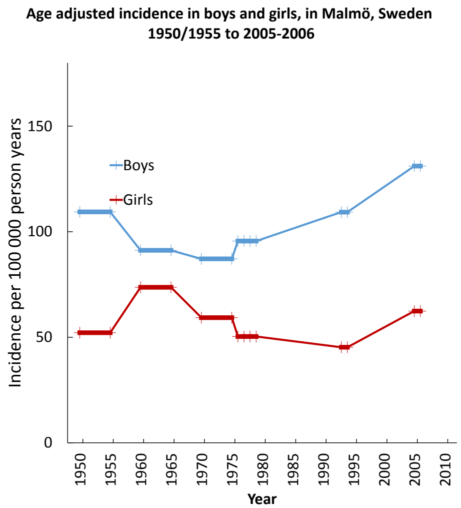
The etiology of diaphyseal forearm fractures in 2005–2006 could be determined in 69% of cases compared to 42% in 1950/1955. In 2005–2006, most fractures occurred due to accidents during playing (43% of diaphyseal forearm fractures with known etiology), sports (27%) and accidents at school (15%). The proportion of fractures due to accidents during sports in 2005–2006 was the highest of all previously evaluated periods. In 2005–2006, the proportion of diaphyseal forearm fractures due to traffic accidents was 8.3%, the lowest of all previously evaluated periods (Table C4).

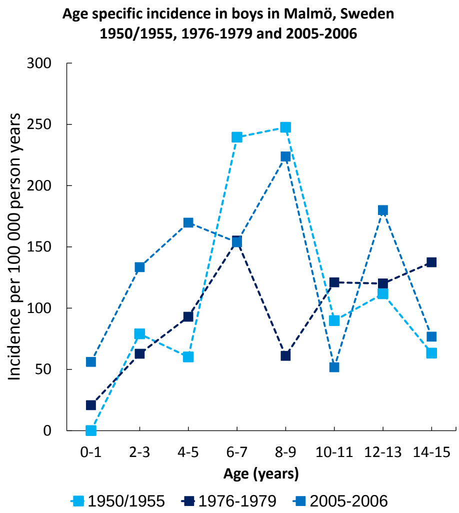
Diaphyseal fractures of the forearm

Gender-specific incidence in relation to age in 2005-2005 (first chart), gender-specific crude and age-adjusted incidences during the different evaluated time periods (second and third chart) and gender-specific incidence in relation to age in different time periods (fourth and fifth chart).









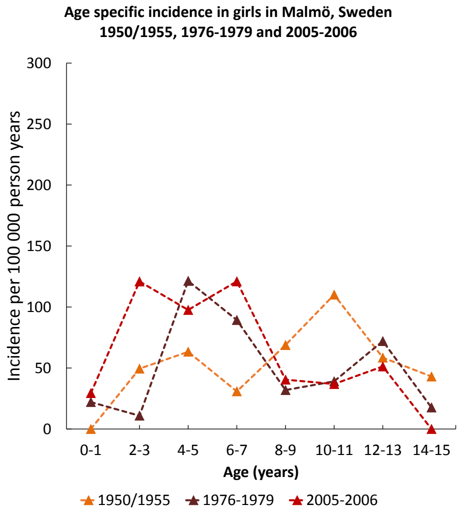


Table A4. The number, incidence and age-adjusted incidence (per 10^5 person years) of diaphyseal forearm fractures in children, in boys and in girls in Malmö, Sweden, during the different evaluated periods.

Diaphyseal forearm fractures in Malmö, Sweden, 1950/1955 to 2005–2006

		1950/1955	1960/1965	1970/1975	1976–1979	1993–1994	2005–2006
Number of fractures	All children	78	85	71	120	63	87
	Boys	54	48	43	81	45	60
	Girls	24	37	28	39	18	27
Crude Incidence	All children	84	82	74	75	77	94
	Boys	113	90	88	98	106	126
	Girls	52	73	60	50	45	60
Age-adjusted Incidence	All children	82	83	74	74	78	98
	Boys	109	91	87	96	109	131
	Girls	52	73	60	50	45	60

Table B4. Time trends in the unadjusted and the age-adjusted incidence of diaphyseal forearm fractures in boys and girls in Malmö, Sweden. Comparisons between 1950/1955, 1976–1979, 1993–1994 and 2005–2006 are presented as rate ratios with 95% CI in parentheses.

	Denominator	1950/1955			1976–1979		1993–1994
	Nominator	1976–1979	1993–1994	2005–2006	1993–1994	2005–2006	2005–2006
	All children	0.9 (0.7 to 1.2)	0.9 (0.6 to 1.3)	1.1 (0.8 to 1.5)	1 (0.7 to 1.4)	1.3 (0.95 to 1.7)	1.2 (0.9 to 1.7)
Unadjusted	Boys	0.9 (0.6 to 1.2)	0.9 (0.6 to 1.4)	1.1 (0.8 to 1.6)	1.1 (0.7 to 1.57)	1.3 (0.9 to 1.8)	1.2 (0.8 to 1.8)
	Girls	0.9 (0.6 to 1.6)	0.9 (0.4 to 1.6)	1.1 (0.6 to 2.1)	0.9 (0.5 to 1.6)	1.2 (0.7 to 2.0)	1.3 (0.7 to 2.6)
	All children	0.9 (0.5 to 1.5)	1.0 (0.6 to 1.6)	1.2 (0.7 to 1.9)	1.1 (0.6 to 1.8)	1.3 (0.8 to 2.2)	1.3 (0.8 to 2.0)
Age-adjusted	Boys	0.9 (0.5 to 1.6)	1.0 (0.5 to 1.8)	1.2 (0.7 to 2.1)	1.1 (0.6 to 2.1)	1.4 (0.8 to 2.5)	1.2 (0.7 to 2.1)
	Girls	1.0 (0.4 to 2.6)	0.9 (0.3 to 2.4)	1.2 (0.5 to 3.1)	0.9 (0.3 to 2.5)	1.2 (0.5 to 3.2)	1.4 (0.5 to 3.8)

Table C4. The etiology of diaphyseal forearm fractures in the different evaluated periods. Data are presented as percentages of all fractures where the etiology could be determined.

Environmental factors		1950/55	1960/65	1970/75	1976–79	1993–94	2005–06		
				All children			All children	Boys	Girls
Known		**42.3%**	**45.9%**	**64.8%**	**59.2%**	**65.1%**	**69.0%**	**70.0%**	**66.7%**
Unknown		**57.7%**	**54.1%**	**35.2%**	**40.8%**	**34.9%**	**31.0%**	**30.0%**	**33.3%**
Home		**3.0%**	**15.4%**	**8.7%**	**12.7%**	**7.3%**	**5.0%**	**2.4%**	**11.1%**
Day nursery		**3.0%**	**0.0%**	**0.0%**	**0.0%**	**4.9%**	**1.7%**	**0.0%**	**5.6%**
School		**21.2%**	**17.9%**	**15.2%**	**14.1%**	**4.9%**	**15.0%**	**16.7%**	**11.1%**
Work		**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Traffic accidents		**12.1%**	**17.9%**	**32.6%**	**21.1%**	**19.5%**	**8.3%**	**11.9%**	**0.0%**
	Bicycle accidents	12.1%	7.7%	30.4%	16.9%	14.6%	8.3%	11.9%	0.0%
	Pedestrian hit by vehicle	0.0%	7.7%	0.0%	2.8%	0.0%	0.0%	0.0%	0.0%
	Moped, motorcycle	0.0%	0.0%	2.2%	0.0%	2.4%	0.0%	0.0%	0.0%
	Car passenger	0.0%	2.6%	0.0%	1.4%	2.4%	0.0%	0.0%	0.0%
	Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Playing accidents		**45.5%**	**41.0%**	**21.7%**	**32.4%**	**31.7%**	**43.3%**	**38.1%**	**55.6%**
	Playground	15.2%	5.1%	4.3%	15.5%	12.2%	30.0%	26.2%	38.9%
	In-lines, skateboard	0.0%	2.6%	0.0%	2.8%	4.9%	6.7%	9.5%	0.0%
	Sledge, other “snow”	0.0%	0.0%	6.5%	1.4%	0.0%	5.0%	0.0%	16.7%
	Other play accidents	30.3%	33.3%	10.9%	12.7%	14.6%	1.7%	2.4%	0.0%
Sports accidents		**12.1%**	**7.7%**	**15.2%**	**16.9%**	**31.7%**	**26.7%**	**31.0%**	**16.7%**
	Ball-game	6.1%	5.1%	8.7%	5.6%	12.2%	13.3%	19.0%	0.0%
	Ice-hockey, skating	0.0%	0.0%	0.0%	0.0%	4.9%	1.7%	2.4%	0.0%
	Gymnastics and athletics	3.0%	2.6%	0.0%	1.4%	4.9%	10.0%	9.5%	11.1%
	Horse accidents	0.0%	0.0%	2.2%	4.2%	0.0%	1.7%	0.0%	5.6%
	Wrestling, boxing, etc.	0.0%	0.0%	2.2%	4.2%	7.3%	0.0%	0.0%	0.0%
	Skiing	3.0%	0.0%	0.0%	0.0%	2.4%	0.0%	0.0%	0.0%
	Other	0.0%	0.0%	2.2%	1.4%	0.0%	0.0%	0.0%	0.0%
Fights		**3.0%**	**0.0%**	**2.2%**	**1.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Other		**0.0%**	**0.0%**	**4.3%**	**1.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Fractures of the diaphysis of the tibia in Malmö, Sweden, 1950/1955 to 2005–2006

During 2005–2006, we found 90 fractures of the diaphysis of the tibia (56 in boys and 34 in girls), accounting for 5% of all fractures (5% in boys and 6% in girls). The crude fracture rate for diaphyseal fractures of the tibia in 2005–2006 was 97 per 10^5 person years (118 in boys and 76 in girls). The age- and gender-adjusted fracture rate was 98 per 10^5 person years (121 in boys and 75 in girls) (Table A5).

Diaphyseal tibia fractures were more common in boys than in girls, with a marginally significant boy-to-girl age-adjusted fracture rate ratio (RR 1.6; 95%CI 1.001 to 2.4).

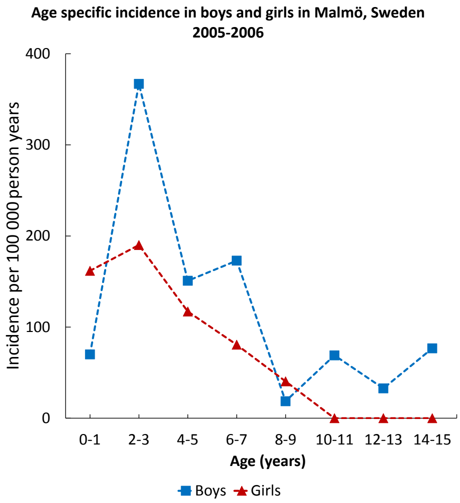
Of all diaphyseal tibia fractures, 57 occurred on the left side (32 in boys and 25 in girls). We found that diaphyseal tibia fractures were more common on the left side in children and in girls, with a significant left-to-right fracture rate ratio in children (RR 1.7; 95%CI 1.1 to 2.7), and in girls (RR 2.8; 95%CI 1.3 to 7.0) but not in boys (RR 1.3; 95%CI 0.8 to 2.3).

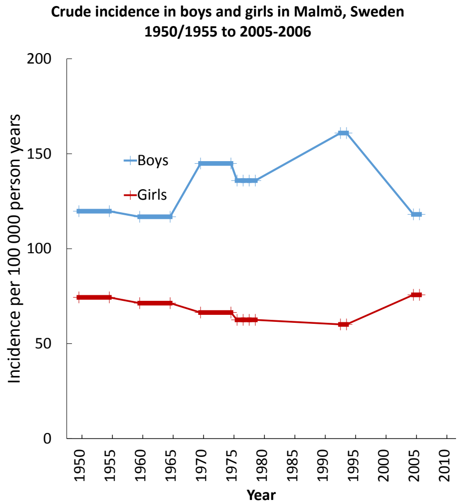
Of all evaluated periods, the highest age- and gender-adjusted incidence in absolute numbers was found in 1976–1979 and the lowest in 1950–1955. We found no evidence of a difference in the age- and gender-adjusted incidence of diaphyseal tibia fractures in children in 2005–2006 compared either to either 1950/1955 or to 1976–1979 (Table B5).

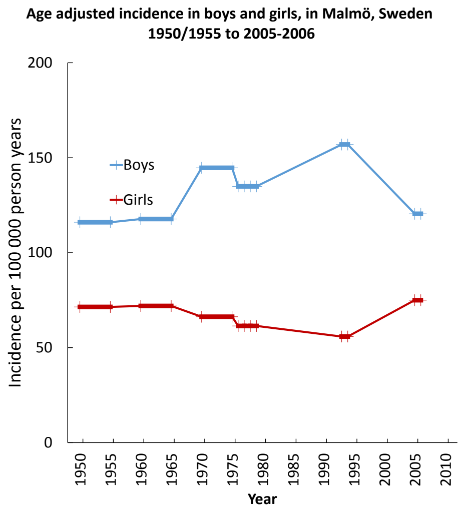
The etiology of fractures of the diaphysis of the tibia in 2005–2006 could be determined in 71% of cases compared to 66% in 1950/1955. In 2005–2006, most fractures occurred due to accidents during sports (38% of diaphysis of the tibia fractures with known etiology), playing (27%) and accidents in traffic (20%). The proportion of fractures due to sports and playing accidents in 2005–2006, was higher than all previously evaluated years, while traffic accidents represented the lowest proportion of all evaluated years. In 2005–2006, fractures due to home accidents represented 3.1%, the smallest percentage of all periods (Table C5).

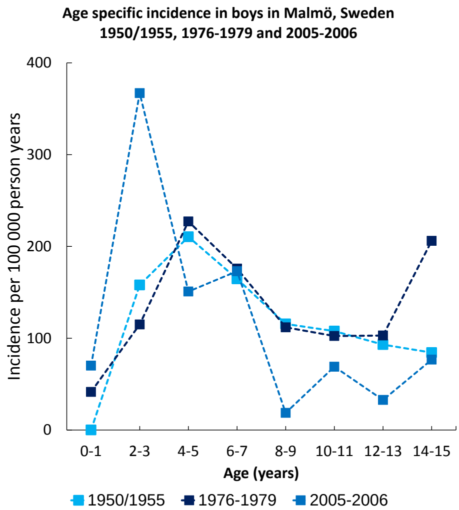
Diaphyseal fractures of the tibia

Gender-specific incidence in relation to age in 2005–2005 (first chart), gender-specific crude and age-adjusted incidences during the different evaluated time periods (second and third chart) and gender-specific incidence in relation to age in different time periods (fourth and fifth chart)-









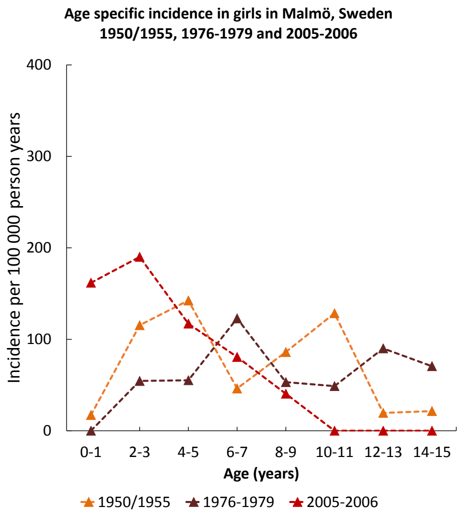


Table A5. The number, incidence and age-adjusted incidence (per 10^5 person years) of diaphyseal tibia fractures in children, in boys and in girls in Malmö, Sweden, during the different evaluated periods.

Diaphyseal tibia fractures in Malmö, Sweden, 1950/1955 to 2005–2006

		1950/1955	1960/1965	1970/1975	1976–1979	1993–1994	2005–2006
Number of fractures	All children	91	98	102	161	92	90
	Boys	57	62	71	112	68	56
	Girls	34	36	31	49	24	34
Crude Incidence	All children	98	95	107	100	112	97
	Boys	120	117	145	136	161	118
	Girls	74	71	66	63	60	76
Age-adjusted Incidence	All children	94	95	106	99	108	98
	Boys	116	118	145	135	157	121
	Girls	74	71	66	63	60	76

Table B5. Time trends in the unadjusted and the age-adjusted incidence of diaphyseal tibia fractures in boys and girls in Malmö, Sweden. Comparisons between 1950/1955, 1976–1979, 1993–1994 and 2005–2006 are presented as rate ratios with 95% CI in parentheses.

Denominator		1950/1955			1976–1979		1993–1994
Nominator		1976–1979	1993–1994	2005–2006	1993–1994	2005–2006	2005–2006
	All children	1.0 (0.8 to 1.3)	1.1 (0.9 to 1.5)	1.0 (0.7 to 1.3)	1.1 (0.9 to 1.4)	1 (0.74 to 1.3)	0.9 (0.6 to 1.2)
Unadjusted	Boys	1.1 (0.8 to 1.6)	1.3 (0.9 to 1.9)	1.0 (0.7 to 1.4)	1.2 (0.9 to 1.6)	0.9 (0.6 to 1.2)	0.7 (0.5 to 1.1)
	Girls	0.8 (0.5 to 1.3)	0.8 (0.5 to 1.4)	1.0 (0.6 to 1.7)	1.0 (0.6 to 1.6)	1.2 (0.8 to 1.9)	1.3 (0.7 to 2.2)
	All children	1.1 (0.7 to 1.6)	1.1 (0.7 to 1.8)	1.0 (0.7 to 1.6)	1.1 (0.7 to 1.7)	1 (0.6 to 1.5)	0.9 (0.6 to 1.4)
Age-adjusted	Boys	1.2 (0.7 to 2.0)	1.4 (0.8 to 2.3)	1.0 (0.6 to 1.8)	1.2 (0.7 to 1.9)	0.9 (0.5 to 1.5)	0.8 (0.4 to 1.3)
	Girls	0.9 (0.4 to 2.0)	0.8 (0.3 to 1.8)	1.0 (0.5 to 2.3)	0.9 (0.4 to 2.2)	1.2 (0.5 to 2.8)	1.3 (0.6 to 3.2)

Table C5. The etiology of diaphyseal tibia fractures in the different evaluated periods. Data are presented as percentages of all fractures where the etiology could be determined.

Environmental factors		**1950/55**	**1960/65**	**1970/75**	**1976–79**	**1993–94**	**2005–06**		
				All children			**All children**	**Boys**	**Girls**
Known		**65.9%**	**65.3%**	**80.4%**	**82.0%**	**78.3%**	**71.1%**	**75.0%**	**64.7%**
Unknown		**34.1%**	**34.7%**	**19.6%**	**18.0%**	**21.7%**	**28.9%**	**25.0%**	**35.3%**
Home		**16.7%**	**15.6%**	**11.0%**	**8.3%**	**12.5%**	**3.1%**	**2.4%**	**4.5%**
Day nursery		**0.0%**	**1.6%**	**0.0%**	**0.8%**	**4.2%**	**4.7%**	**7.1%**	**0.0%**
School		**6.7%**	**1.6%**	**1.2%**	**1.5%**	**1.4%**	**4.7%**	**4.8%**	**4.5%**
Work		**0.0%**	**0.0%**	**0.0%**	**0.0%**	**1.4%**	**0.0%**	**0.0%**	**0.0%**
Traffic accidents		**43.3%**	**48.4%**	**47.6%**	**28.8%**	**31.9%**	**20.3%**	**19.0%**	**22.7%**
	Bicycle accidents	21.7%	18.8%	18.3%	15.2%	13.9%	9.4%	4.8%	18.2%
	Pedestrian hit by vehicle	20.0%	25.0%	17.1%	9.1%	9.7%	7.8%	9.5%	4.5%
	Moped, motorcycle	0.0%	1.6%	4.9%	4.5%	5.6%	3.1%	4.8%	0.0%
	Car passenger	0.0%	1.6%	2.4%	0.0%	1.4%	0.0%	0.0%	0.0%
	Other	1.7%	1.6%	4.9%	0.0%	1.4%	0.0%	0.0%	0.0%

Playing accidents		**13.3%**	**20.3%**	**14.6%**	**29.5%**	**16.7%**	**26.6%**	**23.8%**	**31.8%**
	Playground	6.7%	4.7%	3.7%	6.1%	9.7%	12.5%	7.1%	22.7%
	In-lines, skateboard	0.0%	0.0%	0.0%	3.8%	2.8%	1.6%	2.4%	0.0%
	Sledge, other “snow”	3.3%	3.1%	2.4%	9.1%	2.8%	6.3%	9.5%	0.0%
	Other play accidents	3.3%	12.5%	8.5%	10.6%	1.4%	6.3%	4.8%	9.1%
Sports accidents		**20.0%**	**12.5%**	**23.2%**	**29.5%**	**30.6%**	**37.5%**	**42.9%**	**27.3%**
	Ball-game	3.3%	0.0%	4.9%	4.5%	13.9%	12.5%	19.0%	0.0%
	Ice-hockey, skating	13.3%	10.9%	7.3%	0.8%	5.6%	0.0%	0.0%	0.0%
	Gymnastics and athletics	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Horse accidents	0.0%	0.0%	1.2%	0.0%	1.4%	0.0%	0.0%	0.0%
	Wrestling, boxing, etc.	0.0%	0.0%	0.0%	0.0%	1.4%	1.6%	2.4%	0.0%
	Skiing	3.3%	1.6%	9.8%	24.2%	8.3%	23.4%	21.4%	27.3%
	Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fights		**0.0%**	**0.0%**	**1.2%**	**0.8%**	**1.4%**	**3.1%**	**0.0%**	**9.1%**
Other		**0.0%**	**0.0%**	**1.2%**	**0.8%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Fractures of the bones of the foot in Malmö, Sweden, 1950/1955 to 2005–2006

During 2005–2006, we found 142 fractures involving the bones of the foot (88 in boys and 54 in girls), accounting for 8% of all fractures (8% in boys and 9% in girls). The crude fracture rate for fractures of the bones of the foot in 2005–2006 was 154 per 10^5 person years (186 in boys and 120 in girls). The age- and gender-adjusted fracture rate was 152 per 10^5 person years (184 in boys and 119 in girls) (Table A7).

Foot fractures were more common in boys than in girls with a boy-to-girl age-adjusted fracture rate ratio (RR 1.5; 95%CI 1.1 to 2.2).

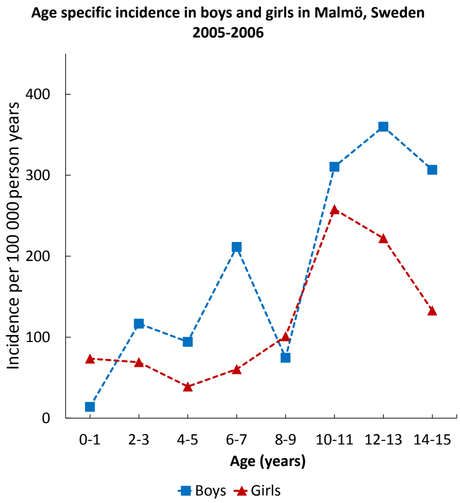
Of all foot fractures, 63 occurred on the left side (42 in boys and 21 in girls). Concerning side preponderance, we found no significant left-to-right fracture rate ratio in children (RR 0.8; 95%CI 0.6 to 1.1), in boys (RR 0.9; 95%CI 0.6 to 1.4) or in girls (RR 0.6; 95%CI 0.4 to 1.1).

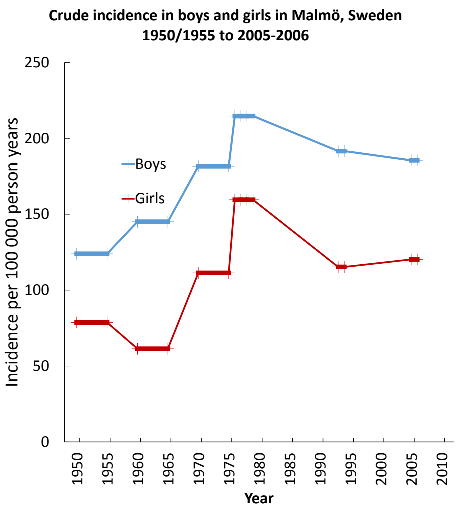
Of all evaluated periods, the lowest age- and gender-adjusted incidence in absolute numbers was found in 1950/1955 and the highest in 1976–1979. We found no evidence of a difference in the age- and gender-adjusted incidence of foot fractures in children in 2005–2006 compared to either 1950/1955 or to 1976–1979 (Table B7).

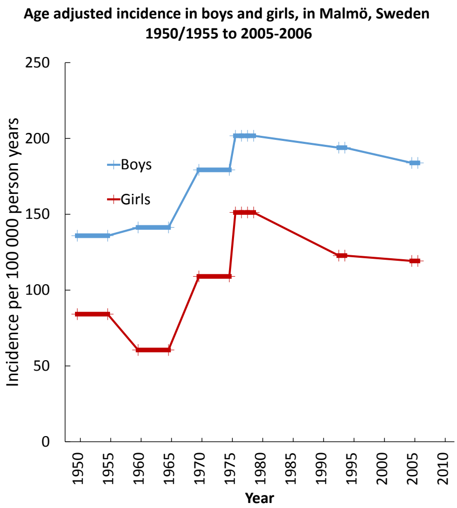
The etiology of foot fractures in 2005–2006 could be determined in 53% of cases compared to 38% in 1950/1955. In 2005–2006, most fractures occurred due to accidents during sports (39% of foot fractures with known etiology), playing (31%), and accidents in traffic (16%). The proportion of fractures due to sports accidents in 2005–2006 was higher than in all previously evaluated years, (Table C7).

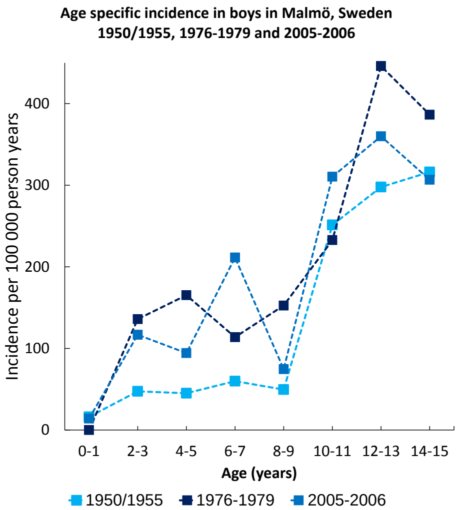
Foot fractures

Gender-specific incidence in relation to age in 2005–2005 (first chart), gender-specific crude and age-adjusted incidences during different time periods (second and third chart) and gender-specific incidence in relation to age in different time periods (fourth and fifth chart).









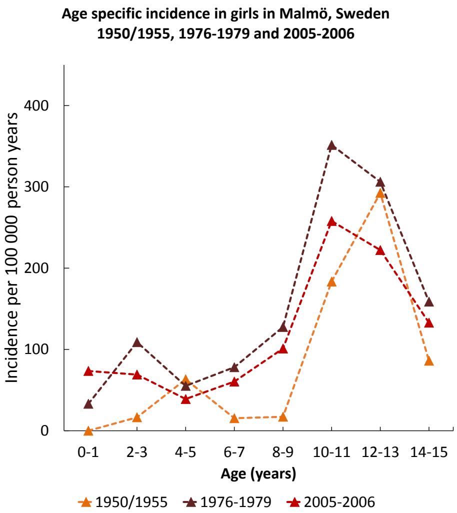


Table A6. The number, incidence and age-adjusted incidence (per 10^5 person years) of foot fractures in children, in boys and in girls in Malmö, Sweden, during the different evaluated periods.

Ankle fractures in Malmö, Sweden, 1950/1955 to 2005–2006

		1950/1955	1960/1965	1970/1975	1976–1979	1993–1994	2005–2006
Number of fractures	All children	95	108	141	302	127	142
	Boys	59	77	89	177	81	88
	Girls	36	31	52	125	46	54
Crude Incidence	All children	102	104	147	188	155	154
	Boys	124	145	182	215	192	186
	Girls	79	61	111	160	115	120
Age-adjusted Incidence	All children	111	102	145	177	159	152
	Boys	136	141	179	202	194	184
	Girls	79	61	111	160	115	120

Table B6 Time differences in unadjusted and age-adjusted incidence of foot fractures in boys and girls in Malmö, Sweden. Comparisons between 1950/1955, 1976–1979, 1993–1994 and 2005–2006 are presented as rate ratios with 95% CI in parentheses.

Denominator		1950/1955			1976–1979		1993–1994
Nominator		1976–1979	1993–1994	2005–2006	1993–1994	2005–2006	2005–2006
	All children	1.8 (1.5 to 2.3)	1.5 (1.2 to 2.0)	1.5 (1.2 to 1.97)	0.8 (0.7 to 1.01)	0.8 (0.7 to 1.0001)	1 (0.8 to 1.3)
Unadjusted	Boys	1.7 (1.3 to 2.3)	1.5 (1.09 to 2.2)	1.5 (1.06 to 2.1)	0.9 (0.7 to 1.2)	0.9 (0.7 to 1.1)	1 (0.7 to 1.3)
	Girls	2.0 (1.4 to 3.0)	1.5 (0.9 to 2.3)	1.5 (0.98 to 2.4)	0.7 (0.5 to 1.02)	0.8 (0.5 to 1.04)	1 (0.7 to 1.6)
	All children	1.6 (1.1 to 2.3)	1.4 (0.98 to 2.1)	1.4 (0.9 to 2)	0.9 (0.6 to 1.3)	0.9 (0.6 to 1.2)	1 (0.7 to 1.4)
Age-adjusted	Boys	1.5 (0.9 to 2.4)	1.4 (0.87 to 2.3)	1.4 (0.8 to 2.2)	1.0 (0.6 to 1.5)	0.9 (0.6 to 1.4)	0.9 (0.6 to 1.5)
	Girls	1.8 (0.97 to 3.4)	1.5 (0.8 to 2.83)	1.4 (0.74 to 2.8)	0.8 (0.46 to 1.4)	0.8 (0.4 to 1.4)	1 (0.5 to 1.7)

Table C6. The etiology of foot fractures at different evaluated periods. Data are presented as percentages of all fractures where the etiology could be determined.

Environmental factors	1950/55	1960/65	1970/75	1976–79	1993–94	2005–06		
	All children					All children	Boys	Girls
Known	**37.9%**	**41.7%**	**48.9%**	**54.3%**	**58.3%**	**52.8%**	**64.8%**	**33.3%**
Unknown	**62.1%**	**58.3%**	**51.1%**	**45.7%**	**41.7%**	**47.2%**	**35.2%**	**66.7%**
Home	**11.1%**	**13.3%**	**11.6%**	**11.6%**	**23.0%**	**0.0%**	**0.0%**	**0.0%**
Day nursery	**0.0%**	**0.0%**	**2.9%**	**1.2%**	**6.8%**	**1.3%**	**1.8%**	**0.0%**
School	**16.7%**	**15.6%**	**11.6%**	**9.1%**	**4.1%**	**8.0%**	**7.0%**	**11.1%**
Work	**8.3%**	**2.2%**	**0.0%**	**0.0%**	**1.4%**	**0.0%**	**0.0%**	**0.0%**
Traffic accidents	**13.9%**	**20.0%**	**4.3%**	**11.6%**	**6.8%**	**16.0%**	**15.8%**	**16.7%**
Bicycle accidents	8.3%	8.9%	1.4%	4.3%	4.1%	6.7%	7.0%	5.6%
Pedestrian hit by vehicle	2.8%	4.4%	1.4%	3.0%	2.7%	6.7%	5.3%	11.1%
Moped, motorcycle	2.8%	6.7%	1.4%	3.7%	0.0%	2.7%	3.5%	0.0%
Car passenger	0.0%	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Playing		**19.4%**	**26.7%**	**49.3%**	**31.7%**	**31.1%**	**30.7%**	**28.1%**	**38.9%**
	Playground	2.8%	2.2%	5.8%	6.7%	12.2%	10.7%	10.5%	11.1%
	In-lines, skateboard	0.0%	0.0%	0.0%	0.6%	0.0%	5.3%	7.0%	0.0%
	Sledge, other “snow”	0.0%	0.0%	0.0%	1.8%	2.7%	1.3%	1.8%	0.0%
	Other play accidents	16.7%	24.4%	43.5%	22.6%	16.2%	13.3%	8.8%	27.8%
Sports accidents		**30.6%**	**20.0%**	**17.4%**	**31.7%**	**27.0%**	**38.7%**	**42.1%**	**27.8%**
	Ball-game	22.2%	11.1%	10.1%	17.1%	10.8%	25.3%	31.6%	5.6%
	Ice-hockey, skating	2.8%	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%
	Gymnastics and athletics	2.8%	2.2%	4.3%	3.0%	8.1%	2.7%	3.5%	0.0%
	Horse accidents	0.0%	2.2%	1.4%	3.7%	5.4%	1.3%	0.0%	5.6%
	Wrestling, boxing, etc.	0.0%	0.0%	0.0%	4.3%	0.0%	5.3%	5.3%	5.6%
	Skiing	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Other	2.8%	4.4%	1.4%	2.4%	2.7%	4.0%	1.8%	11.1%
Fights		**0.0%**	**0.0%**	**0.0%**	**0.6%**	**0.0%**	**5.3%**	**5.3%**	**5.6%**
Other		**0.0%**	**2.2%**	**2.9%**	**2.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Descriptive table: The epidemiology of different fracture types in children, in boys and in girls in Malmö, Sweden, 1950–2006

Table D. Fracture distribution in Malmö children <16 in the years 2005–2006. Data are presented as absolute numbers, incidence per 10^5 person years and proportion (%) of all fractures.

	All children			Boys			Girls		
	Number	**Incidence**	**Proportion**	**Number**	**Incidence**	**Proportion**	**Number**	**Incidence**	**Proportion**
All fractures	**1692**	**1832**	**100.0%**	**1119**	**2359**	**100.0%**	**573**	**1276**	**100.0%**
Axial	**28**	**30**	**1.7%**	**18**	**38**	**1.6%**	**10**	**22**	**1.7%**
Face	**16**	**17**	**0.9%**	**11**	**23**	**1.0%**	**5**	**11**	**0.9%**
Spine	**8**	**9**	**0.5%**	**5**	**11**	**0.4%**	**3**	**7**	**0.5%**
pelvis	**4**	**4**	**0.2%**	**2**	**4**	**0.2%**	**2**	**4**	**0.3%**
Appendicular	**1664**	**1802**	**98.3%**	**1101**	**2321**	**98.4%**	**563**	**1254**	**98.3%**
Upper Extremity	**1334**	**1445**	**78.8%**	**894**	**1885**	**79.9%**	**440**	**980**	**76.8%**
Scapula	**2**	**2**	**0.1%**	**2**	**4**	**0.2%**	**0**	**0**	**0.0%**
Clavicle	**114**	**123**	**6.7%**	**75**	**158**	**6.7%**	**39**	**87**	**6.8%**
Humerus	**171**	**185**	**10.1%**	**96**	**202**	**8.6%**	**75**	**167**	**13.1%**
Proximal	52	56	3.1%	24	51	2.1%	28	62	4.9%
Diaphyseal	15	16	0.9%	9	19	0.8%	6	13	1.0%
Distal	104	113	6.1%	63	133	5.6%	41	91	7.2%
Forearm	**633**	**686**	**37.4%**	**418**	**881**	**37.4%**	**215**	**479**	**37.5%**
Proximal	25	27	1.5%	17	36	1.5%	8	18	1.4%
Diaphyseal	87	94	5.1%	60	126	5.4%	27	60	4.7%
Distal	521	564	30.8%	341	719	30.5%	180	401	31.4%

Hand		**414**	**448**	**24.5%**	**303**	**639**	**27.1%**	**111**	**247**	**19.4%**
	Carpal and Metacarpal	166	180	9.8%	143	301	12.8%	23	51	4.0%
	Finger	248	269	14.7%	160	337	14.3%	88	196	15.4%
Lower Extremity		**330**	**357**	**19.5%**	**207**	**436**	**18.5%**	**123**	**274**	**21.5%**
Femur		**22**	**24**	**1.3%**	**13**	**27**	**1.2%**	**9**	**20**	**1.6%**
	Proximal	2	2	0.1%	1	2	0.1%	1	2	0.2%
	Diaphyseal	16	17	0.9%	8	17	0.7%	8	18	1.4%
	Distal	4	4	0.2%	4	8	0.4%	0	0	0.0%
Patella		**4**	**4**	**0.2%**	**4**	**8**	**0.4%**	**0**	**0**	**0.0%**
Tibia		**132**	**143**	**7.8%**	**80**	**169**	**7.1%**	**52**	**116**	**9.1%**
	Proximal	9	10	0.5%	5	11	0.4%	4	9	0.7%
	Diaphyseal	90	97	5.3%	56	118	5.0%	34	76	5.9%
	Distal[a]	33	36	2.0%	19	40	1.7%	14	31	2.4%
Fibula		**30**	**32**	**1.8%**	**22**	**46**	**2.0%**	**8**	**18**	**1.4%**
	Proximal or diaphyseal	6	6	0.4%	6	13	0.5%	0	0	0.0%
	Distal	24	26	1.4%	16	34	1.4%	8	18	1.4%
Ankle[b]		**33**	**36**	**2.0%**	**22**	**46**	**2.0%**	**11**	**24**	**1.9%**
Foot		**142**	**154**	**8.4%**	**88**	**186**	**7.9%**	**54**	**120**	**9.4%**
	Mid- and	2	2	0.1%	1	2	0.1%	1	2	0.2%
	Metatarsals	73	79	4.3%	51	108	4.6%	22	49	3.8%
	Toe	67	73	4.0%	36	76	3.2%	31	69	5.4%

a) *Two fractures where both the medial and lateral malleoli were involved were found in boys and are reported in the distal tibia category (not distal fibula)*

b) *Ankle fractures include fractures of the medial or lateral malleoli, bimalleolar fractures, and combined ankle fractures, and thus include some of the fractures in the distal fibula and distal tibia categories. All fractures in this category are therefore reported in other categories also and ankle fractures should be excluded when summing up for control purposes.*

General discussion

Fracture ascertainment methods

Fracture ascertainment in Malmö, papers I, III and IV

When looking at epidemiological studies, perhaps the most relevant question is how data are ascertained. In papers I, III and IV, we primarily collected data on fracture cases through the hospital diagnosis register. When we identified a diagnostic code corresponding to a fracture, we reviewed the medical reports, referrals and X-ray reports, and looked at X-rays in cases with ambiguities before we finally registered a fracture in the study database. The method that was used for 2005–2006, differed from the ascertainment system used by Landin and Tiderius when they identified fractures during previous periods in our city (Landin 1983, Tiderius et al. 1999). Data were then collected through the radiology archive and X-ray films were reviewed when the fracture diagnosis was uncertain. This system, together with defining fractures in radiographic reports, is usually considered the gold standard when classifying fractures in fracture epidemiology studies (Berecki-Gisolf et al. 2012).

As our new fracture ascertainment system was different from that in previous historical reports, we undertook a validation. We found that the proportion of fractures that would not be registered was similar for the two ascertainment methods, three out of 103 fractures (3%), for both the old (registrations directly through X-ray verified fractures) (Landin 1983, Tiderius et al. 1999) and the new ascertainment method (registrations through diagnostic register and in questionable cases verified by X-ray examinations).

Neither of the two methods was perfect, however. Both methods would miss fractures if the patient did not seek medical care. We would also miss fractures if the treating physician chose to abstain from X-ray examinations, regardless of whether they set or discarded a fracture diagnosis. Likewise, fractures treated exclusively elsewhere would not be registered. This problem often accompanies single-center epidemiological studies but is probably of minor concern in our studies as the standard practice in Sweden is to refer patients with fractures sustained elsewhere to the home hospital for follow-up visits. Our registration would however miss fractures that were primarily treated out of the city and did not require follow-up. Examples of such fractures are undisplaced fractures of the fingers or toes and torus fractures of the radius. We would also miss fractures treated exclusively in primary care. This is also a minor concern, as it is standard practice for primary care physicians in our region to refer patients with suspected fractures to the radiology department of the city hospital for X-rays. The radiology department then refers patients with a fracture to the hospital emergency department. There are also a few private X-ray units in our city, that may receive referrals from primary care but these also refer virtually all patients with radiologically verified fractures to the city emergency department. A study by Jonsson et al. investigated this issue and reported that that two of a sample of 70 fractures which were primarily diagnosed in the private X-ray clinics could not be found in the hospital archives (Jonsson 1993).

Fracture data in the hospital archives could also suffer from lack of registration or misclassification (regarding both fracture site classification in medical records and X-ray reports but also diagnosis registration). This too has been addressed by Jonsson et al., in a study that included adults where 7% of the fractures that the patients remembered and stated that they had been treated for at the hospital could not be found in the hospital archives (Jonsson 1993). It is unclear whether there was recall bias by the patients or if there was an actual 7% misclassification in the hospital archives. The same report also highlighted that patient memory is not a reliable source of data collection, as the evaluated patients had forgotten 40% of the fractures identified in the archives. The uncertainty when using patient recall in fracture epidemiological studies is further supported by Åkesson et al., who reported that the incidence rate of distal radius fractures in elderly women was underestimated by recall by 30%, (Akesson et al. 1992). We have no evidence that the miscalculation rate was the same or different in the different evaluated periods. Due to the relatively low miscalculation rate, however, it seems less probable that different misclassification proportions during different evaluated periods influenced the time trend analyses in this thesis.

In both our studies and the studies by Landin and Tiderius et al. (Landin 1983, Tiderius et al. 1999) a single investigator made the decision whether a fracture registered in the hospital archive should be included or excluded in the study database. This approach seems more reliable than automatically including the diagnostic codes found in the medical charts that have been registered by multiple physicians with different levels of experience, and knowledge of fracture classification and diagnosis coding.

However, fracture classification by a single investigator may contribute to erroneous data, if the researcher conducts a systematic error. This may also affect time trend evaluations, if different researchers classified fractures differently in the included periods. To minimize this possible source of error, when the author of this thesis (VL) identified a case with uncertain diagnosis he consulted a senior orthopedic surgeon (LL), who was also the author that evaluated ten of the twelve previously evaluated periods (Landin 1983). After the author (VL) evaluated the medical charts, referrals, reports and X-ray reports for the period 2005–2006 (4459 visits), but also X-rays of uncertain cases, he found 58 cases with questionable fracture diagnosis or classification. After having reviewed the uncertain X-rays with a senior orthopedic surgeon (LL), 28 cases had to be removed from the database as not being fractures, two received changed fracture classification, while 28 were left with the same fracture classification.

In studies that span long periods, reported incidences and time trend calculations may also be affected by the introduction of new diagnostic tools. The evaluated periods in papers I, III, IV, span from the beginning of the 1950s to the mid-2000s. During this period, there have been changes in the routines when diagnosing fractures. The increased availability, and use, of new diagnostic tools such as computer tomography (CT) and magnetic resonance imaging (MRI), can be expected to identify fractures that have been missed by conventional X-ray examinations. For this the reason we excluded fractures of the skull, nowadays routinely examined by CT scans (and in addition, often referred to the Department of Neurosurgery in the nearby hospital in Lund for treatment and follow-up evaluations). Another example is fractures of the scaphoid bone. During the years 2005–2006, 23 of the 25 scaphoid fractures included in our study had been evaluated by MRI. However, this was not simply due to the availability of MRI. During the years 2004–2008 a study of scaphoid fractures was conducted in our hospital and the protocol in this study required an MRI investigation of patients with radial wrist pain regardless of the findings of the primary X-ray (Clementson et al. 2017). We also speculate (even if there are to our knowledge no objective data that support this speculation), that patients nowadays, due to changed attitudes in society and greater availability and accessibility of health care, more often seek care for minor fractures. These fractures in the past may have been neglected and untreated. Another possible bias is that doctors nowadays, due to higher demands of the patients and demands of insurance companies to objectively verify fractures, are more prone to refer patients to X-ray evaluations to verify a specific diagnosis, even if a diagnosis does not change the treatment algorithm. Such an approach would probably also identify more fractures.

Another concern is that the diagnostic codes we used for identification of fractures in papers I–IV did not include the ICD-10 codes for fractures at birth (P13.1 to P13.9) and that we did not include the neonatal department in the database search. That physicians in the neonatal department classified birth fractures with these diagnostic codes was something we did not realize when we started the study. Pediatric orthopedic surgeons routinely classify birth fractures using the ICD-10 fracture codes (included in our study). Fractures acquired at birth in 2005–2006 would therefore be missed, unless the fracture also was also registered with a diagnostic code in our orthopedic diagnosis database or if the newborn was referred to the department of orthopedics for follow-up evaluations. Nevertheless, all these fractures would be identified in the historic reports that directly used X-rays to conduct fracture identification (Landin 1983, Tiderius et al. 1999). In the database, when including all previous evaluated periods, we found 45 fractures which were acquired at birth, 40 fractures of the clavicle, four fractures of the humerus diaphysis and one diaphyseal fracture of the forearm (Landin 1983, Tiderius et al. 1999). These fractures represented a great proportion of fractures in children under the age of one year, ranging from all fractures in 1960/1965 (five out of five fractures) to more than half of fractures in 1993–1994 (13 of 32 fractures). All of the 13 fractures at birth during the years 1993–1994 were sustained in 1994 and all were fractures of the clavicle. This uneven distribution indicates that even previously there may have been registration problems with birth fractures. In 2005–2006, we found 24 fractures in children younger than one year of age, five of which were classified as fractures acquired at birth. All these were fractures of the humerus shaft, captured by our ascertainment system at the follow-up evaluation at the department of orthopedics. If we estimate fractures at birth as a ratio of all fractures in children by using the same ratio as 1993–1994, this would translate to eight missed fractures in our survey from 2005–2006. In the literature the incidence of perinatal clavicle fractures is estimated to be 0.5–1.6% (Beall et al. 2001, Hsu et al. 2002, Lam et al. 2002) and of perinatal long bone fractures to be 0.028 to 0.054% (Nadas et al. 1993). If we apply the lower estimates to the number of 7477 newborn children in Malmö during 2005–2006 (Statistics Sweden 2007a), we can estimate an expected number of 37 clavicular fractures and two long bone fractures during the years 2005–2006 (this compared to no clavicular fractures and five long bone fractures in our database). We must further highlight the difficulty of conducting epidemiological studies in newborn, since many fractures, especially in the clavicle, are only clinically diagnosed and not verified by X-rays. Unfortunately, we lack approval from the regional ethical review board to broaden our search and include the neonatal department and the codes stated above. The fracture epidemiology in our studies (as well as in other studies) in children below age one should therefore be interpreted with the greatest caution.

Fracture ascertainment in the Skåne Health Care Register (SHR)

In paper II, we utilized register data from the Skåne health care register (SHR). This register includes data from all in- and outpatient visits in the healthcare system in the southernmost part of Sweden including the diagnostic codes (ICD-10). We included data first from 1999 but we also collected data from 1998 in order to determine the washout for 1999. We searched for visits of patients aged <17 years with the diagnostic codes S52.50, S52.51, S52.60 and s52.61. The lack of a diagnostic code will lead to no data being included. Registration of an incorrect diagnostic code at the time of visit could lead to the inclusion of cases that did not have a distal forearm fracture, or the exclusion of cases with a distal forearm fracture.

Register coverage and completeness usually improves in the first years after a register is started. Figure 6 below shows how the coverage has improved in the SHR.

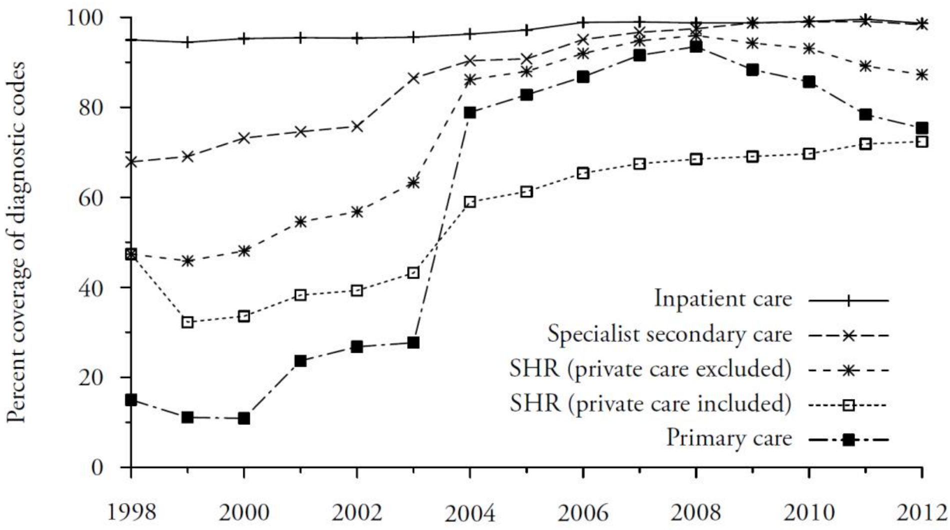


Figure 6. Coverage in the SHR 1998-2014 as a proportion of physician visits with a diagnostic code in relation to all physician visits reported to the SHR. Data from visits in private care are reported to the SHR but does not include the diagnostic codes. Published with permission from the author (Jöud 2013).

Coverage for all diagnostic codes during inpatient care was already high in 1998 and coverage for secondary specialist care (including orthopedics) improved gradually, reaching above 90% in 2004. One could then argue that this improvement could affect the calculation of time trends. Patients with fractures, however, are most often primarily treated at the hospital emergency units (sometimes even in inpatient care), and are usually followed by multiple visits to the department of orthopedics thereafter. If the treating pediatric orthopedic surgeon set an adequate diagnostic code in any one of these instances, the fracture would be captured. We speculate that coverage of fractures diagnosis in children may be even higher than with other diagnoses, as most of these children are treated within specialist secondary care and in most cases (except maybe in the neonatal period) are diagnosed by X-ray examination. With this background, few alternative diagnoses are available. The SHR has also been validated against medical reports for acute radial fractures. This validation found a sensitivity of 90% and positive predictive value of 94% (Rosengren et al. 2015).

Discussion of results

General pediatric fracture incidence

For epidemiological studies of fractures in children, it is essential to compare new results with other published studies to be able to achieve an overview of the field and to estimate changes in incidence over time (in absolute values), differences between regions, countries and ethnic subgroups and differences between different types of fractures. The following table presents the overall pediatric fracture incidences in different studies (Table 4).

Table 4. Various studies of pediatric fracture epidemiology, where fracture identification through the review of X-rays and charts is considered the gold standard. Hedström et al. primarily collected register data for 1993–2007 but reviewed X-rays for all fractures during 2006–2007. (Landin 1983, Kopjar et al. 1998, Tiderius et al. 1999, Lyons et al. 2000, Moustaki et al. 2001, Brudvik et al. 2003, Cooper et al. 2004, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010, Naranje et al. 2016, Lempesis et al. 2017).

First	Included	Age	County	Study design	Data source	Incidence per
Cooper	1988–1998	0–17	United	Multi Center	Register	1330
Lyons	1996	0–14	Wales	Multi Center	Register	3610
Lyons	1996	0–14	Sweden	Multi Center	Register	1537
Lyons	1996	0–14	Norway	Multi Center	Register	1718
Lyons	1996	0–14	Finland	Multi Center	Register	1775
Moustaki	1996–1998	0–14	Greece	Multi Center	Register	1200
Naranje	2010	0–19	USA	Multi Center	Register	1800
Mäyränpää	2005	0–15	Finland	Single Center	Gold Standard	1630
Brudvik	1998	0–15	Norway	Single Center	Gold Standard	2450
Rennie	2000	0–15	Scotland	Two Centers	Gold Standard	2020
Kopjar	1992–1995	0–12	Norway	Single Center	Gold Standard	1280
Hedström	1993–2007	0–19	Sweden	Single Center	Combined	2010
Landin	1950–1979	0–16	Sweden	Single Center	Gold Standard	2120
Tiderius	1993–1994	0–16	Sweden	Single Center	Gold Standard	1930
Paper I	2005–2006	0–15	Sweden	Single Center	Gold Standard	1832

Why do the pediatric fracture incidences differ?

As seen in table 4 above, the incidence in paper I is different from the incidences reported from other regions, also within Sweden (Lyons et al. 2000, Hedstrom et al. 2010). The reasons could of course be that there are actual differences in fracture incidence. For example, in the Jämtland region of Sweden and south Finland snowy and icy conditions are more prevalent (Lyons et al. 2000, Hedstrom et al. 2010) than in the Malmö region (our catchment area), which probably influences fracture incidence (Worldweatheronline 2018a , Worldweatheronline, 2018b, Worldweatheronline 2018c). In addition, different ascertainment methods may result in different fractures incidences (Lyons et al. 1999). Small differences in the evaluated age strata, as can be seen in Table 4, may result in populations at risk with different fracture incidence rates, another possible explanation for at least some of the differences in fracture incidences seen in Table 4. Even if the same age strata are included, we cannot rule out differences in age distribution. Differences in fracture incidence within a country have previously been reported in the UK, where fracture incidences varied with a factor up to 1.7 (Cooper et al. 2004). Another study found twice as high pediatric fracture incidence in Wales compared to Scandinavian regions (Lyons et al. 2000).

Ethnicity is another factor that may influence pediatric fracture incidence. For example, a UK study reported more than twice as high fracture incidence in white children as in black children (Moon et al. 2016). This could explain some fracture incidence differences within Sweden. According to Statistics Sweden (SCB), in 2005–2006, 38% of children aged 0–15 year in the city of Malmö, Sweden, were of foreign background (defined by the SCB as children born abroad or with both parents born abroad) (Statistics Sweden 2005a). However, in the city of Umeå, the catchment area of Hedström et al. (Hedstrom et al. 2010), only 9% of children were of foreign background (Statistics Sweden 2005a). But even more intriguingly, there are also differences in the origin of the persons of foreign background. In Malmö, the most common foreign origin was the Balkan countries while in Umeå it was Scandinavia and mostly Finland (Statistics Sweden 2005b). These differences in ethnicity may also influence fracture risk, but we unfortunately have no patient-level data on ethnicity and are unable to take account of this in our examinations.

Fracture incidence in Malmö 2005–2006

In paper I, fractures were more commonly found in boys than in girls (fracture rate ratio 1.8). This gender rate ratio is slightly higher than reported in literature, where the boys-to-girls ratio has most commonly been reported between 1.5 and 1.6 (Landin 1983, Lyons et al. 1999, Tiderius et al. 1999, Cooper et al. 2004, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010). A Norwegian study, however, reported a rate ratio as low ratio as 1.2 (Kopjar et al. 1998), and a Greek study a rate ratio as high ratio as 1.9 (Moustaki et al. 2001).

We also found different peak fracture incidence in boys and girls. The fracture incidence was higher in the higher ages in both boys and girls from birth until girls reached a peak at about age 12 and in boys about age 14. Boys also had a statistically significant higher incidence than girls at the age of eight and at ages 11–15. These data too are supported by previous publications, which infer that there is a higher age-specific incidence in boys than in girls and that girls reach a peak incidence at a younger age than boys (Landin 1983, Tiderius et al. 1999, Cooper et al. 2004, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010, Moon et al. 2016). One explanation that has been put forward is that the pubertal growth spurt in height precedes the peak in mineralization (Wang et al. 2008), thus resulting in a temporarily weaker skeleton with lower bone mineral density (BMD) (Bailey et al. 1989, Faulkner et al. 2006, Krabbe et al. 1979). However, puberty also results in changes in lifestyle, including changes in the level of physical activity and risk-taking behavior that may affect fracture incidence. An example of this is the increased participation in organized sports, which reaches a lifetime peak in the ages 10–14 years (Eime et al. 2016), and thus also more exposure to trauma.

Distribution of fracture types in Malmö 2005–2006

The most common fracture type in Malmö children in 2005–2006 was the distal forearm fracture (31% of all fractures in children; 30% of all in boys and 31% of all in girls). That the distal forearm fracture is the most common fracture in children is supported in the literature which reports 26–43% of all pediatric fractures to occur in this anatomic region (Landin 1983, Tiderius et al. 1999, Moustaki et al. 2001, Brudvik et al. 2003, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010). The following table lists the most common types of fractures in different studies (Table 5) (Landin 1983, Tiderius et al. 1999, Moustaki et al. 2001, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010, Lempesis et al. 2017).

Table 5. Distribution of the most common type of fractures in children. Data are presented as proportions (%) of all fractures, with order of commonness for each type of fracture within each study presented in parentheses.

First Author	Included years	Age strata	Distal forearm	Fingers	Metacarpals	Clavicle
Moustaki	1996–1998	0–14	43% (1)	13.9% (2)	4.8% (4)	N/A
Mäyränpää	2005	0–15	30.4% (1)	16.3% (2)	7.4% (4)	6.4% (3)
Rennie	2000	0–15	33% (1)	15% (2)	7.4% (3)	7% (4)
Hedström	2006–2007	0–19	26% (1)	10% (3)	11% (2)	5% (4)
Landin	1975–1979	0–16	21% (1)	19% (2)	8.3% (3)	8.1%(4)
Tiderius	1993–1994	0–16	26% (1)	16% (2)	8.8% (3)	8% (4)
Our study	2005–2006	0–15	30.8 (1)	14.7% (2)	9.8% (3)	6.7% (4)

In 2005–2006 we found that, as in previous reports from our region (Landin 1983, Tiderius et al. 1999), a distal radius fracture was the most common type of fracture, followed by finger, metacarpal and fractures of the clavicle. Differences in fracture distribution between studies in Table 5 could be the result of actual differences based on for example, different lifestyle. Different sports activities may be popular in different regions and different regions within the same country, and different regions are exposed to different climates. As already discussed, there are several possible explanations for differences in fracture epidemiology data (see section "*Why do the pediatric fracture incidences differ?").*

Pediatric fracture etiology in Malmö 2005–2006

Information regarding the fracture-related activity in 2005–2006 was not provided in 29.5% of the cases. When we evaluated fracture etiology in children with available information, we found that most fractures had occurred during sports (27.7%), playing (19%), traffic (9%) and in school (6.6%). The most common trauma mechanism was falls in the same plane (42%), falls between planes (26%), animate mechanical forces (24%) and not possible to classify (8%). An example of animate mechanical forces is collision with a moving object or living organism.

It could be argued that the classification system we used is not the best. However, we chose the system to be able to compare the new data with the previous data from the same region published by Landin and Tiderius (Landin 1983, Tiderius et al. 1999). More modern classification systems in children classify fractures according to the geographical location and where the fracture occurred (home, school, traffic, playground), precipitating activity (playing, sports, traffic, school activities) or trauma mechanism (falls, hit by a moving object, hit by human, crush injury).

Results can also be presented as numbers of fractures, as proportion (%) of all fractures, as proportion (%) of all fractures with known etiology and/or as fracture incidence within each etiological category. One drawback in our studies is that the proportion of fractures with unknown etiology is different between the evaluated periods. The uncertainty this creates is the reason why we chose to present results as proportions among the known etiology, and why we refrained from conducting statistical calculations regarding changes in fracture etiologies over time. Therefore, all conclusions, interpretation and speculation with regard to fracture etiologies and especially changes in fracture etiologies must be put forward with great care.

Other studies have also evaluated fracture etiology in children (Lyons et al. 2000, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010). However, due to the differences in classification systems and the way results are presented, it is difficult to conduct direct comparisons. A pediatric fracture epidemiology study from Umeå, Sweden (Hedstrom et al. 2010) reported that the most common fracture-related activities were participating in sports (37%) and playing (26%). Sports and playing were also the most common fracture related activities in our study, but each represented a lower proportion than in the study by Hedström et al. (Hedstrom et al. 2010). The reasons for this difference in proportion are unknown. We speculate that differences could be due to a difference in the proportion of children that participate in sports and playing activities in the two regions. Also differences in climate, hours with daylight and tradition all possibly lead children to participate in different activities with different duration and different intensity.

Distal forearm fracture incidence

In the following table, pediatric distal forearm fracture incidence data from different studies are presented (Table 6).

Table 6. Various studies of pediatric distal forearm fracture epidemiology, where fracture identification through the review of X-rays and medical charts is considered the gold standard. Hedström et al. collected primarily register data for 1993–2007 but reviewed X-rays for all fractures for 2006–2007. (Landin 1983, Tiderius et al. 1999, Moustaki et al. 2001, Brudvik et al. 2003, Khosla et al. 2003, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010, Randsborg et al. 2013, Jerrhag et al. 2016, Lempesis et al. 2017)

First Author	Included years	Age strata	Country	Study design	Data source	Incidence per 10^5 person years
Khosla	1969–1971	0–19	USA	Single Center	Gold Standard	394
Khosla	1979–1981	0–19	USA	Single Center	Gold Standard	449
Khosla	1989–1991	0–19	USA	Single Center	Gold Standard	611
Khosla	1999–2001	0–19	USA	Single Center	Gold Standard	571
Moustaki	1996–1998	0–14	Greece	Multi Center	Register	516
Rennie	2000	0–15	Scotland	Two Centers	Gold Standard	664
Mäyränpää	2005	0–15	Finland	Single Center	Gold Standard	496
Brudvik	1998	0–15	Norway	Single Center	Gold Standard	662
Randsborg	2010*	0–16	Norway	Single Center	Gold Standard	560
Wilcke	2004–2010	0–16	Stockholm, Sweden	Multi Center	Register	535
Hedström	2006–2007	0–19	Umeå, Sweden	Single Center	Gold Standard	591
Landin	1975–1979	0–16	Malmö, Sweden	Single Center	Gold Standard	481
Tiderius	1993–1994	0–16	Malmö, Sweden	Single Center	Gold Standard	432
Paper II	1999–2010	0–16	Skåne, Sweden	Multi Center	Register	634
Paper III	2005–2006	0–15	Malmö, Sweden	Single Center	Gold Standard	564

As the table above shows, the highest absolute pediatric distal forearm fracture incidences have been reported in the Skåne Region 1999–2010 (paper II) (Jerrhag et al. 2016), then in Umeå, Sweden 2006–2007 (Hedstrom et al. 2010), followed by Malmö, Sweden 2005–2006 (paper III) and lowest in Helsinki, Finland, 2005 (Mayranpaa et al. 2010) and Stockholm, Sweden, 2004–2010 (Wilcke et al. 2013). Possible explanations for differences in overall epidemiology between studies have already been discussed (see the section "*Why do the pediatric fracture incidences differ?*). The same discussion could be applied to pediatric distal forearm fractures. However, there may also be a specific problem when comparing pediatric distal forearm epidemiology, as discussed below.

Classifications of distal and diaphyseal forearm fractures

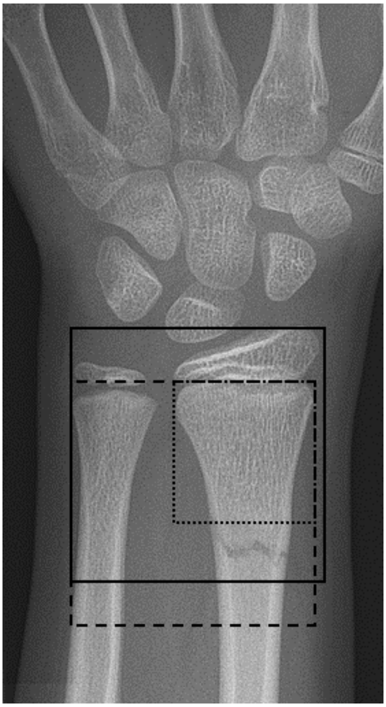
There are obvious differences in pediatric distal forearm fracture incidences between studies. One reason could be how distal forearm fractures are classified. However, most of the studies in Table 4 do not provide information about this. Some of the register-based studies report all forearm fractures (proximal, diaphyseal and distal) as one category (Lyons et al. 2000, Cooper et al. 2004). In addition, studies that collect data through X-rays and medical charts are affected by classification problems. For example, the study by Hedström et al. from Umeå (in northern Sweden) collected data from the hospital diagnosis register (Hedstrom et al. 2010). When they validated their fracture site classification in the register against X-ray examinations, they found that 19% of pediatric distal forearm fracture cases were classified incorrectly in relation to the AO pediatric fracture classification (Slongo et al. 2006).

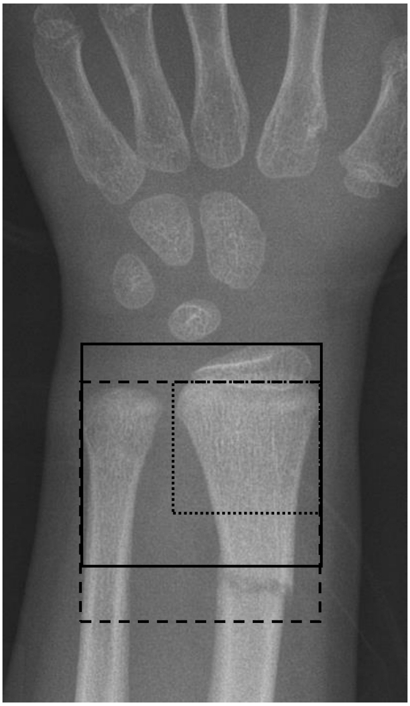
Different classification systems have different distinctions between diaphyseal and distal forearm fractures. In papers I, III and IV, we defined the limit between the metaphysis and diaphysis as the point where the cortex attained a stable thickness, the same classification as was used in the Landin and Tiderius studies (Landin 1983, Tiderius et al. 1999). However, Alffram et al. from our department, in a study that included both children and adults, defined the limit between the metaphysis and the diaphysis to lie exactly three centimeters from the radiocarpal joint (Alffram et al. 1962). It seems problematic, however, to apply the classification used by Alffram et al. to the growing pediatric skeleton as it sets the limit between the diaphysis and metaphysis at the same distance from the wrist joint for both very small and nearly fully-grown children. Furthermore, the Müller classification of long bone fractures that was introduced in 1987 by the AO foundation (Arbeitsgemeinschaft für Osteosynthesefragen) promoted the "rule of the square" when separating metaphyseal and diaphyseal regions: "*The proximal* *and distal segments of long bones are defined by a square whose sides are the same length as the widest part of the epiphysis*" (Müller et al. 1987, Müller et al. 1990). When this rule is applied to the distal forearm, the distal end of the square is drawn through the radiocarpal joint and the width of the square is defined by the width of both the ulna and radius. The "rule of the square" was modernized in 2004 for classification of pediatric long-bone fractures (Audigé et al. 2004), and the method was later validated with good results (Slongo et al. 2006). In this updated version, the distal end of the square is drawn through the physis of the bone, while the width is still decided by both bones. This results in a more proximal limit between distal forearm fractures and diaphyseal fractures than in the Müller version. Another classification, initially described in 2000 by von Laer (von Laer et al. 2000), later validated by Schneidmuller (Schneidmuller et al. 2011,) is the LiLa (Licht und Lachen für kranke Kinder – Effizienz in der Medizin) classification. In this classification, the square is drawn through the physis, while the width is decided only by the width of the radius. This results in a more distal limit between distal forearm fractures and diaphyseal fractures than in the Müller and AO classifications. The AO pediatric classification will therefore define the most proximal line between the diaphyseal and the distal forearm region, Müller classification the intermediate line and the LiLa classification the most distal line. In Figure 7, we illustrate where the limit between diaphyseal and distal forearm fractures is defined with the different classification systems in two children with different ages and different fractures in the forearm.

Figure 7. Comparison of different classification systems when distinguishing between distal and diaphyseal fractures of the distal forearm. On the left is a fracture of the radius in a 9-year-old boy after a fall from a swing. The fracture is classified as distal forearm fracture according to Müller (solid square) and the AO classification of pediatric fractures (dashed square) but as diaphyseal fracture according to LiLa classification (dotted square).

On the right is a fracture of the radius in a 5-year-old boy after a fall from a height of 1.5 meters. The fracture is classified as a distal forearm fracture according to the AO classification of pediatric fractures (dashed square) but as diaphyseal according to Müller (solid square) and LiLa classification (dotted square).

Both these fractures were classified as diaphyseal in our study.





Distal forearm fracture epidemiology in Skåne 1999–2010 and in Malmö 2005–2006

In Paper II, we collected register data (SHR) and included children in Skåne (0–16 years) with a fracture diagnosis during 1999–2010. In paper III, we collected data through medical charts and X-rays and included Malmö children (0–15 years) with a fracture during 2005–2006. Paper II included 17,686 fractures sustained in both rural and urban populations, while paper III focuses on 521 fractures sustained in an urban population (Malmö). As shown previously, we found different fracture incidence rates (see *table 6 pediatric distal forearm fracture incidences*). In order to investigate whether the different included years and age strata affected the results, we recalculated the incidence of distal forearm fractures in Skåne, and only including the period 2005–2006 and only children aged 0–15 (in harmony with paper III). We finally age-adjusted the Malmö results against the Skåne population by direct standardization (Table 7).

Table 7. Distal forearm fractures rates per 10^5 person years in 1) Skåne 1999–2010 in children aged 0–16, 2) Skåne 1999–2010 in children aged 0–15, 3) Skåne 2005–2006 in children aged 0–15, 4) Malmö 2005–2006 in children aged 0–15 and 5) Malmö 2005–2006 in children aged 0–15 age- and gender-adjusted to the Skåne population.

	Paper	Region	Included years	Age strata	All children	Boys	Girls
1	II	Skåne	1999–2010	0–16	634	750	512
2	II	Skåne	1999–2010	0–15	648	758	531
3	II	Skåne	2005–2006	0–15	659	771	541
4	III unadjusted	Malmö	2005–2006	0–15	564	719	401
5	III adjusted	Malmö	2005–2006	0–15	593	759	417

The distal forearm fracture rate in children in Skåne for the age span 0–15 and during the years 2005–2006 (Table 7) was higher than in Malmö children during the same period (rate ratio (RR) 1.17; 95% CI 1.06, 1.28) (Table 8). After age- and gender-adjustment of the distal forearm fracture rate in children, boys and girls in Malmö to the corresponding Skåne population, the rate in Skåne children was still higher (RR 1.11; 95% CI 1.05, 1.17).

Table 8. Comparisons of the distal forearm fracture rate in Skåne in 2005–2006 (0–15 years) in relation to the crude distal forearm fracture rate in Malmö and in relation to the age- and gender-adjusted distal forearm fracture rate in Malmö. Results are provided as rate ratios (RR) with 95% CI). Statistically significantly higher ratios are noted with asterisks.

	Rate ratios		
Paper	All children	Boys	Girls
Paper II 2005–2006 (0–15) vs Paper III unadjusted	1.17 (1.06, 1.28)*	1.07 (0.95, 1.20)	1.35 (1.15, 1.58)*
Paper II 2005–2006 (0–15) vs Paper III age-adjusted	1.11 (1.05, 1.17)*	1.02 (0.95, 1.09)	1.30 (1.19,1.42)*

We thus found no significant differences in the distal forearm fracture incidence between Malmö and Skåne boys, with or without age adjustment. In contrast, the fracture incidence in Skåne girls was 30% higher than in Malmö girls, also after age adjustments (Table 8). We speculate that this difference could be based on different ethnic compositions in the two populations at risk. In 2005–2006, 42% of the Malmö pediatric population was of foreign background compared to only 20% in the Skåne population (Statistics Sweden 2007b, Statistics Sweden 2007c). Furthermore, 10% of the pediatric population in Malmö in 2005–2006 was born abroad compared to only 6% in the Skåne population (Statistics Sweden 2007b, Statistics Sweden 2007c). There are indications of lower participation in organized sports in girls of foreign descent compared to girls of Swedish descent. A study by the Swedish Sports Association (Riksidrottsförbundet) found that 54% of 13–20-year-old boys of Swedish background (born in Sweden with at least one Swedish parent) and 52% of boys in the same ages but with foreign background participate in sports (The Swedish Sports Confederation 2010). In contrast, 47% of girls with Swedish background but only 31% in girls with foreign background do the same (The Swedish Sports Confederation 2010). Furthermore, in children that were born abroad, participation in sports varied depending on the country of origin. Only 27% of girls born in countries outside of Europe participate in organized sports, compared to 50% of girls born in Sweden (50%), while 59% of boys born in countries outside of Europe participate in organized sports, compared to 55% of boys born in Sweden (The Swedish Sports Confederation 2002). This could explain some of the gender differences in Skåne and Malmö children since vigorous physical activity is a risk factor for fractures (Clark et al. 2008).

The age-specific incidence in boys and girls was higher in the older ages and in the Skåne population reached the peak for boys at ages 13–14 years (paper II) and in Malmö at ages 12–13 (paper III). Skåne girls reached their peak fracture rate at ages 11–12 years (paper II) and the Malmö girls at ages 10–11 years (paper III). Results in papers II and III thus follow the same pattern, even though there seems to be a more pronounced peak in Malmö boys (paper III) than in Skåne boys (paper II) and in Skåne girls (paper II) than in Malmö girls (paper III). The differences could be real, or be based on the different included age strata, different age distribution within the age strata, different ethnic composition within the population at risk and different evaluated years (see discussion in the section *"Why do the pediatric fracture incidences differ?"*).

Pediatric distal forearm fracture etiology in Malmö 2005–2006

Information regarding the fracture-related activity for distal forearm fractures in 2005–2006 was not available in 25% of the cases. When we evaluated fracture etiology in children with available information, we found that most fractures occurred during sports (41%), playing (32%), traffic activities (11%) and school activities (11%). Further discussion of limitations of the etiology data can be found in the section *"Pediatric fracture etiology in Malmö 2005–2006".* A similar discussion could be applied to the distal forearm fracture etiology data.

In New Zealand, sports injuries in boys accounted for 37% of distal forearm fractures and in girls 27%, while playground accidents were responsible for 19% of distal forearm fractures in boys and 28% in girls (Jones et al. 2000). We found (paper III) that sports injury was the reason for 45% of the fractures in boys and 33% in girls and playground injuries for 8% of the fractures in boys and 24% in girls. As the New Zealand study reported considerably higher incidences compared to our study and found similar incidence in boys and girls (Jones et al. 2000), we speculate that there are differences in lifestyle that may partly explain the difference.

A high proportion of sports injuries as fracture etiology for distal forearm fractures in individuals aged 5–19 has also been reported from the Netherlands. During the years 2006–2007, sports injuries in the age groups 10–14 years explained in boys 67% and in girls 53% of the distal forearm fractures. The corresponding proportion in ages 15–19 was 60% in boys and 46% in girls (de Putter et al. 2011). The high proportion of sports injuries in the study by de Putter et al. may be partly due to the fact that they specifically evaluated older children and that they only used six variables to describe etiology (home, sports, traffic, occupational, violence and self-mutilation). The study by de Putter et al. (de Putter et al. 2011) also found that home accidents were the most common etiology in the 5–9 age group (61% in boys and 64% in girls), a notion supported by a study from Washington, USA, that included children aged 0–17 during the years 2003–2006 (Ryan et al. 2010). Ryan et al. found that the most common fracture etiology in the age group 0–4 years was playing accidents (26%), in the age group 5–9 years falls from monkey bars (32.7%), while in age groups 10–14 and 15–17 years sports accidents were the most common fracture etiology (Ryan et al. 2010). In a comprehensive distal forearm fracture study from Olmstead County, Minnesota, USA (Khosla et al. 2003), Khosla et al. examined trauma severity and fractures due to recreational activities in subjects aged 0–34. Their results are thus difficult to compare with ours. Finally, possible reasons for different etiology data in different studies have also been further discussed in the section *"Pediatric fracture etiology in Malmö 2005–2006*".

Hand fractures in Malmö 2005–2006

In paper IV, we aimed to provide detailed information about the anatomical distribution of hand fractures in Malmö, Sweden, during the years 2005–2006, but we also aimed to make comparisons with previous data from Malmö. To provide detailed data for the anatomical distribution of hand fractures, we registered each specific fracture in detail, counting fractures affecting multiple phalanges and metacarpals separately. However, when we evaluated differences in incidence between periods, we aggregated the data, so that fractures were registered in accordance with the same registration protocol as in the studies by Landin and Tiderius (that is, multiple phalangeal or metacarpal fractures in the same hand were counted as one fracture, as were combinations of fractures of carpal-metacarpal bones in the same hand) (Landin 1983, Tiderius et al. 1999). During 2005–2006 we found 437 fractures in 402 children and by using the protocol by Landin and Tiderius (Landin 1983, Tiderius et al. 1999), 414 fractures in the 402 children. In the following table we present the pediatric hand fracture incidence reported by different studies as well as from paper IV (estimated in accordance to the classification system used by Landin and Tiderius) (Table 9) (Landin 1983, Lyons et al. 1999, Tiderius et al. 1999, Lyons et al. 2000, Moustaki et al. 2001, Brudvik et al. 2003, Vadivelu et al. 2006, Rennie et al. 2007, Hedstrom et al. 2010, Mayranpaa et al. 2010, Naranje et al. 2016, Lempesis et al. 2017).

Table 9. Various studies of pediatric hand fracture epidemiology, where fracture identification through the review of X-rays and medical charts is considered the gold standard. Hedström et al. collected primarily register data for 1993–2007 but reviewed X-rays for all fractures for 2006–2007.

First Author	Included years	Age strata	Country	Study design	Data source	Incidence per 10^5 person years
Lyons	1996	0–14	Wales	Multi Center	Register	961
Lyons	1996	0–14	Norway	Multi Center	Register	695
Lyons	1996	0–14	Finland	Multi Center	Register	383
Lyons	1996	0–14	Jämtland, Sweden	Multi Center	Register	307
Moustaki	1996–1998	0–14	Greece	Multi Center	Register	224
Naranje	2010	0–19	USA	Multi Center	Register	660
Mäyränpää	2005	0–15	Finland	Single Center	Gold Standard	344
Brudvik	1998	0–15	Norway	Single Center	Gold Standard	465
Rennie	2000	0–15	Scotland	Two Centers	Gold Standard	484
Vadivelu	2000	0–16	UK	Single Center	Gold Standard	418
Hedström	2006–2007	0–19	Umeå, Sweden	Single Center	Gold Standard	389
Landin	1975–1979	0–16	Malmö, Sweden	Single Center	Gold Standard	576
Tiderius	1993–1994	0–16	Malmö, Sweden	Single Center	Gold Standard	432
Paper IV	2005–2006	0–15	Malmö, Sweden	Single Center	Gold Standard	448

The results from Malmö in 2005–2006 (Paper IV) are in accordance with studies from Scotland (Rennie et al. 2007), Derby, UK (Vadivelu et al. 2006), and Norway (Brudvik et al. 2003), while the incidence in Wales (Lyons et al. 2000) was twice as high and the incidence in Greece was only half as high in paper IV (Moustaki et al. 2001) (Table 9). It should also be noted that the hand fracture incidence in Umeå, Sweden, in 2006–2007 was about 20% lower than the hand fracture incidence in Malmö, while the overall fracture incidence was almost 25% higher than the overall Malmö incidence (Hedstrom et al. 2010). We have no explanation for this discrepancy. For further discussions why pediatric fracture incidences may differ between studies, see this discussion in the section "*Pediatric fracture incidence in Malmö 2005–2006").*

The highest age-specific hand fracture incidence in absolute numbers occurred in boys at the age of 12–13 and in girls at the age of 14–15. Most other studies which report that peak hand fracture incidence occurs after the age of ten (Worlock et al. 1986, Mahabir et al. 2001, Feehan et al. 2006, Vadivelu et al. 2006, Chew et al. 2012, Young et al. 2013 , Liu et al. 2014, Weum et al. 2016). Studies presenting results in one-year age strata report a later peak in boys, at ages 14 or 15 years (Vadivelu et al. 2006, Chew et al. 2012, Young et al. 2013) and an earlier peak in girls, at ages 11 to 12 years (Worlock et al. 1986, Vadivelu et al. 2006, Chew et al. 2012, Young et al. 2013). Also most studies report that the peak in hand fracture incidence for girls occurs at an earlier age than boys (Worlock et al. 1986, Feehan et al. 2006, Vadivelu et al. 2006, Young et al. 2013), in contrast to most other types of fractures.

Boys had a 2.5 higher age-adjusted hand fracture incidence than girls, 70% higher age-adjusted incidence of phalangeal fractures and 8 times higher age-adjusted incidence of metacarpal fractures. The higher hand fracture incidence in boys is supported in literature, where the boy-to-girl rate ratio is usually reported to be between 1.5 to 3.1 (Worlock et al. 1986, Vadivelu et al. 2006, Rennie et al. 2007, Chew et al. 2012, Young et al. 2013, Liu et al. 2014). The higher boy-to-girl ratio in metacarpal fractures is also supported by a Scottish study that reported a rate ratio of 5.6 for metacarpal fractures and 1.9 for phalangeal fractures (Rennie et al. 2007).

In Table 10, we report side preponderance for hand fractures. Unfortunately, we could not report the dominant to non-dominant preponderance, since these data were not available. As presented in table 10, we however found a right-to-left side predominance for any fracture and metacarpal fractures. In the literature, there are studies that support a dominant side preponderance for hand fractures, in both children and adults (Rosberg et al. 2004, Stanton et al. 2007, Jeon et al. 2016), while another study could not find a significant side preponderance (Young et al. 2013).

Table 10. The table shows the right-to-left incidence rate for any hand fracture, phalangeal or metacarpal fracture in all children and in boys and girls separately. Results are presented as rate rations with 95% confidence intervals. Statistically significant fracture rate ratios are marked with asterisks.

	All children	Boys	Girls
All hand fractures	1.2(0.99 to 1.5)	1.4(1.1 to 1.8)*	0.8(0.6 to 1.2)
Phalanges	1.0(0.8 to 1.3)	1.1(0.8 to 1.5)	0.8(0.5 to 1.2)
Metacarpal/carpal bones	2.1(1.5 to 3.1)*	2.3(1.6 to 3.4)*	1.3(0.4 to 4.1)

Pediatric hand fracture etiology in Malmö 2005–2006

Information regarding the fracture-related activity for hand fractures in 2005–2006 was not available in 30% of the cases When we evaluated hand fracture etiologies in children with available information, we found that most fractures has occurred during sports (42%), fights (20%), traffic activities (13%) and activities at school (10%). Further discussion as regard weaknesses and problems with our etiology data is found in the section *"Pediatric fracture etiology in Malmö 2005–2006".* A similar discussion could be applied to our pediatric hand fracture etiology data.

Our findings support the current literature, inferring that sports are the most common hand fracture etiology and fights the second (or in some the third) (Worlock et al. 1986, Mahabir et al. 2001, Chew et al. 2012, Young et al. 2013, Liu et al. 2014). Fights seem also to be a more common etiology in boys (20%) than in girls (7%). This was even more striking for metacarpal fractures, where fights in boys explained 45% of the fractures but only 18% in girls. These figures may however be influenced by cultural differences. One interesting pediatric hand fracture study from Saudi Arabia highlights this. They found that at younger age only a few more fractures occur in boys than in girls, and that most fractures, in both genders, occurred at home. In contrast, in the higher age, more fractures occurred in boys than in girls, where in boys the hand fractures occurred equally often at home and outdoors, while in girls they occurred nearly all at home. The authors speculated that this difference could be the result of girls in Arab and Muslim cultures in older ages spending more time at home than boys (Al-Jasser et al. 2015).

Time trends in fracture epidemiology

The highest overall fracture incidence in absolute numbers occurred in 1976–1979 and the lowest in 1950/1955. Compared to 1950/1955, in 2005–2006 we found a 33% higher age- and gender-adjusted incidence but no significant time differences in age- and gender-adjusted fracture incidence compared to 1976–1979. We also found that the previously reported reduction of overall fracture incidence from 1976–1979 to 1993–1994 (Tiderius et al. 1999) was related to demographic changes, as no significant time differences remained after adjustment for age and gender distribution in the population,.

There are conflicting data in the literature as regards recent time trends in pediatric fracture incidence. Mayranpaa et al. reported a 18.5% lower fracture incidence in Finland in 2005 compared to 1983 (Mayranpaa et al. 2010), a register-based UK study found stable rates between 1988 and 1998 (Cooper et al. 2004), while a study from northern Sweden reported an increased incidence between 1993 and 2007 of 13% (Hedstrom et al. 2010). One possible explanation for the lower incidence in 2005–2006 compared to 1975–1979 in our region could be, as discussed earlier, a higher proportion of children with foreign background in the later period (Statistics Sweden 1993, Statistics Sweden 2005). Other factors that may affect the pediatric fracture incidence are the gradually improved maternal health during pregnancy and the improvements in pre- and postnatal healthcare, reflected in reduced birth mortality (The National Board of Health and Welfare 2006a). Newborns in our region nowadays have a higher birth weight than previously (The National Board of Health and Welfare 2006a), and a high birth weight is associated with high bone mineral density (BMD) (Gale et al. 2001). Structured prevention of traffic accidents, reflected in a reduction of pediatric motor vehicle accident deaths (The National Board of Health and Welfare 2006b), as well as structured home safety programs (se previous discussion) may also have reduced the pediatric fracture incidence. The lower level of physical activity than previously (Folkhälsomyndigheten 2011) may also influence fracture incidence since intense physical activity has been linked to more trauma and a high fracture risk (Clark et al. 2008), despite the fact that physical activity (in general) is associated with high BMD) (Clark et al. 2008). Media consumption and screen time activities have also increased among modern children (Folkhälsomyndigheten 2008) and children today walk less often to school and to friends than previously (Folkhälsomyndigheten 2008). All these lifestyle changes may affect the neuromuscular and skeletal functions, and secondary to this, bring about changes in fracture incidence.

The highest distal forearm fracture incidence in absolute numbers occurred in 2005–2006 and the lowest in 1950/1955. Compared to 1950/1955, in 2005–2006 we found a 44% higher age- and gender-adjusted distal forearm fracture incidence.

Compared to 1993–1994, however, we found a similar age- and gender-adjusted distal forearm fracture incidence in 2005–2006. There may however be gender specific time trend differences, since when these two periods were compared, boys had a rate ratio (RR) of 1.2 (95% CI 0.98 to 1.6) while girls had a RR of 0.8 (95% CI 0.6 to 1.1). There may also be differences in different regions. In paper II, which included all children in the Region of Skåne, there was a 2.2% increase in distal forearm fracture incidence during the period 1999–2010. Other studies have inferred that there has been an increase in distal forearm fracture incidence in children during recent years (Mayranpaa et al. 2010, de Putter et al. 2011), while a register-based study from Stockholm, Sweden, reported a decreasing incidence in children between 2004 and 2010 (Wilcke et al. 2013). One strength of the Stockholm study was that there were no changes in the proportion of children with foreign background (Statistics Sweden 2018). For further speculation with regard to possible explanations for time trend changes, see the section "*Pediatric distal forearm fracture etiology in Malmö 2005–2006".*

Of all evaluated periods, the highest hand fracture incidence in absolute numbers occurred in 1976–1979 and the lowest in 1950/1955. Compared to 1950/1955, in 2005–2006 we found a 100% higher age- and gender-adjusted incidence. Compared to 1976–1979, in 2005–2006 we found no different age- and gender-adjusted incidence. Changes in hand fracture epidemiology thus follow a similar pattern as the overall fracture epidemiology. The only study we have found examining hand fracture time trends is a Finnish study that reports 50% higher pediatric hand fracture incidence in 2005 compared to 1983. This is a rough estimate we can extract from a chart presented in the article and no statistical calculations are provided (Mayranpaa et al. 2010).

Time trends in etiology

Once again, we would like to emphasize that, due to the large proportion of fractures with unknown etiology, which also differed between different periods; inferences regarding etiology must be interpreted with care. We therefore also chose to refrain from statistical calculations. Nevertheless, from a broad perspective, accidents at home and in traffic as fracture etiology for any type of fracture, as well as distal forearm fractures, in 2005–2006 represented the lowest proportion of all evaluated years. As discussed earlier, this may reflect the improvements in traffic and home safety work. Sporting and playing activities, in addition to fights, were in 2005–2006 related to the highest proportion of all fractures as well as distal forearm fractures of all evaluated periods. This is supported by data from the Netherlands which infer that in children aged 5–19, the proportion of sports-related distal forearm fractures has increased while the proportion of traffic-related distal forearm fractures decreased between 1997 and

2009 (de Putter et al. 2011). We must also emphasize that there are great difficulties in comparing our data with other studies, due to different classification system, (see the discussion in the section *"Pediatric fracture etiology in Malmö 2005–2006*").

For hand fractures, traffic and home injuries in 2005–2006 represented the lowest proportion of hand fracture causes during all evaluated periods, while the proportion of hand fractures as a result of sports and fight injuries was the highest in 2005–2006 during all evaluated periods. In 2005–2006 fights were the second most common fracture related activity (20%), compared to being the fifth most common activity in 1950/1955 (10%). This could of course be due to more frequent and violent fights today, but also because children today more often reveal the true etiology of the fracture and/or seek health care more often with this kind of injury than in the past. When reviewing the literature, we found no other study that had evaluated time trend changes in pediatric hand fracture epidemiology

Strengths and limitations

Study strengths

Study strengths in papers I, III and IV include data collection within a defined geographical area that is served by a single hospital and that pediatric fracture epidemiology data have been available from the same city since 1950 (Landin 1983, Tiderius et al. 1999). Official population data, in a well-defined population at risk, available in one-year age classes, allowed for the calculation of age- and gender-adjusted rates, which provided the possibility to estimate the influence of changes in demographics for crude fracture incidence. The inclusion of only objectively verified fractures is another study strength.

Study strengths in paper II include the large sample size with extensive number of person years, collected in a well-defined pediatric population at risk. Fracture data were retrieved by the SHR, a register that has been validated for fractures of the distal forearm against the gold standard with good outcome. Official population-at-risk data was available in one-year classes for the entire evaluated period, allowing for the calculation of age-adjusted rates.

Study limitations

Study limitations in papers I, III and IV include the use of a different fracture ascertainment method in the last period. However, our validation study revealed that both the old and the new methods missed the same proportion, 3% of fractures. Both the old and new method would miss fractures in city children treated at other hospitals, only clinically diagnosed fractures and misclassified or inaccurately registered diagnostic codes and/or X-ray examinations. The increasing usage of new diagnostic tools, such as CT or MRI, and changes in patients', doctors' and insurance companies' (needing objectively verified fractures) attitudes in modern society compared to previous years, may to some extent result in more X-rays, more CT and MRI scanning and thereby more fracture diagnosis. There is also the risk that these papers are affected by type II errors. Even if we were bound by the defined population at risk, it might have been advantageous to increase the person years by evaluation of a longer time period.

Study limitations in paper II include the risk of random or systematic errors (as in all register studies). In the register data, it was not possible to distinguish whether multiple visits were due to new or old fractures. This is the reason why we used a one-year washout period. A new fracture within one year of the index fracture would therefore be missed. Furthermore, bilateral distal forearm fractures would be registered as one fracture. However, within the two-year period of observation 2005–2006 in Malmö (23% of the Skåne population during 2005–2006) there were only six pairs of bilateral fractures that occurred at the same injury event (out of the total of 521 registered distal forearm fractures) (see paper III). Furthermore, this problem would probably not influence the estimation of time trends, as the washout period was the same during all evaluated years.

General conclusions

In individuals aged 0–15 in Malmö, Sweden, during the years 2005–2006:

- overall fracture rate was 1,832 fractures per 10^5 person years (2,359 in boys and 1,276 in girls).
- the most common fracture types included fractures of the distal forearm (31%), fractures of the bones of the finger phalanges (15%) and fractures of the carpal/metacarpal bones (10%).
- distal forearm fracture rate was 564 fractures per 10^5 person years (719 in boys and 491 in girls).
- hand fracture rate was 448 per 10^5 person years (639 in boys and 247 in girls).
- in patients with a fracture and known etiology, the most common etiologies were sports (28%), playing accidents (19%) and traffic accidents (9%).
- in patients with a distal forearm fracture and known etiology, the most common etiologies were sports (41%), playing accidents (32%) and traffic accidents (11%).
- in patients with hand fracture and known etiology, the most common etiologies were sports (42%), fights (20%) and traffic accidents (13%).
- the overall fracture rate was 36% higher in 2005–2006 than in 1950–1955, also after adjusting for changes in demographics (33% higher)
- the distal forearm fracture rate was 46% higher in 2005–2006 than in 1950–1955, also after adjusting for changes in demographics (44% higher).
- the hand fracture rate was 118% higher in 2005–2006 than in 1950–1955, also after adjusting for changes in demographics (100% higher).
- the overall fracture rate was 11% lower in 2005–2006 than in 1976–1979, also after adjusting for changes in demographics (7% lower).
- the hand fracture rate was 12% lower in 2005–2006 than in 1976–1979, while there was no difference after adjusting for changes in demographics
- the overall distal forearm and hand fracture rate was no different in 2005–2006 than 1993–1994

In individuals aged 0–16 in Skåne, Sweden, during the years 1999–2010:

- the age- and gender-adjusted distal forearm fracture incidence was 634 fractures per 10^5 person years (750 in boys and 512 in girls).
- The age- and gender-adjusted distal forearm fracture incidence increased by 2.2% per year

Future perspectives

We speculate that since a distal forearm fracture in childhood is associated with both osteoporosis and high fracture risk in adulthood, the increase found in pediatric distal forearm fracture incidence, together with an expected increase in life expectancy, may predict a major increase of fracture numbers in adults and older persons in the future, thereby requiring an increased health care resources.

Further studies are needed with information on present epidemiology and etiology of childhood fractures, from our region and other regions in Sweden and in other countries. These studies should preferably also include patient-level information on factors that influence the fracture risk, e.g. ethnicity, BMD and BMI. Future studies should also evaluate whether the prediction of future fracture numbers was correct.

Populärvetenskaplig sammanfattning på svenska – Summary in Swedish

Varje år drabbas var fjärde barn av en skada som leder till besök på en akutmottagning. Ungefär var femte av dessa har ett benbrott. Antalet svenska barn som varje år råkar ut för benbrott motsvarar sålunda ca 2000 skolklasser. Pojkar drabbas dessutom nästan dubbelt så ofta som flickor. Ett benbrott medför inte bara besvär för den enskilde, utan då frakturer är vanligt förekommande, även stora kostnader för samhället. Från födseln blir benbrott successivt allt vanligare ju äldre barnet blir, tills flickor når en topp kring 12 årsåldern medan pojkarna når toppen i 14-årsåldern. Det vanligaste benbrottet hos såväl pojkar som flickor är handledsfrakturer. Orsaken till denna topp beror bl.a. på att när barnen växer som snabbast hinner skelettet inte mineraliseras tillräckligt snabbt. Skelettet blir då temporärt mindre motståndskraftigt mot yttre våld. Men i denna ålder förändrar många barn även sina aktivitetsvanor. De deltar helt enkelt i aktiviteter som utsätter dem för mer yttre skador. Från den beskrivna toppen sjunker sedan frakturförekomsten fram till 25–30-årsålder. Från dessa år sker en liten ökning av frakturförekomsten under vuxenlivet fram till äldre åldrar då den ånyo ökar dramatiskt. Ser man över hela livet är risken att flickor skall drabbas av ett benbrott när de är i puberteten är lika stor som att drabbas när de blivit 50 år.

För att värdera förekomsten av och orsaker till benbrott hos barn, samt hur denna förekomst har förändrats över tiden har vi undersökt alla benbrott som finns registrerade på vårt sjukhus där Malmöbarn (yngre än 16 år) drabbades under åren 2005–2006. Vi jämförde sen våra siffror med fem tidigare utvärderade perioder från 1950 till 1994. Vi fann då att frakturförekomsten per 2005–2006 var 36 % högre än 1950/1955. Vid en detaljerad granskning fann vi att frakturförekomsten 1976–1979 var 49 % högre än 1950/1955, medan frakturförekomsten 2005–2006 var 5 % lägre än 1976–1979. Om något verkar sålunda barnfrakturerna nu minska i förekomst.

Det verkar även som om orsaker till benbrott har förändrats. Andelen trafikolyckor som frakturorsak var 2005–2006 endast hälften mot 1950/1955 och andelen olyckor i hemmet endast en femtedel så många. Däremot var andelen som orsakades av idrott 53 % större och andelen som orsakats av slagsmål fyra gånger större. När vi undersökte förekomsten av den vanligaste frakturtypen, handledsfrakturer, såg vi att dessa hade ökat med 2.2 % per år i Skåne under åren 1999–2010. Det var även ovanligare för Malmöbarn att ådra sig en handledsfraktur än för Skånebarn. Denna skillnad berodde på att frakturförekomsten var lägre bland Malmöflickor än Skåneflickor. Däremot var det ingen skillnad mellan pojkarna i Malmö och Skåne.

När vi sammanfattar fynden verkar det som om det strukturerade förebyggande arbetet mot olyckor i trafik och hemmet har gett resultat. Den ökande andelen av frakturer inom idrott gör att vi framöver bör försöka minska frakturförekomsten inom de här aktiviteterna, genom att införa frakturförebyggande åtgärder i form av skydd och regler som minskar frakturrisken.

Acknowledgments

Sofie, Maria and Athena, my wonderful family, who have stood by me during my struggles.

Professor Magnus Karlsson, my supervisor, for your endless energy, patience and your ability to inspire.

Björn Rosengren my co-supervisor, for support, attention to detail and constructive criticism.

Lennart Landin, my co-supervisor, for being a mentor and for conducting the world-famous study that my work builds upon and for inspiring and helping me through the initial part of the journey.

Daniel Jerrhag, for interesting and amusing collaboration though this voyage and being co-author in two of my studies.

Jan-Åke Nilsson, for help with statistical calculations.

Hans Erik Rosberg, for assistance with collection of hand fracture cases.

Carl-Johan Tiderius, co-author, for permission to use your data and help to improve the manuscripts.

Martin Englund and Ingmar Petersson, co-authors of paper II, for your help with data collection and manuscript preparation.

Appendix

Table 9. The protocol used in Paper I, III and IV for the registration of fractures, the fracture related activity and trauma mechanism.

Fracture type

Axial skeleton

- Cervical vertebrae
- Thoracic vertebrae
- Lumbar vertebrae
- Sacrum
- Pelvis

Appendicular skeleton

Upper extremity

- Scapula
- Clavicle
- Humerus, collum chirurgicum.
- Humerus, physiolysis proximal
- Humerus, diaphysis
- Humerus, supracondylar
- Humerus, physiolysis distal
- Humerus, lateral condyle
- Humerus, medial epicondyle
- Humerus, medial condyle
- Humerus, distal Y-fracture
- Radius, proximal physiolysis
- Radius collum
- Radius caput
- Ulna, olecranon
- Radius and ulna proximal + diaphysis
- Radius diaphysis only
- Ulna diaphysis only

Monteggia
Galeazzi
Radius and ulna distal
Radius distal
Radius distal, physiolysis
Ulna distal, including physiolysis
Scaphoid
Other carpal bones or metacarpal bones
Phalanges of the fingers

Lower extremity

Femur, collum
Femur trochanteric fractures
Femur subtrochanteric
Femur diaphysis
Femur, supracondylar
Femur, medial condyle
Femur, lateral condyle
Femur distal , Y shaped or comminuted
Femur distal physiolysis
Patella
Tibia, medial condyle
Tibia, lateral condyle
Tibia, both condyles
Tibia, eminentia
Tibia, proximal physiolysis
Tibia, proximal, other
Tibia, diaphysis up to distal metaphysis
Fibula proximal + diaphysis (without a tibia fracture)
Tibia, distal physiolysis
Fibula, lateral malleolus
Fibula, lateral malleolus, physiolysis
Tibia, medial malleolus
Bimaleollar ankle fracture
Other ankle fracture
Calcaneus
Talus
Other tarsal and metatarsal bone
Phalanges of the toes

Fracture related activity

- Unknown
- Home
- Nursing, home, day-care center
- School
  - School yard
  - School sports
- Play activities
  - Play-ground
  - Play-ground fixture such as swings and slides
  - Sleigh
  - Pedal car
  - Tricycle
  - Skateboard
  - Roller-skates
  - Play-ground scuffles
  - Other play accidents
- Traffic
  - Bicycle injuries (single injuries, falling off bicycle, collisions with pedestrians, other cyclists or unmoving objects, passenger on a bicycle)
  - Cyclist hit by car or other heavier vehicle
  - Extremity caught in bicycle wheel (spoke injuries)
  - Pedestrian hit by bicycle or moped
  - Pedestrian hit by car, bus, motor-cycle or street car
  - Passenger or driver of car or tractor
  - Passenger or driver of moped or motorcycle in single accidents or collision with pedestrian, bicycle or unmoving object
  - Passenger or driver of moped or motorcycle in collision with car, bus
- Labor accidents
  - Falls
  - Injuries from tools, tractor, harvesting machine, chain saw or other machinery
  - Other labor accidents

Sports

- Ball sports
- Skiing
- Ice-hockey - skating
- Water sports
- Gymnastics
- Contact sports such as wrestling, karate, judo and boxing
- Falling from horse
- Horse-bites or kicks
- Other sport injuries

Type of trauma

- Falling from height
- Bites
- Blows
- Caught or squeezed
- Hit by moving object
- Birth injury
- Battered child
- Repeated minor trauma – stress fracture
- Not classified
- Unknown

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Paper I

OPEN ACCESS

Time trends in pediatric fracture incidence in Sweden during the period 1950–2006

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Submitted 2016-10-22. Accepted 2017-03-07.

Background and purpose — Pediatric fracture incidence may not be stable. We describe recent pediatric fracture epidemiology and etiology and compare this to earlier data.

Patients and methods — The city of Malmö (population 271,271 in 2005) in Sweden is served by 1 hospital. Using the hospital diagnosis registry, medical charts, and the radiographic archive, we identified fractures in individuals < 16 years that had occurred during 2005 and 2006. We also retrieved previously collected fracture data from between 1950 and 1994, from the hospital's pediatric fracture database. We used official population data to estimate period-specific fracture incidence (the number of fractures per 10^5 person-years) and also age- and sex-adjusted incidence. Differences are reported as rate ratios (RRs) with 95% confidence intervals.

Results — The pediatric fracture incidence during the period 2005–2006 was 1,832 per 10^5 person-years (2,359 in boys and 1,276 in girls), with an age-adjusted boy-to-girl ratio of 1.8 (1.6–2.1). Compared to the period 1993–1994, age-adjusted rates were unchanged (RR = 0.9, 95% CI: 0.8–1.03) in 2005–2006, with lower rates in girls (RR = 0.8, 95% CI: 0.7–0.99) but not in boys (RR = 1.0, 95% CI: 0.9–1.1). We also found that the previously reported decrease in unadjusted incidence in Malmö from 1976–1979 to 1993–1994 was based on changes in demography, as the age-adjusted incidences were similar in the 2 periods (RR = 1.0, 95% CI: 0.9–1.1).

Interpretation — In Malmö, pediatric fracture incidence decreased from 1993–1994 to 2005–2006 in girls but not in boys. Changes in demography, and also other factors, influence the recent time trends.

Each year, 1 child in every 4 sustains traumatic injury that require medical attention, and almost 20% of pediatric trauma cases in an emergency department are treated for fractures (Hedström et al. 2012).

We have reported an increase in pediatric fracture incidence from 1950 to 1979 in the city of Malmö, Sweden (Landin 1983), but a decline during the following 15 years (Tiderius et al. 1999). No age adjustment was used in these studies, however, and the results may therefore entirely, partly, or not at all reflect changes in demography.

The information that is available regarding time trends in pediatric fracture incidence is limited and conflicting. While a Swedish study found an increase in pediatric fracture incidence from 1998 to 2007 (Hedström et al. 2010), a Finnish study found a decrease from 1983 to 2005 (Mayranpaa et al. 2010). However, different fracture ascertainment methods in the 2 studies make direct comparisons difficult.

In order to allocate future healthcare resources, it is essential to use the same fracture ascertainment system to facilitate identification of changes in fracture occurrence and to take changes in demography during the period of examination into account.

With this in mind, we aimed to (1) describe recent pediatric fracture epidemiology including etiology in Malmö and compare this to data from as far back as 1950; (2) describe changes in age- and sex-adjusted pediatric fracture incidences, to identify time trends independent of changes in demographics.

Patients and methods

Background information

Malmö is the third largest city in Sweden, with a population of 271,271 inhabitants (45,910 < 16 years of age) in the year 2005 and 276,244 inhabitants in 2006 (46,429 < 16 years of age) (Statistics Sweden 2007). Virtually all trauma care in the city is provided by the emergency department of the only hospital, and all referrals, radiographs, and reports have been saved for the past 100 years (Herbertsson et al. 2009).

DOI 10.1080/17453674.2017.1334284

Earlier data from 1950 to 1994

Until year 2001, all radiographs were sorted according to diagnosis, anatomical region, and year of injury. This archive has previously been used to identify fractures and to set up a pediatric fracture database including fractures sustained in city residents in the years 1950, 1955, 1960, 1965, 1970, 1975–1979 (Landin 1983) and 1993–1994 (Tiderius et al.1999). These previous reports have not included age- and gender adjustments, and it is therefore not known whether the time trends described earlier depended entirely, partly, or not at all on changes in demography. From the existing database, we included all fractures in children aged < 16 years except those of the skull and sternum.

New data from 2005–2006

In 2001, the hospital switched from physical to digital radiographic films and set up a new archive. This archive includes all radiographs taken within the general healthcare system of the region. However, the radiographs are no longer classified according to diagnosis but according to the unique 10-digit national personal identity number of the patient. To identify pediatric fracture cases in 2005–2006 we performed searches in the digital in- and outpatient diagnosis records at the Emergency Department and the Departments of Orthopedics, Hand Surgery, and Otorhinolaryngology of the hospital. Records included met the following criteria: (1) ICD-10 fracture diagnoses S02.3–S02.4, S02.6–S02.9, S12.0–S12.2, S12.7, S22.0, S32.0–S32.8, S42.0–S42.9, S52.0–S52.9, S62.0–S62.8, S72.0–S72.9, S82.0–S82.9, and S92.0–S92.9; (2) patient age < 16 years; and (3) city residency at the fracture event. We identified 4,459 visits. All visits for each individual patient (identified by the personal identity number) were reviewed (medical charts, referrals, and reports from each radiograph) to verify any fracture. If the fracture diagnosis was unclear, the original radiographs were re-reviewed before any fracture was registered. That is, as in the previous publications (Landin 1983, Tiderius et al. 1999), we only included objectively verified fractures. The ascertainment method with chart reviews allowed us—as in historical reports—to preclude double counting of fractures (due to multiple visits or multiple sequential radiographs).

For each verified fracture, we registered the age and sex of the patient, the date of fracture, fractured region, fracture side, injury mechanism, and injury-related activity. We used the same registration protocol as in the previous studies (that evaluated the period 1950–1994) (Landin 1983, Tiderius et al. 1999), and thus registered multiple fractures as independent fractures and re-fractures as new fractures. Multiple fractures of the fingers, toes, and metacarpals were, however, registered as a single fracture—as in previous studies.

Validation

To validate the 2005–2006 ascertainment method, 1 author (VL) reviewed all digital skeletal radiographs (irrespective of referral unit or reason for referral) performed on city residents < 17 years of age, during the period January 1, 2005 to February 28, 2005. The review identified 103 fractures. A search for childhood fracture diagnoses in the digital hospital inpatient and outpatient records during the same 2 months also identified 103 fractures. When comparing the 2 methods, 100 fractures were identified by both methods while 3 fractures were only identified by 1 of the methods. This represents a misclassification rate of 3%.

Statistics

We used Microsoft Excel 2010 for data management and statistical calculations. Data are presented as numbers, mean incidences per 10^5 person-years, or as proportions (%) of all fractures. From the complete dataset, which was comprised of data from 2005–2006 and previously examined years (Landin 1983, Tiderius et al. 1999), we estimated the total and sex-specific incidence rates per 10^5 person-years during each period. Population at risk (city residents < 16 years) during each period were derived from official records. To estimate age- and gender-adjusted rates, we used direct standardization with the average population of the city of Malmö during the examined period (in 1-year classes) as reference. To evaluate time trends, we grouped fracture data from the previously examined years into 5 periods: 1950–1955, 1960–1965, 1970–1975, 1976–1979, and 1993–1994. Relative risk was estimated by rate ratios (RRs) and 95% confidence intervals by the chi-square distribution. We considered $p < 0.05$ to represent a statistically significant difference.

Ethics, funding, and potential conflicts of interest

The study was approved by the Regional Ethics Review Board in Lund (reference number 2010/191) and was conducted in accordance with the Declaration of Helsinki. Financial support for the study was provided by ALF, the Herman Järnhardt Foundation, the Greta and Johan Kock Foundation, and Region Skåne FoU. The sources of funding were not involved in the design, conduction, or interpretation of the study, or in the writing of the manuscript. None of the authors have any competing interests.

Results

During 2005–2006, we found 1,692 fractures (1,119 in boys and 573 in girls) in 1,615 children during 92,339 patient-years, corresponding to a fracture incidence of 1,832 per 10^5 person-years (2,359 per 10^5 in boys and 1,276 per 10^5 in girls), with an age-adjusted boy-to-girl ratio of 1.8 (95% CI: 1.6–2.1). Detailed data are presented in Figures 1 and 2 (see also Table 1, Supplementary data). Only 1.7% of fractures occurred in the axial skeleton, while 78.8% were in the upper extremities and 19.5% were in the lower extremities. In the upper extremity, the incidence of fractures on the left side was 13% higher

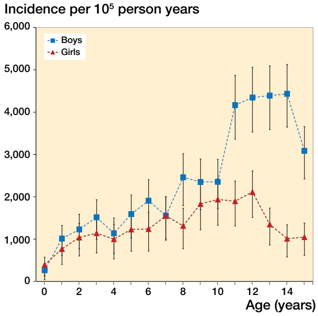

Figure 1. Sex- and age-specific fracture incidence in 1-year classes during the period 2005–2006. Data are expressed as number of fractures per 10^5 person-years, with 95% CI.

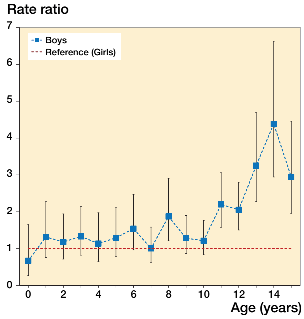

Figure 2. Age-specific boy-to-girl rate ratio (RR) with 95% CI per 1-year age class during the period 2005–2006.

Table 2. Differences in unadjusted and age-adjusted fracture incidence in children between periods of interest in Malmö, Sweden, presented as rate ratios (RRs) with 95% confidence intervals (95% CIs)

	Differences in fracture incidence between periods, RR (95% CI)				
Denominator	1950–1955		1976–1979		1993–1994
Nominator	2005–2006	1976–1979	2005–2006	1993–1994	2005–2006
Unadjusted	1.4 (1.3–1.5) [a]	1.5 (1.4–1.6) [a]	0.9 (0.8–0.9) [a]	0.9 (0.9–0.97) [a]	1.0 (0.9–1.04)
Age-adjusted	1.3 (1.2–1.4) [a]	1.4 (1.3–1.6) [a]	0.9 (0.8–1.03)	1.0 (0.9–1.1)	0.9 (0.8–1.03)

[a] Statistically significant changes

than on the right side (RR = 1.1, 95% CI: 1.01–1.3), while we found no such difference for the lower extremity (RR = 1.0, 95% CI: 0.8–1.3).

63 children had more than 1 fracture. These children had 140 fractures in total, corresponding to 2.2 fractures per child. Of these fractures, 106 occurred in 49 boys and 34 in 14 girls. 57 children (44 boys and 13 girls) had 2 fractures, 4 children (all boys) had 3 fractures, and 2 children (1 boy and 1 girl) had 6 fractures. Of the 140 fractures, 96 occurred at the first injury event, a further 41 at the second, 1 at the third, 1 at the fourth, and 1 at the fifth. 136 of 140 fractures involved the extremities and 4 the axial skeleton. Of 136 extremity fractures, 106 occurred in the upper and 30 in the lower extremity. The 5 most common locations for these fractures were the distal forearm (39 fractures, 29%), the metacarpals (12 fractures, 9%), the fingers (10 fractures, 7%), the clavicle (9 fractures, 7%), and the distal humerus (8 fractures, 6%).

During 2005–2006, the age-specific fracture incidence increased by age in both sexes and reached a peak around the age of 14 years in boys and 12 years in girls (Figure 1). Boys and girls had similar fracture incidences until the age of 10 years, after which boys had higher incidences—by as much as 4 times (RR = 4.4, 95% CI: 2.9–6.6) at the age of 14 (Figure 2).

Compared to 1993–1994, age-adjusted overall rates were unchanged (RR = 0.9, 95% CI: 0.8–1.03) in 2005–2006, with lower rates in girls (RR = 0.8, 95% CI: 0.7–0.99) but not in boys (RR = 1.0, 95% CI: 0.9–1.1). During the overall study period (1950–2006), the highest fracture incidence was found during the period 1976–1979. Between 1950–1955 and 1976–1979, the unadjusted fracture rate increased by about 50% (RR = 1.5, 95% CI: 1.4–1.6) followed by a decrease by 11% until 2005–2006 (RR = 0.9, 95% CI: 0.8–0.9). Details of absolute and age-adjusted changes are presented in Table 2, and sex-specific data are given in Figure 3. We also found that the previously reported decrease in unadjusted incidence from 1976–1979 to 1993–1994 was based on changes in demography, as the age-adjusted incidence was similar in the 2 periods (RR = 1.0, 95% CI: 0.9–1.1)(Table 2).

The most common injury mechanism in children during every period evaluated was a fall on the same plane, and—except in 1960–1965—the most common trauma-related activity was sports (Table 3, see Supplementary data). The fracture-related activity could not be determined in 683 cases (54%) in 1950–1955, 721 cases (48%) in 1960–1965, 651 cases (39%) in 1970–1975, 1,327 cases (40%) in 1976–1979, 518 cases (34%) in 1993–1994, and 499 cases (30%) in 2005–2006. The trauma mechanism could not be determined in 203 cases (16%) in 1950–1955, 139 cases (9%) in 1960–1965, 89

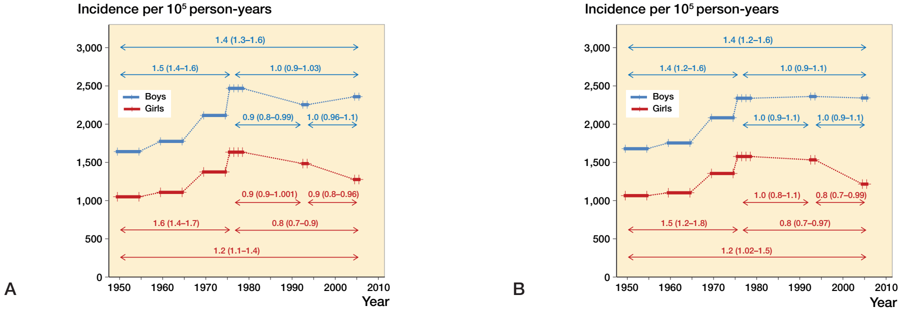

Figure 3. Sex-specific unadjusted (A) and age-adjusted (B) fracture incidence during different periods, from 1950 to 2006. Data are expressed as number of fractures per 10^5 person-years per period of examination, with thick line markers representing the number of years measured in the period. Rate ratios (RRs) between periods of interest are presented with 95% CI on arrows with pointer between the time periods compared.

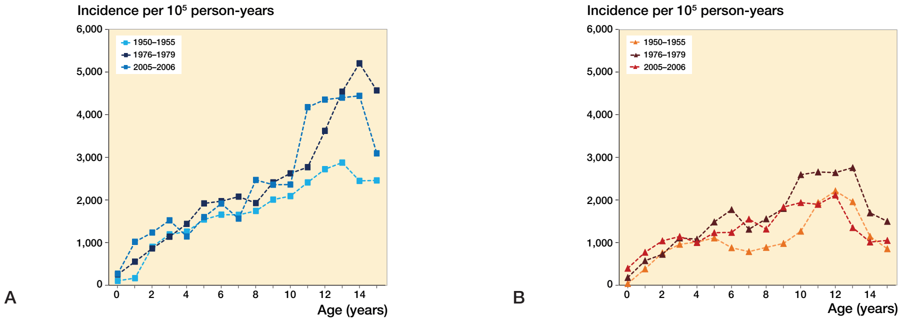

Figure 4. Age-specific fracture incidence in boys (A) and girls (B) during the periods 1950–1955, 1976–1979, and 2005–2006 in Malmö, Sweden. These 3 periods were selected as to show incidences at study start, during the period with highest incidence, and at study end. Data are incidences in 1-year age classes.

cases (5%) in 1970–1975, 155 cases (5%) in 1976–1979, 64 cases (4%) in 1993–1994, and 0 cases (0%) in 2005–2006.

Discussion

The previously reported decrease in overall pediatric fracture rate from 1975–1979 to 1993–1994 (Tiderius et al. 1999) has not continued from 1993–1994 to 2005–2006, where we found a decrease in girls, but not in boys. In the most recent period evaluated, the peak in fracture risk occurred 1–2 years earlier in girls than in boys, fractures in the upper extremities were 4 times more common than in the lower extremities, and more fractures occurred on the left side. We also found that the decrease in unadjusted fracture incidence from 1976–1979 to 1993–1994 was the result of changes in demography. In contrast, the decrease from 1993–1994 to 2005–2006 in girls depended on factors others than changes in demography.

Comparisons of rates for 2005–2006 with other studies

In the present study, the unadjusted pediatric fracture rate (< 16 years) was 1,832 per 10^5 person-years. A study in Northern Sweden found an age- and sex-adjusted incidence of 2,240 per 10^5 person-years in 2005 (Hedström et al. 2010) in individuals younger than 21 years. The difference may be due to the different age spans and the colder climate, with snow and ice in the north, but also other factors—some of which are discussed below. Differences in pediatric fracture rates in a single country have also been found in the UK, with rate ratios ranging from 1.0 to 1.7 between London and other regions (Cooper et al. 2004). In Helsinki, Finland, the unadjusted incidence of fractures in children (< 16 years) was 1,630 per 10^5 person-years in the year 2005 (Mayranpaa et al. 2010), which was lower than in our city (1,832 per 10^5 person-years). The notion that fracture rates differ between countries is further supported by the boy-to-girl unadjusted fracture ratio of 1.6 in Finland (Mayranpaa et al. 2010), 1.5 in Scotland (Rennie et al. 2007), and 1.9 in our study.

Comparisons of time trends

Previous studies from Malmö examining the period 1950–1955 to 1975–1979 have reported on trends in the unadjusted pediatric fracture incidence: mainly an increase until 1975–1979 (Landin 1983) and a decrease from 1975–1979 to 1993–1994 (Tiderius et al. 1999). When we re-examined these data, we found that the decrease from 1976–1979 to 1993–1994 occurred due to changes in demography. We also found that the decrease in girls from 1993–1994 to 2005–2006 was dependent of factors beyond changes in demography (since the age-adjusted incidence also decreased). A recent Finnish study found an 18% decrease in fracture rate in children under the age of 15 from 1983 to 2005 (Mayranpaa et al. 2010). This contrasts with a study in Northern Sweden, which found an increase in individuals younger than 20 years from 1993 to 2007 (Hedström et al. 2010). The reasons for the differences are unknown.

The decline in female pediatric fracture incidence in Malmö during the last period evaluated highlights the importance of continuously monitoring pediatric fracture epidemiology in order to predict and accurately allocate future healthcare resources. Changes in fracture occurrence during the last period were found in girls but not in boys, highlighting the necessity for sex-specific evaluation of fracture epidemiology.

Potential explanations for time trends and differences between regions

We speculate that differences in prevalence of overweight, exposure to trauma, social environment, and risk taking behavior may explain the different fracture incidences. There has also been a marked improvement in traffic safety during the period evaluated, reflected in a reduction in pediatric deaths from motor vehicle accidents (The National Board of Health and Welfare – Socialstyrelsen), which is also supported by our data regarding fracture etiology. Structured pediatric injury prevention in the home environment during the last 60 years may also have contributed, which is also supported by our data regarding fracture etiology. The generally lower level of physical activity in society today than earlier (Public Health Agency of Sweden 2008, 2011) may also have contributed. Children of today walk to school to a lesser extent, and screen time and media consumption have increased since the early 1990s (Public Health Agency of Sweden 2008, 2011). However, how this affects fracture risk is debatable, since both low and high levels of physical activity are associated with high fracture risk (Clark et al. 2008, Fritz et al. 2016).

The distribution of ethnicity in a population may also be of importance, since fracture risks may differ between ethnic groups (Moon et al. 2016). In the year 2005, 42% of Malmö children were of foreign background (i.e. were immigrants or had at least one parent who was immigrant), as compared to 9% in Northern Sweden (Statistics Sweden 2005). Time trends in immigration could also be important, since the proportion of immigrants in our region increased from 18% in 1993 to 26% in 2005 whereas the corresponding increase in the northern part of our country was only from 7% to 8% (Statistics Sweden 2006). More immigrants in Malmö originate from far-away countries, while the largest proportion in Northern Sweden come from Finland (Statistics Sweden 2006).

The proportion of children of foreign background in our city is higher than in some major Scandinavian cities, such as Copenhagen (26% in 2008) (Statistics Denmark 2016), Stockholm (24% in 2005) (Statistics Sweden 2006), and Oslo (one-third of all residents were of foreign background in January 2016) (Statistics Norway 2016) but is comparable to that in other OECD countries (Widmaier and Dumont 2011). Immigrants constitute up to 39% of the population in many major cities (for example, New York (US Census Bureau), Los Angeles (US Census Bureau), and London (Migrant Observatory)). We consider that our results are relevant to areas with a significant proportion of immigrants but that they are not directly generalizable to areas with an exclusively white native population.

Strengths and limitations

The strengths of the study include the long study period in a defined region with detailed official annual population data and an ascertainment method allowing objective verification of all fractures without double counting. The main weakness was the transition in ascertainment method in 2005–2006 compared to earlier. Still, our validation against a gold standard indicated that only 3% of fractures were misclassified, which is similar to that with the previous method (Jonsson 1993). As in our previous studies, children who did not get any medical treatment for their fracture or children living in Malmö but only treated elsewhere for a fracture (both the primary treatment and all follow-up treatments) would not be registered. Most children in Sweden with fractures have been—and still are—referred to their home hospital for any follow-up. Thus, the same risk of misclassification has existed for all the years previously evaluated. It would also have been advantageous to adjust for changes in ethnicity in the population at risk, but these data were not available. Concerning fracture etiology, there was a high proportion of missing data that also differed between the different periods. The data presented in Table 3 should therefore be viewed with caution, and they are more suitable for comparisons of different categories within the same year rather than for comparisons over time.

Conclusion

Female pediatric fracture incidence has decreased in the new millennium, with factors other than changes in demography influencing the recent time trends. Future studies should examine even more recent time trends, preferably with information on patient-specific risk factors to reveal information on causal factors.

Supplementary data

Tables 1 and 3 are available as supplementary data in the online version of this article, http://dx.doi.org/10.1080/17453674.2017.1334284

VL, LL, BR, and MK designed the study. VL collected the 2005–2006 data. Historic data had previously been collected by LL and CJT. VL performed all calculations. VL wrote the first draft of the manuscript, and VL, BR, and MK finalized the manuscript. JÅN provided assistance with statistical calculations.

We thank Hans Eric Rosberg, Department of Hand Surgery, Skåne University Hospital, for his help with data collection concerning hand fractures.

Acta thanks Johannes Mayr and Ole Brink for help with peer-review of this study.

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Supplementary data

Table 1. Fracture distribution in Malmö children < 17 years old, in the period 2005–2006. The data are presented as absolute numbers, incidence per 10^5 person-years, and proportion (%) of all fractures

	All Children			Boys			Girls		
	Number	Incidence	Proportion	Number	Incidence	Proportion	Number	Incidence	Proportion
ALL FRACTURES	1,692	1,832	100	1,119	2,359	100	573	1,276	100
AXIAL	28	30	1.7	18	38	1.6	10	22	1.7
Face	16	17	0.9	11	23	1.0	5	11	0.9
Spine	8	9	0.5	5	11	0.4	3	7	0.5
Pelvis	4	4	0.2	2	4	0.2	2	5	0.3
APPENDICULAR	1,664	1,802	98.3	1,101	2,321	98.4	563	1,254	98.3
Upper extremity	1,334	1,445	78.8	894	1,885	79.9	440	980	76.8
Scapula	2	2	0.1	2	4	0.2	0	0	0.0
Clavicle	114	124	6.7	75	158	6.7	39	87	6.8
Humerus	171	185	10.1	96	202	8.6	75	167	13.1
Proximal	52	56	3.1	24	51	2.1	28	62	4.9
Diaphyseal	15	16	0.9	9	19	0.8	6	13	1.0
Distal	104	113	6.1	63	133	5.6	41	91	7.2
Forearm	633	686	37.4	418	881	37.4	215	479	37.5
Proximal	25	27	1.5	17	36	1.5	8	18	1.4
Diaphyseal	87	94	5.1	60	126	5.4	27	60	4.7
Distal	521	564	30.8	341	719	30.5	180	401	31.4
Hand	414	448	24.5	303	639	27.1	111	247	19.4
Carpal or metacarpal	167	181	9.9	144	304	12.9	23	51	4.0
Finger	247	268	14.6	159	335	14.2	88	196	15.4
Lower extremity	330	357	19.5	207	436	18.5	123	274	21.5
Femur	22	24	1.3	13	27	1.2	9	20	1.6
Proximal	2	2	0.1	1	2	0.1	1	2	0.2
Diaphyseal	16	17	0.9	8	17	0.7	8	18	1.4
Distal	4	4	0.2	4	8	0.4	0	0	0.0
Patella	4	4	0.2	4	8	0.4	0	0	0.0
Tibia	132	143	7.8	80	169	7.1	52	116	9.1
Proximal	9	10	0.5	5	11	0.4	4	9	0.7
Diaphyseal	90	98	5.3	56	118	5.0	34	76	5.9
Distal [a]	33	36	2.0	19	40	1.7	14	31	2.4
Fibula	30	33	1.8	22	46	2.0	8	18	1.4
Proximal and diaphyseal	6	7	0.4	6	13	0.5	0	0	0.0
Distal	24	26	1.4	16	34	1.4	8	18	1.4
Ankle [b]	33	36	2.0	22	46	2.0	11	25	1.9
Foot	142	154	8.4	88	186	7.9	54	120	9.4
Mid- and hindfoot	2	2	0.1	1	2	0.1	1	2	0.2
Metatarsals	73	79	4.3	51	108	4.6	22	49	3.8
Toe	67	73	4.0	36	76	3.2	31	69	5.4

[a] 2 fractures involving both the medial and lateral maleoli were found in boys and are reported in the distal tibia category only (not distal fibula).
[b] Ankle fractures include fractures of the medial or lateral maleoli, bimaleolar fractures, and combined ankle fractures, and thus include some of the fractures in the distal fibula and distal tibia categories.

Table 3. Etiology of pediatric fractures in Malmö, Sweden, 1950–2006, in relation to activity and trauma mechanism for the fractures for which the information was available. Data are presented as a proportion (%) of all fractures

	1950–1955	1960–1965	1970–1975	1976–1979	1993–1994	2005–2006
ACTIVITY						
Home	5.3	5.7	6.3	4.5	6.9	1.5
Day nursery	0.2	0.1	0.7	0.6	1.6	1.1
School	4.3	3.8	5.1	4.1	3.4	6.6
Work	0.5	0.1	0.0	0.0	0.4	0.0
Traffic accidents	11.3	12.7	13.2	10.4	12.2	9.0
Bicycle accidents	8.1	5.3	7.4	6.5	8.4	6.7
Pedestrian hit by vehicle	2.5	4.7	2.6	1.5	1.2	1.2
Moped, motorcycle	0.3	1.2	1.7	1.2	1.3	1.1
Car passenger	0.3	1.0	0.9	1.1	0.6	0.0
Other	0.1	0.5	0.6	0.1	0.8	0.0
Playing accidents	11.6	14.7	14.2	16.1	16.9	19.0
Playground	2.9	3.1	3.7	3.9	6.5	8.9
In-lines, skateboard	0.1	0.1	0.2	2.1	1.9	3.9
Sledge, other “snow”	0.8	0.4	1.1	1.9	1.4	1.7
Other playing accidents	7.8	11.1	9.2	8.2	7.1	4.6
Sports accidents	11.7	13.1	17.8	20.1	21.8	27.7
Ball game	3.6	5.1	8.0	9.8	10.0	17.3
Ice-hockey, skating	5.6	4.7	4.4	2.7	3.2	1.9
Gymnastics and athletics	0.6	0.7	0.6	1.0	2.6	1.5
Horse accidents	1.0	1.0	2.8	3.0	2.5	2.1
Wrestling, boxing, etc.	0.2	0.6	0.7	1.4	1.7	1.2
Skiing	0.4	0.6	1.0	1.9	1.2	2.8
Other	0.3	0.3	0.3	0.4	0.5	0.9
Fights	0.9	1.7	2.9	2.4	2.9	5.4
Other	0.2	0.1	1.1	1.7	0.4	0.1
Unknown	54.2	48.0	38.8	40.0	33.6	29.5
TRAUMA MECHANISM						
Falls	70	74	77	80	67	68
On the same plane	50	50	52	58	41	42
Between planes	20	25	25	22	26	26
Animate mechanical forces	14	16	17	15	23	24
Unclassifiable	0	1	1	1	5	8
Unknown	16	9	5	5	4	0

Paper II

Increasing wrist fracture rates in children may have major implications for future adult fracture burden

A registry study involving 2.8 million patient years based on the Skåne region of Sweden, 1999–2010

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Submitted 2015-09-09. Accepted 2015-12-18.

Background and purpose — Childhood fractures are associated with lower peak bone mass (a determinant of osteoporosis in old age) and higher adult fracture risk. By examining time trends in childhood fracture epidemiology, it may be possible to estimate the vector of fragility fracture risk in the future.

Patients and methods — By using official inpatient and outpatient data from the county of Skåne in Sweden, 1999–2010, we ascertained distal forearm fractures in children aged ≤ 16 years and estimated overall and age- and sex-specific rates and time trends (over 2.8 million patient years) and compared the results to earlier estimations in the same region from 1950 onwards.

Results — During the period 1999–2010, the distal forearm fracture rate was 634 per 10^5 patient years (750 in boys and 512 in girls). This was 50% higher than in the 1950s with a different age-rate distribution ($p < 0.001$) that was most evident during puberty. Also, within the period 1999–2010, there were increasing fracture rates per 10^5 and year (boys +2.0% (95% CI: 1.5–2.6), girls +2.4% (95% CI: 1.7–3.1)).

Interpretation — The distal forearm fracture rate in children is currently 50% higher than in the 1950s, and it still appears to be increasing. If this higher fracture risk follows the children into old age, numbers of fragility fractures may increase sharply—as an upturn in life expectancy has also been predicted. The origin of the increase remains unknown, but it may be associated with a more sedentary lifestyle or with changes in risk behavior.

Almost half of all boys and one third of all girls sustain a fracture during childhood, most commonly in the distal forearm (Hedström et al. 2010, Mayranpaa et al. 2010). There is recent evidence to suggest that a childhood fracture is a predictor of lower adult bone mass and increased risk of fracture in adulthood (Amin et al. 2013, Buttazzoni et al. 2013). As estimations suggest that 50% of the children born today will live to be at least 100 years old (Christensen et al. 2009), current fracture rates may provide important clues to the burden of adult fractures in the future.

The epidemiology of forearm fractures in children has been described earlier (Alffram and Bauer 1962, Landin 1983, Tiderius et al. 1999, Khosla et al. 2003), but only a few large studies have been published recently (Hedström et al. 2010, de Putter et al. 2011, Wilcke et al. 2013)—and very few with long-term time trends (Khosla et al. 2003).

In this paper we describe the current epidemiology and recent time trends in distal forearm fractures in children in southern Sweden, and we relate these results to older fracture data involving children, which are relevant to those at risk of fragility fractures today (current age up to 80 years).

Patients and methods

The Skåne Healthcare Register (SHR) covers all inpatient and outpatient healthcare provided to residents in Skåne, the southernmost county of Sweden. For the period 1999 to 2010, we used the SHR to identify all forearm fractures in individuals who were ≤ 16 years old and who resided in the region (corresponding to 2.8 million person years at risk) by using physician-set diagnostic codes according to the Swedish version of the International Classification of Diseases (ICD) 10 system (S52.50, S52.51, S52.60, S52.61). The washout period was set to 1 year (365 days) for each forearm fracture and unique individual, and we therefore also included data from 1998 as

DOI 10.3109/17453674.2016.1152855

Table 1. Population annually and number of distal forearm fractures for each sex in children ≤ 16 years of age in Skåne, Sweden, from 1999 through 2010

	Boys		Girls		All	
Year	Population	No. of fractures	Population	No. of fractures	Population	No. of fractures
1999	118,200	791	112,569	477	230,769	1,268
2000	118,317	804	112,710	575	231,027	1,379
2001	118,490	776	112,975	546	231,465	1,322
2002	118,749	902	113,194	545	231,943	1,447
2003	118,957	917	113,222	620	232,179	1,537
2004	119,074	983	113,076	626	232,150	1,609
2005	118,882	891	112,772	591	231,654	1,482
2006	118,951	910	112,796	587	231,747	1,497
2007	119,393	975	113,078	576	232,470	1,551
2008	119,861	986	113,457	590	233,318	1,576
2009	120,510	916	114,167	611	234,676	1,527
2010	121,333	876	114,843	615	236,176	1,491
Total	1,430,716	10,727	1,358,858	6,959	2,789,573	17,686

Table 2. Overall wrist fracture incidence rate (per 10^5 person years) and average crude and age-standardized annual change in incidence rate during the period 1999–2010 in children ≤ 16 years of age in Skåne, Sweden. 95% CI within parentheses

	Overall rate	Average annual change in rate Crude	Age-standardized [a]
Boys	750 (711–788)	+1.2% (0.7–1.8)	+2.0% (1.5–2.6)
Girls	512 (489–535)	+1.2% (0.5–1.9)	+2.4% (1.7–3.1)
Total	634 (606–662)	+1.2% (0.8–1.7)	+2.2% (1.7–2.6)

[a] The average annual population during the years examined was used as the standard population.

a reference for washouts in 1999. To estimate persons at risk (for each sex and each 1-year age class) during each individual year of observation, we used the average of the population at the start of the year (December 31 in the year before) and at the end of the year (December 31 in the year of interest), obtained from Statistics Sweden. The denominator for the overall incidence estimations (1999–2010) was estimated in person years, by summing up the estimates above for each of the years under consideration (1999–2010). For estimation of temporal trends in rates, we tabulated data by year and used Poisson regression of annual crude as well as annual direct age-standardized incidence rates (with the average annual population during the years examined as the standard population). Results are presented as annual percentage (%) change with 95% confidence intervals (CIs). Differences in age-rate distribution between periods were examined by Poisson regression with incidence as dependent variable and time and period as factors with interaction.

The validity of the SHR in terms of distal forearm fractures has been examined previously. The register had a sensitivity of 90% and a positive predictive value (PPV) of 94% compared to a gold standard (Rosengren et al. 2015).

To allow comparison with more distant time points, we retrieved older fracture data (collected from manual review of charts and/or radiographs) from previously published studies on fractures in children in Malmö (Alffram and Bauer 1962, Landin 1983, Tiderius et al. 1999), which is the largest city in Skåne.

The study only involved coded (de-identified) data. We used SAS system version 9.2, SPSS version 17.0, and Microsoft Excel 2003 for data management and statistical calculations. All tests were 2-tailed and we considered that any p-value of less than 0.05 was statistically significant.

Results

During the 12-year examination period, we found 17,686 distal forearm fractures (10,727 in boys and 6,959 in girls) over 2.8 million person years (1.4 million person years for boys and the same for girls). Compared to the year 1999, there were 18% more fractures in 2010 (Table 1).

The overall distal forearm fracture rate during the 12-year study period was 634 per 10^5 patient years (750 in boys and 512 in girls), but time trends were evident with a statistically significant increase in overall age-standardized rate of +2.2% (95% CI: 1.7–2.6) per 10^5 and year (+2.0% (95% CI: 1.5–2.6) for boys and +2.4% (95% CI: 1.7–3.1) for girls) (Table 2).

Compared to earlier (i.e. the period 1950–1994), the current distal forearm fracture rate was high (Figures 1 and 2). The children of today (examination period 1999–2010, born in the period 1982–2010) had a 50% higher incidence rate of distal forearm fractures than their counterparts who were examined during the period 1950–1965 (i.e. born in the period 1933–1965). The age-specific difference was most evident during puberty (Figure 2), with a different age-rate distribution (Poisson interaction between curves, $p < 0.001$). Sex-specific analyses revealed that this difference was already evident in 1993–1994 for girls, but only in the most recent period for boys (data not shown).

Discussion

In our study involving 2.8 million person years during the period 1999–2010 in a Swedish childhood population (≤ 16 years of age), we found a high incidence of distal forearm fractures—50% higher than during the period 1950–1965 (Alffram and Bauer 1962, Landin 1983, Tiderius et al. 1999). Also, within the examination period 1999–2010, the age-standardized incidence increased statistically significantly in both boys and girls (Table 2).

In a recent study from northern Sweden based on the years 1993–2007, Hedström et al. (2010) reported distal forearm

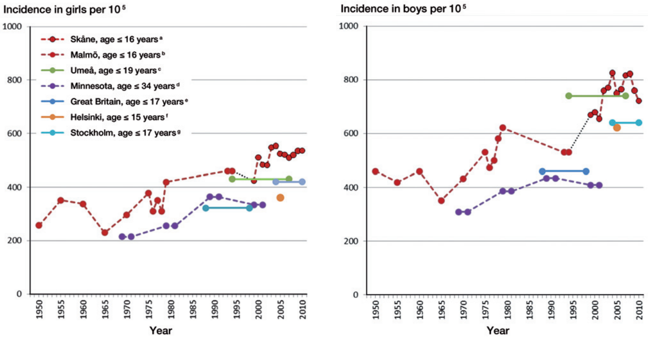

Figure 1. Incidence of distal forearm fractures in girls and boys per 10^5, in different settings and time periods. [a] Current study. [b] Allfram and Bauer 1962, Landin 1983, Tiderius et al. 1999. [c] Hedström et al. 2010. [d] Khosla et al. 2003. [e] Cooper et al. 2004. [f] Mayranpaa et al. 2010. [g] Wilcke et al. 2013.

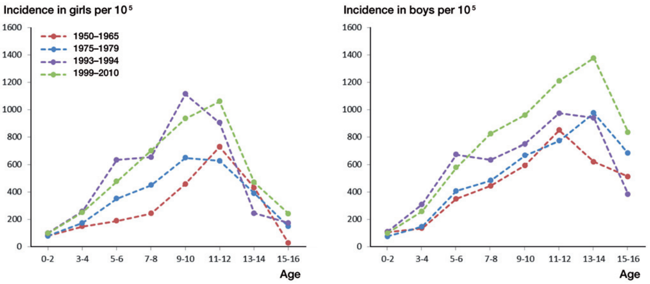

Figure 2. Sex and age class-specific incidence of distal forearm fracture per 10^5 during different periods in children ≤ 16 years of age in Malmö (1950–1994; Allfram and Bauer 1962, Landin 1983, Tiderius et al. 1999) and in the county of Skåne (1999–2010; current study), in 2-year age class strata.

fracture rates in children (≤ 19 years) of 740 per 10^5 person years in boys and 430 per 10^5 person years in girls, which are figures similar to ours. Since they ascertained fractures through radiographs and medical charts (the gold standard), not registry data, direct comparison with our study must be done with caution, yet the concordance of rates strengthens the usefulness of such comparisons (Figure 1).

In another Swedish registry-based study from Stockholm, Wilcke et al. (2013) reported an overall incidence for children who were ≤ 17 years old of 530 per 10^5 person years, and there were decreasing incidence rates from 2004 to 2010. Their results must be interpreted with care, however, as only 1 fracture per individual was counted, giving a decreasing population at risk over successive years without any corresponding decrease in the denominator—and without adjustment for lower risks in those who remained eligible.

Internationally, few recent epidemiological studies have focused on distal forearm fractures in children and young adults. In a study based on evaluation of medical records from the years 1999 to 2001 in Olmstead County, Minnesota, Kohsla et al. (2003) reported an age-adjusted incidence in younger men and women (≤ 34 years old) of 409 and 334 per 10^5 person years, respectively. These rates are lower than ours, but since the incidence of distal forearm fractures decreases considerably after adolescence in both sexes (Buhr and Cooke 1959, Rosengren et al. 2015), the age span 0–34 years in their study would give lower rates than studies with an upper age limit in late teenage. Interestingly, Kohsla et al. (2003) also reported a higher incidence of distal forearm fractures in both sexes in people aged ≤ 34 years during the period 1999–2001 than during the period 1969–1971.

In another report, a registry-based study from the Netherlands, de Putter et al. (2011) reported that the incidence of wrist fractures in boys and girls aged 5–14 years increased from 1997 to 2007, but they did not present any overall rates for the examination period.

In Finland, in an examination of overall fracture epidemiology in children (< 16 years), Mayranpaa et al. (2010) examined charts and radiographs from a single large center in Helsinki and reported a distal radius fracture rate of 622 per 10^5 in boys and 361 per 10^5 in girls over a 12-month period (2005–2006). Despite the fact that they found a decreasing overall fracture rate from 1983 to 2005, the distal radius fracture rate increased by more than 30%.

In Norway, in a prospective 12-month study of children 0–16 years of age in 2010–2011, Randsborg et al. (2013) found an overall incidence of distal radius fractures of 560 per 10^5. The method included evaluation of radiographs and medical charts.

In a study from Britain, Cooper et al. (2004) used the General Practice Research Database to determine the overall fracture epidemiology in children (< 18 years) from 1988 to 1998, and they found a rate of radius/ulna fracture (not specifically distal forearm fracture) of 460 per 10^5 for boys and 322 for girls. This may seem low compared to our results, but as they also included 17-year-olds and only registered 1 fracture per individual, it may be similar to our results. There was, however, also a separate category of green stick fractures with a rate of 173 and 155 per 10^5, and it is not clear whether or not these fractures were included in the rate of radius/ulna fractures.

In New Zealand, in a small single-center study over a 12-month period (1994–1995 for girls and 1998–1999 for boys), Jones et al. (2000) found wrist fracture rates of about 1,000 per 10^5, which were similar in boys and girls (aged 3–15 years). Why their rates were higher than in other studies is still unclear, but this may partly be explained by the small study size and by the fact that there are very few children aged 0–2 with wrist fracture.

The rates and the recent increase in distal forearm fracture rates for both boys and girls in our study are in line with previous reports as mentioned above (Khosla et al. 2003, Hedström et al. 2010, Mayranpaa et al. 2010, de Putter et al. 2011), but the major long-term increase in rates that we identified has not been presented before.

Some authors have suggested that the level of physical activity has had a major role in the change in fracture incidence in children (Tiderius et al. 1999, Hedström et al. 2010, de Putter et al. 2011), but there is conflicting evidence in the literature regarding the connection between physical activity and fracture risk. Clark et al. (2008) found a positive association between a high level of physical activity and fracture risk in children aged 9–11 years, while Detter et al. (2013) found no increase in fracture risk in a long-term moderate exercise intervention program in schoolchildren. Physical activity in childhood is, however, also known to increase peak bone mass (Karlsson et al. 2008), which in turn probably prevents low bone mineral density later in life (Hui et al. 1990). Even more interesting is that childhood fracture appears to be associated with low bone mineral density in young adulthood (Ferrari et al. 2006, Buttazzoni et al. 2013, Farr et al. 2014)—at least in boys—and also a higher risk of fragility fracture later in life (Amin et al. 2013).

Data from a randomized prospective study in schoolchildren (the POP study), where the intervention group received more physical education, indirectly support the notion that low physical activity may be responsible (Fritz et al. 2015). They found the usual age trend, with a higher fracture rate during puberty in the controls but not in the intervention children. This indicates that their study intervention probably addressed at least one of the factors responsible for the temporal increments in risk that we found, especially evident during the initial pubertal period (Figure 2).

It should be emphasized that it has not yet been established whether children who have fractures carry an increased risk of fracture with them into adulthood and old age (Ferrari et al. 2006), but as mentioned above, there is a fair amount of evidence in favor of this (Amin et al. 2013, Buttazzoni et al. 2013, Farr et al. 2014).

As 50% of the children born today have been projected to live to their hundredth birthday (Christensen et al. 2009), and as fragility fracture rates increase in old age (Rosengren et al. 2015), the increasing rate of distal forearm fractures in children is worrying. Previous studies have indicated that a childhood fracture predicts both lower adult bone mass and higher risk of fragility fracture in adulthood (Amin et al. 2013, Buttazzoni et al. 2013). As the children of today grow old, the prevalence of high fracture risk in the elderly may increase—and this, together with the anticipated increase in lifespan, could give a sharp increase in the number of fragility fractures in the future.

The origin of the increase in distal forearm fractures in children remains to be elucidated, but it may be associated with a change in lifestyle. A more sedentary childhood with digital amusements, less organized and spontaneous physical activity, and changes in risk behavior may lead to changes in, for example, bone strength (or specific bone traits), muscle strength, balance, risk of falling, vitamin D levels, BMI, diet, or factors that are yet to be discovered. Certain activities that have become popular in recent years such as skateboarding, trampoline jumping, and mountain biking may also have contributed to a higher risk of trauma. Inability to find and address the factors responsible may lead to an even higher incidence of childhood fractures and of fragility fractures in the future. Some clues may be simple to gather from already collected, older normative or control group data from previous studies, but unfortunately we do not have access to such data.

The strengths of the present study include the well-defined complete and large population of children followed over a long period (12 years) with data from a register validated (with good results) for distal forearm fractures (Rosengren et al. 2015), though not specifically for children. The examination of registers rather than individual patients, charts, or radiographs makes selection bias (random or systematic) possible. However, our results are very similar to those of Hedström et al. (2010), who used the gold standard of chart and radiograph review in a Swedish setting. We have no indication of any changes in diagnosis coverage of distal forearm fractures between 1999 and 2010, but this cannot be ruled out. However, any change—if present—would undoubtedly be towards better coverage. This would result in an underestimation of the overall period rate and a falsely low difference compared to earlier decades. It could, however, also result in an overestimation of the time-dependent increment in rates between 1999 and 2010. We set the washout period to 1 year, as the vast majority of distal forearm fractures would have healed by then and would therefore not appear in the medical records again as a result of that fracture. Consequently, if an individual was to appear in the register again, after more than a year (from the previous fracture diagnosis), with the same diagnosis, the most likely reason would be a new fracture, and the fracture would be counted as a new fracture. However, simultaneous bilateral fractures would be counted as only 1 fracture, as the register does not include information about side (left or right). It would have been preferable to have had data collection from the same geographical area by the same ascertainment method throughout the 60-year period, but this was not possible. It could be argued that the threshold for seeking medical treatment more than 60 years ago may have been higher than it is today, possibly resulting in falsely low rates long ago. Due to patient demands, physicians today may also be more liberal with radiological examinations, thereby also identifying minor torus or greenstick fractures that would not have been registered 50 years ago. Since most distal forearm fractures are associated with significant pain, those cases are probably few and their contribution to rates low.

The current rate of distal forearm fractures in Swedish children is high, and 50% higher than in the 1950s. If the increase in fracture risk follows the present children as they grow old, this may lead to a sharp increase in the number of fragility fractures—specially as a radical upturn in life expectancy in the not-too-distant future has been predicted. The origin of the increase in the rate of children's distal forearm fractures remains to be elucidated, but it may be caused by a more sedentary lifestyle with digital amusements and less organized and spontaneous physical activities—and it could also be related to changes in risk behavior.

After a joint discussion between the authors, BR designed the study. BR and ME extracted the original data and then DJ did all the calculations. DJ wrote the first draft of the manuscript and edited it—first together with BR and then together with all the authors. All the authors read, revised, and approved the final manuscript.

No competing interests declared.

Funding was received from the Swedish Research Council, from Government Funding of Clinical Research within the National Health Service (ALF), from FoU Skåne, from the Herman Järnhardt Foundation, from the Johan and Greta Kock Foundation, and from the Faculty of Medicine, Lund University, Sweden.

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