Diploma Thesis

A Cohort Study on Fractures in Children and Adolescents

submitted by

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Graz, April 8th 2009 (signature)

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Zusammenfassung

Verletzungen zählen nach wie vor zu einem der weltweit größten Probleme im Kindes- und Jugendalter, wobei in 10-25% der Fälle Knochenbrüche daraus resultieren. Trotz der Häufigkeit von Frakturen ist nur wenig bekannt über ihre Verteilung, Ursachen und Mechanismen. Das Ziel dieser Arbeit war, eine epidemiologische Aufstellung der Häufigkeiten und Geschlechtsverteilung zu machen, sowie die näheren Umstände, die zu diesen Verletzungen führen, zu erheben.

Alle Kinder die im Zeitraum zwischen Dezember 2004 und Oktober 2006 an der Universitätsklinik für Kinder- und Jungendchirurgie in Graz behandelt wurden, wurden prospektiv dokumentiert. Diese wurden dann in 4 Altersgruppen unterteilt: Kinder jünger als ein Jahr, Vorschüler (1-6 Jahre), Schüler bis zur Pubertät (6-14 Jahre) und Jugendliche über 14 Jahre.

In diese retrospektive Studie wurden 3.339 Patient/Innen mit 3421 Frakturen eingeschlossen. In 61,3% (n=2096) der Untersuchten konnten Knochenbrüche bei männlichen Patienten festgestellt werden, wobei Mädchen in nur 38,7% (n=1325) betroffen waren. Bei der Betrachtung des Durchschnittsalters beider Geschlechter konnte gezeigt werden, dass Mädchen mit 8,2 Jahren früher betroffen waren als Jungen (9,8 Jahre). Es wurde außerdem sichtbar, dass es einen Anstieg der Inzidenzen bis zum Alter von 11 Jahren bei weiblichen beziehungsweise 12 Jahren bei männlichen Patienten gab. Mehr als ein Drittel aller Knochenbrüche fanden an Sportstätten statt (34,7%), während Unfälle zu Hause (17,6%) und im Freien (16,7%) nur halb so häufig auftraten. Anhand der Analyse der erhobenen Daten konnten die drei häufigsten Mechanismen gezeigt werden: Stürze in der Ebene (41,9%), Stürze von einer Höhe unter drei Metern (23,2%) und unabsichtlicher Zusammenstoß mit einer Person oder einem Gegenstand (18,2%). Diese Mechanismen zusammen waren für 83,3% aller Frakturen verantwortlich. Die distale Radiusfraktur wurde in 15,3% der Fälle diagnostiziert und war somit die häufigste Verletzung in der Studie. Außerdem waren Frakturen an den Finger mit 14% und der Bruch beider distaler Unterarmknochen (Ulna und Radius) mit 8% ebenfalls häufige Lokalisationen. Die Resultate aus dieser Arbeit könnten hilfreich sein, Strategien zur Verletzungsprävention zu entwickeln. Eine Risikoreduktion könnte erreicht werden durch das Tragen von Schutzausrüstungen.

Abstract

Injury still represents a major problem for children and adolescents all over the world. 10-25% of all pediatric injuries will result in fractures. However, relatively little is known about the distribution of fractures and the circumstances and mechanisms of fractures in children. The aim of the survey was to find out the epidemiological incidences, gender distribution, age, and circumstances of fractures in childhood.

All children who were treated in the Department of Pediatric and Adolescent Surgery of Graz between December 2004 and October 2006 were prospectively evaluated. Patients were subdivided into 4 age groups: children younger than one year of age (<1 a), preschool children before the age of six (1-6 a), children until puberty (6-14 a) and adolescents (>14 a).

3,339 patients younger than 19 years of age presenting with 3,421 fractures were included in this retrospective study. The male to female ratio was 61.3% (n=2096) to 38.7% (n=1325). However, girls had a lower mean age at presentation with 9.8 years in boys and 8.2 years in girls, respectively. The study showed an increase of fracture incidences until reaching a peak at the age of 11 years in girls and 12 years in boys. More than one third of all fractures occurred at sports facilities (34.7%), while accidents at home (17.6%) and outdoors (16.7%) were half as frequent. The three most common mechanisms of accidents were falls on level surface (41.9%), falls from a height less than 3 meters (23.2%) and involuntary contact with persons or objects (18.2%). These three mechanisms accounted for 83.3% of all fractures. The most frequent single childhood fracture was the fracture of the distal radius accounting for 15.3% of all fractures followed by finger fractures with 14%. Distal forearm fractures (fractures of both radius and ulna) were diagnosed in 8% of our patients, thereby representing the third most common fracture type.

The results of this study may help to set priorities for injury prevention in childhood and may help to develop future prevention strategies. These prevention strategies should not aim to reduce the level of exposure but should increase the risk-awareness and encourage young people and their parents to use safety equipment.

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Abbreviations

n	number of patients
$	Dollar
EHLASS	European Home and Leisure Accidents Surveillance System
IDB	The Injury Database
EU	European Union
SAP	System Application and Products in Data Procession
ICD 10	International Classification of Diseases; Version 2006
MVA	motor vehicle accidents
a	year
DXA	Dual-Energy-X-Ray-Absorptiometry
BMD	bone mineral density

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1 Introduction

Injury still represents a major problem for children and adolescents all over the world and is cause of significant morbidity and mortality. The "Atlas on mortality in the European Union" identified trauma as the leading cause of death in children and adolescents older than one year of age [1]. In America's children aged from 1 to 17 years trauma was identified as the most frequent cause of mortality as well [2]. Unintentional trauma is common in childhood and Danseco et al. have shown that one in four children will sustain an unintentional injury requiring medical care each year [3]. 10-25% of all pediatric injuries will result in fractures [4, 5]. The incidence of pediatric fractures was estimated with 16 to 20 per 1,000 [6, 7] children while Cooper et al. [8] reported an incidence of 13 per 10,000 person years. Rennie et al. demonstrated that a third of all boys and girls can expect to have a fracture before the age of 16 [6]. Previous studies have shown that the overall incidence of children requiring hospitalization following trauma is rising [9]. Walsh and co-workers demonstrated a similar trend regarding the incidence of fractures [10].

The increasing numbers of childhood injuries have a major financial effect on the public health system. In 1996, the costs of childhood injury in America were estimated with $14 billion in lifetime medical spending, $1 billion in other resource costs, and $66 billion in present and future work losses [11]. For prevention of fractures and to reduce the costs, the knowledge of the causes, gender and age group distribution play a pivotal role. However, there is little data on causes and circumstances of accidents in children and adolescents. While in many countries death rates are well documented due to compulsory registration, statistics on the number of accidents are frequently based on social insurance databases or extrapolated for a whole country from single centre experiences [12-14]. A federal agency called "Statistics Austria" contributes the Austrian data on trauma related morbidity and mortality to the EU network. The numbers of the annual statistics are collected for all age groups from sample hospitals, police reports, registration offices and death certificates [15]. Apart from an overview of locations and circumstances it is not possible to gain more detailed information from these institutional reports. In 1986, the European Union established a "European Home and Leisure Accident Surveillance System" (EHLASS) based on face to face

interviews to collect comprehensive European data on home-accidents. In 1999, “The Injury Database” (IDB) was designed in order to provide central access to the data collected from the EU-member states and has been made publicly accessible in 2006 [16]. However, the related coding manual extends 100 pages [17] and handling is difficult and error prone. In addition the system draws on sample hospitals with general medical service all over Europe but does not particularly include data from pediatric hospitals. Therefore the system provides valid information regarding adult trauma but does not meet the specific needs to analyze pediatric accidents. For instance, the manual includes a coding on playground equipment, the specific reason e.g. for a fall from a slide (slipping, standing up while sliding, falling from the ladder etc.) remains unclear. To establish effective prevention measures it is mandatory to learn especially from these details.

The present paper focuses on demographics, circumstance of accidents and type of injuries in a series of children and adolescents with fractures using a hospital based trauma surveillance system.

2 Material and Methods

The Department of Pediatric Surgery in Graz, Austria is the only pediatric level one trauma centre within the respective catchment area for children and adolescents from 0 to 18 years of age. Patients´ administration is performed using a computerized documentation system called MEDOCS, based on a SAP healthcare solution (System Applications and Products in Data Processing, Walldorf, Germany). This documentation system has been primarily designed for administration of the patient's master data, cost accounting, processing and storage of medical reports. In 2004, a pediatric injury data entry form (**Figure 1, Appendix B**) has been integrated to the hospital information system to collect locations, circumstances and diagnoses of accidents. This form is based on a previous system for collection of pediatric trauma-data which was introduced 10 years before but was less detailed and difficult to access. For all children seeking medical attention following an accident, the trauma survey is completed by the attending doctors at first presentation. In addition, the ICD 10-coding of the related diagnosis is recorded. For subsequent completion of missing trauma-data sheets, these are identified by matching of the trauma reports with the stored injury data entry forms.

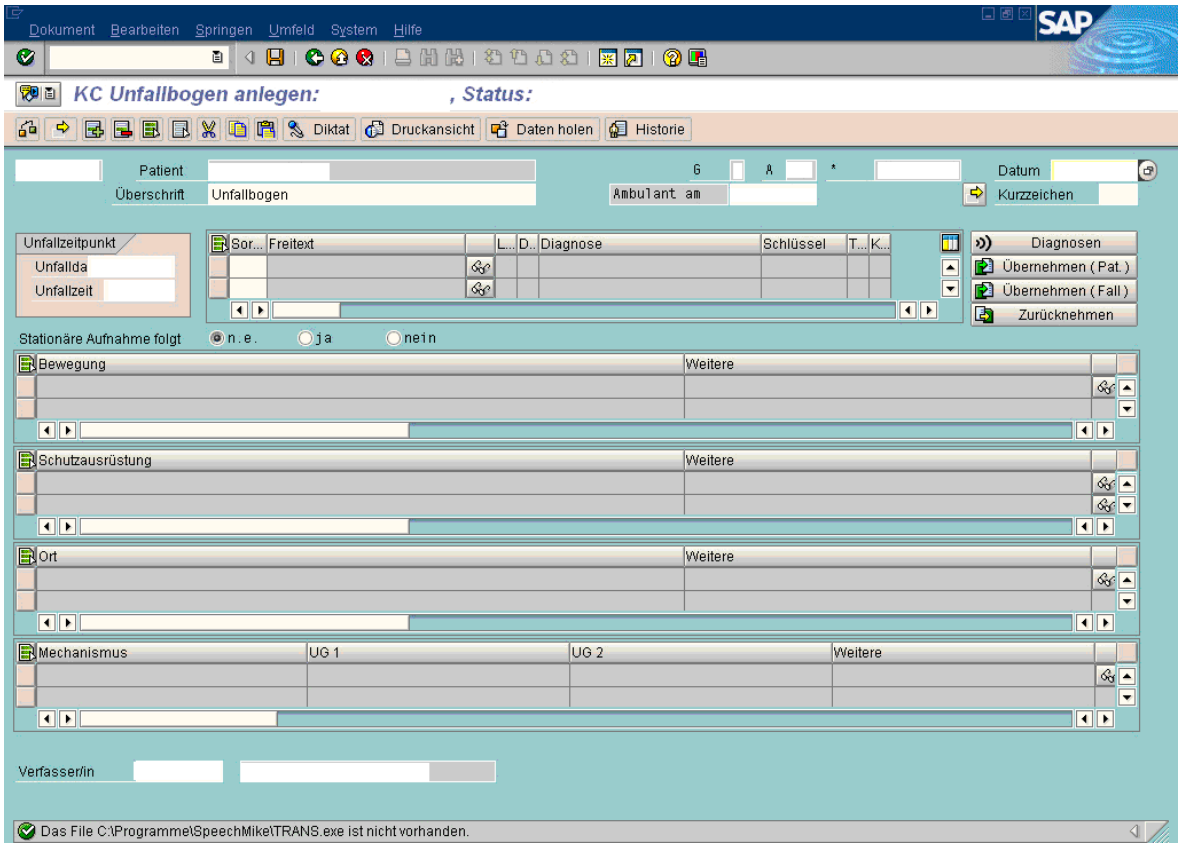

Figure 1: The pediatric injury data entry form used for this study

To facilitate analysis, the trauma documentation system has been supplemented by a tool called “export assistant”. This software-application has been developed by the in-house Institute for Medical Informatics, Statistics and Documentation and enables the researcher to extract any variables from all patient related documents in the system. In addition, a full text search is possible in all trauma related documents. For example, the search term “swing” will identify all documents of all children and adolescents, who had accidents related to a swing. Therefore not only the categories of the trauma documentation system will be displayed but there is access to all relevant medical documents. In consideration of data security and ethical aspects, the researcher can log on to the portal to retrieve the search results via intranet or export the files to spreadsheets for further analysis. If follow-up inquiries become necessary, the system provides access to the patient’s master data. Every database query as well as the researcher’s personal identification is recorded to exclude misuse.

All children who were treated in the Department of Pediatric and Adolescent Surgery of Graz between December 2004 and October 2006 were prospectively evaluated. In this period 21,582 cases were documented in the database system MEDOCS. All patients younger than 19 years of age with fractures (n=3,339) were selected from this collective. The data from the pediatric injury data entry form were completed with accident details gained from the trauma reports. All patients with incomplete questionnaires which could not be completed from the trauma reports were excluded from further analysis.

All data were entered into a computerized database (Microsoft Excel®). To facilitate analysis, we grouped the **locations of accidents** in

- home
- sports facilities
- school and kindergarden
- outdoor
- traffic
- playground and
- others

Similarly, we classified the **mechanisms of accidents** as

- fall on level surface
- fall from a height less than 3 meters
- fall from a height more than 3 meters
- contact with person/object
- pedestrian
- car passenger
- bicycle/motorcycle-accident and
- others

Patients were classified in different age groups, thereby responding to the age related pattern of behavior and anatomic changes of the growing skeleton.

Fractures were diagnosed by x-rays. Since the primary diagnosis is made by the attending surgeon, we reviewed the reports of the radiologist in all cases to exclude possible misinterpretation.

3 Results

3.1 General overview

From December 2004 to October 2007, a total of 3,339 children and adolescents younger than 18 years of age presented with fractures to the emergency room and were included in our study. Out of these, 74 patients (2.2%) had more than one fracture in different body regions, resulting in a total of 3,421 fractures. In patients with multiple fractures we documented two fractures in 68 children, three fractures in 5 children and one child presented with 5 traumatic fractures.

The male to female ratio was about three to two with 2,096 fractures (61.3%) in boys and 1,325 (38.7%) in girls **(Figure 2)**.

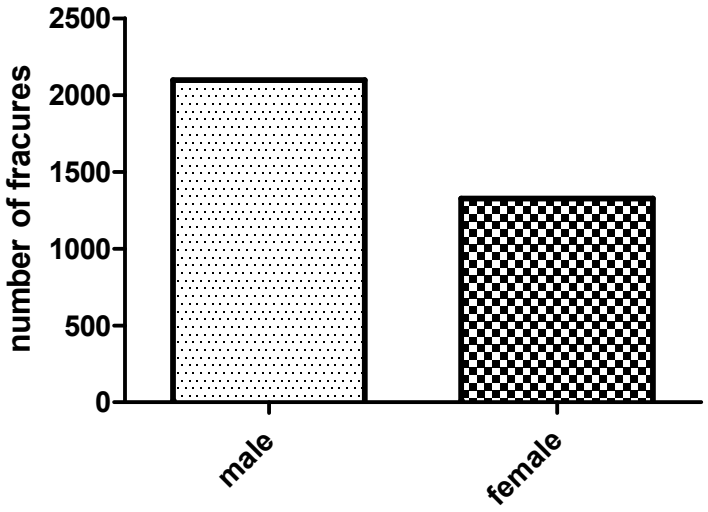

Figure 2: Gender distribution of 3,421 fractures treated in our Department

However, girls had a lower mean age at presentation with 9.8 years in boys and 8.2 years in girls, respectively. Similarly, the peak of fracture incidence was reached at 11 years in girls and at 12 years in boys. A significant increase of fractures was seen at the age of one when children start to walk; another peak in the fracture incidence was noted around 6 years of age in both genders which may

be attributed to the start of compulsory education in Austria. Overall, the mean age for sustaining a fracture was 9.2 years. The age related incidence of fractures is presented in **Figure 3**.

A large part of the accidents happened during sports: More than one third of all fractures occurred at sports facilities (34.7%), while accidents at home (17.6%) and outdoors (16.7%) were half as frequent. Playground accidents (10.8%), traffic accidents (10.7%) and accidents at school or kindergarten (6.1%) were less frequent. Other locations accounted for 3.4% of all fractures.

The three most common mechanisms of accidents were falls on level surface (41.9%), falls from a height less than 3 meters (23.2%) and involuntary contact with persons or objects (18.2%). These three mechanisms accounted for 83.3% of all fractures. The remaining 16.7% comprise falls with bicycle, inline-skaters, skateboards and non-motorized scooters (10.1%), traffic accidents as car passengers or motorbike accidents (3.2%), falls from a height more than 3 meters (1.9%), traffic accidents as pedestrians (0.5%) and others (1%).

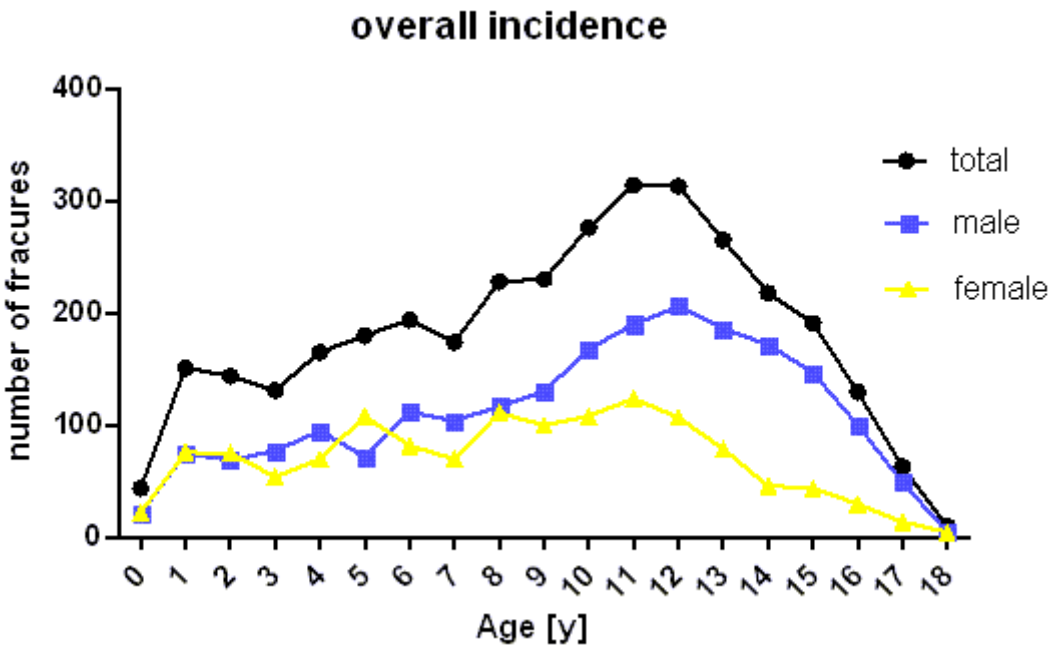

Figure 3: Age and gender distribution of 3,421 fractures

According to our data, the most frequent single childhood fracture is the fracture of the distal radius accounting for 15.3% of all fractures followed by finger fractures with 14%. Distal forearm fractures (fractures of both radius and ulna) were diagnosed in 8% of our patients, thereby representing the third most common fracture type. These “top three fractures” account for 37.3% of all bone-injuries in our study **(Figure 4)**.

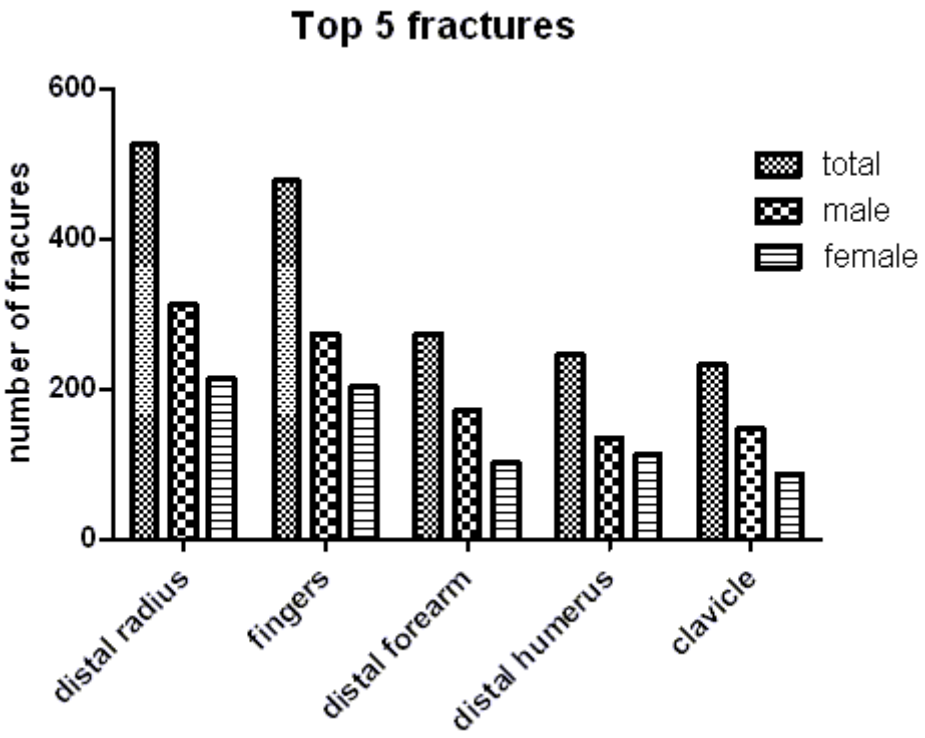

Figure 4: The five most common fractures

The majority of fractures were fractures of the upper extremity (n=2,060; 60%) followed by fractures of the lower extremity with 873 cases (25.5%). The remaining 488 fractures were attributed to head, spine, clavicle, scapula, ribs and pelvis.

The rarest fracture-types were injuries to the proximal fibula and its shaft, fractures of the proximal tibia and fibula, the isolated distal ulna fracture, and the scapula fracture, with each of these accounting for 0.1% of all fractures. The vast majority of all fracture types was more frequent in boys while certain fracture types were found in more than 80% of all cases in boys: Carpal- and metacarpal

fractures, fractures of pelvis and thorax including the scapula and fractures of the patella. However, the prevalence of fractures to the proximal humerus, the proximal radius, the proximal tibia and the spine was higher in girls (**Table 1**).

fractures	total [n]	male [n]	female [n]	total [%]	male[%]	female [%]
distal radius	525	312	213	15.3	59.4	40.6
fingers	477	273	204	13.9	57.2	42.8
distal radius/ulna	273	171	102	8.0	62.6	37.4
distal humerus	246	134	112	7.2	54.5	45.5
clavicle	232	146	86	6.8	62.9	37.1
toes	213	135	78	6.2	63.4	36.6
metatarsals	164	103	61	4.8	62.8	37.2
metacarpals	112	92	20	3.3	82.1	17.9
facial bones	108	75	33	3.2	69.4	30.6
radius/ulna shaft	104	68	36	3.0	65.4	34.6
hallux	96	61	35	2.8	63.5	36.5
skull	94	59	35	2.7	62.8	37.2
thumb	85	54	31	2.5	63.5	36.5
distal tibia	84	54	30	2.5	64.3	35.7
tibia shaft	78	46	32	2.3	59	41
proximal humerus	72	25	47	2.1	34.7	65.3
distal fibula	55	32	23	1.6	58.2	41.8
proximal radius	47	22	25	1.4	46.8	53.2
distal tibia/fibula	44	33	11	1.3	75	25
proximal tibia	34	15	19	1.0	44.1	55.9
ulna shaft	25	14	11	0.7	56	44
tibia/fibula shaft	23	14	9	0.7	60.9	39.1
proximal ulna	22	16	6	0.6	72.7	27.3
carpal bones	22	18	4	0.6	81.2	18.2
spine	21	8	13	0.6	38.1	61.9
femur shaft	21	15	6	0.6	71.4	28.6
tarsal bones	21	15	6	0.6	71.4	28.6
humerus shaft	17	9	8	0.5	52.9	47.1
proximal radius/ulna	16	8	8	0.5	50	50
pelvis	15	13	2	0.4	86.7	13.3
thorax	13	11	2	0.4	84.6	15.4
distal femur	10	6	4	0.3	60	40
patella	10	9	1	0.3	90	10
radius shaft	9	7	2	0.3	77.8	22.2
proximal femur	9	7	2	0.3	77.8	22.2
distal ulna	8	5	3	0.2	62.5	37.5
scapula	5	4	1	0.1	80	20
fibula shaft	4	3	1	0.1	75	25
Proximal tibia/fibula	4	2	2	0.1	50	50
proximal fibula	3	2	1	0.1	66.7	33.3

Table 1: Distribution of fractures and occurrence in boys and girls.

3.2 Fractures related to age groups

In order to account for the age related pattern of behavior and anatomic changes of the growing skeleton, the patients were divided in four age groups:

- children younger than one year of age (<1 a)
- preschool children before the age of six (1-5 a)
- children until puberty (6-14 a) and
- adolescents (>14 a).

3.2.1 Fractures of children younger than one year of age

In this age group 1.3% (n=44) of all fractures were recorded. The distribution of fractures was equal between both genders with 22 fractures each. The most frequent fracture in this age group was the skull fracture (n=29; 65.9%), followed by fractures of the clavicle (n=5; 11.4%). The majority of the accidents happened inside at home (n=35; 79.5%) while the remaining children were injured in the yard or elsewhere (n=8; 18.2%). A fall from a height less than three meters was the most frequent mechanism of accident (n=27; 61.4%). In detail, these children were mainly falling out of the bed, from the changing table, from the high chair or out of a child seat or baby-carrier. Falls on level surface in children younger than one year of age (n=8; 18.2%) were mainly attributed to the first attempts to walk, thereby sustaining fractures of the head and arm.

3.2.2 Fractures in pre-school children

A total of 771 fractures occurred in the group of children from one to five years of age. Similar to children below one year of age, the distribution of fractures was equal between boys (n=388; 50.3%) and girls (n=383; 49.7%). The most common single fractures in this age group were fractures of the clavicle (n=111; 14.4%) and fractures of the distal humerus (n=99; 12.8%). Less frequent were

injuries to the distal radius accounting for 81 fractures (10.5%). While these fractures predominantly happened indoors at home (n=302; 39.2%), a significant number of children suffered from playground accidents (n=157; 20.4%). Outdoor accidents at locations other than playgrounds were recorded in 123 children (16%).

The mechanism of accident was a fall from a height less than 3 meters in the majority of preschool children (n=366; 47.5%). These falls were mainly attributed to furniture (chairs, beds and sofas), playground-equipment (slide, swing, jungle gym) and stairs. Falls on level surface (running, stumbling on objects) were recorded in 226 cases (29.3%). Another main focus were collisions with other children or objects (n=109; 14.1%).

3.2.3 Fractures in school aged children before puberty

Fractures in school aged children before puberty (6 to 14 years of age) represent the largest group among all pediatric trauma patients. Almost two thousand fractures were recorded in this subgroup (n=1,994; 58.3%) with boys being injured more frequently compared to girls (n=1,213 and 781; 60.8% and 39.2%, respectively). Fractures of the distal radius were most common (n=353; 17.7%) followed by finger-fractures (n=322; 16.1%). Fractures of the distal forearm accounted for 171 fracture-cases (8.6%). Sports facilities were the main site of accident (n=861; 43.2%). Half as many fractures (n=361, 18.1%) were the consequence of outdoor-injuries during leisure activities. The third most common localization was at home, where 10.8% of all accidents (n=215) occurred.

A fall on level surface was the cause of a fracture in 47.2% (n=941), followed by a contact with a person or an object (n=400; 20%), while a fall from a height less than three meters causes fractures in 4.7% of all patients (n=94).

3.2.4 Fractures in adolescents

In this age group, 17.9% of all fractures (n=612) were documented. The majority of fractures in this age-group occurred in boys (n=473; 77.3%), while 139 fractures (22.7%) were recorded in girls. The most frequent fracture localization was the distal radius and fingers with each of them accounting for 14.5% (n=89) of all fractures. Fractures of the facial bones and toes were documented in 6.0% each (n=37) similar to fractures of both bones of the distal lower arm and metacarpal fractures with 5.2% (n=32) each.

In 269 cases (44%) the fractures happened at sport facilities while traffic related fractures accounted for 159 (26%) of all incidences. Outdoor activities other than sports caused 13.4% (n=82) of all fractures.

A fall on level surface resulted in 42.3% (n=259) of all adolescent fractures. Collisions with persons or objects caused 18.3% of all fractures (n=112), followed by motor vehicle accidents (MVA) (n=94; 15.4%).

3.3 Analysis of affected bones

3.3.1 Skull

In 94 patients (2.7%) aged between 0 and 15 years fractures of the skull were found in the two years period. The male to female ratio was approximately 2:1 (boys: n=59; 62.8%, girls: n=35; 37.2%). The mean age was 3.2 years. A peak of incidence occurred in children younger than one year of age while the incidence of skull fractures decreased with age. One third of the cases occurred during the first year of life (n=29; 30.9%) and children until the age of 4 accounted for nearly 80% (n=75; 79.8%) of skull fractures (**Figure 5**).

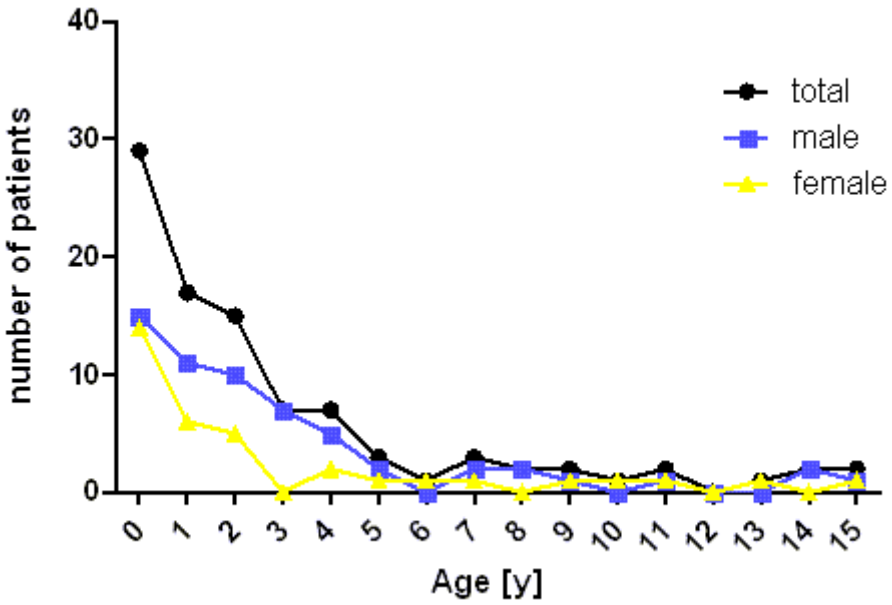

Figure 5: Age and gender distribution of skull fractures

Accident site: The most common site of accident was the home with 63.8% of all skull fractures (n=60). In 14 cases (14.9%) skull fractures occurred in the yard followed by 7 fractures (7.4%) at sports facilities. Traffic-accidents, playground-accidents, and others resulted in skull fractures in 4 children each.

Mechanism of accident: A fall from a height less then 3 meters was the most common mechanism of accident in children and adolescents (n=66; 1.9% of all fractures), thereby causing almost two thirds (70.2%) of all skull fractures. In detail, children were falling from the diaper changing table, the bed, staircase and highchairs.

Falls on a level surface (12.8%) were less common and typically related to the first attempts to walk. In 6 cases (6.4%) the accident happened as a result of a contact with a person or an object.

3.3.2 Facial bone fractures

Fractures of the cheekbone, the jaw, the nasal bone, the nasal septum, the orbital cavity, and multiple fractures of facial bones all have been assigned to the group of facial bone fractures. From a total of 108 facial bone fractures (3.2% of all fractures), two thirds (69.4%) were found in boys (girls: 30.6%). The average age was 10.5 years, while a peak of incidence was noted at 5, 11, and 16 years of age (**Figure 6**).

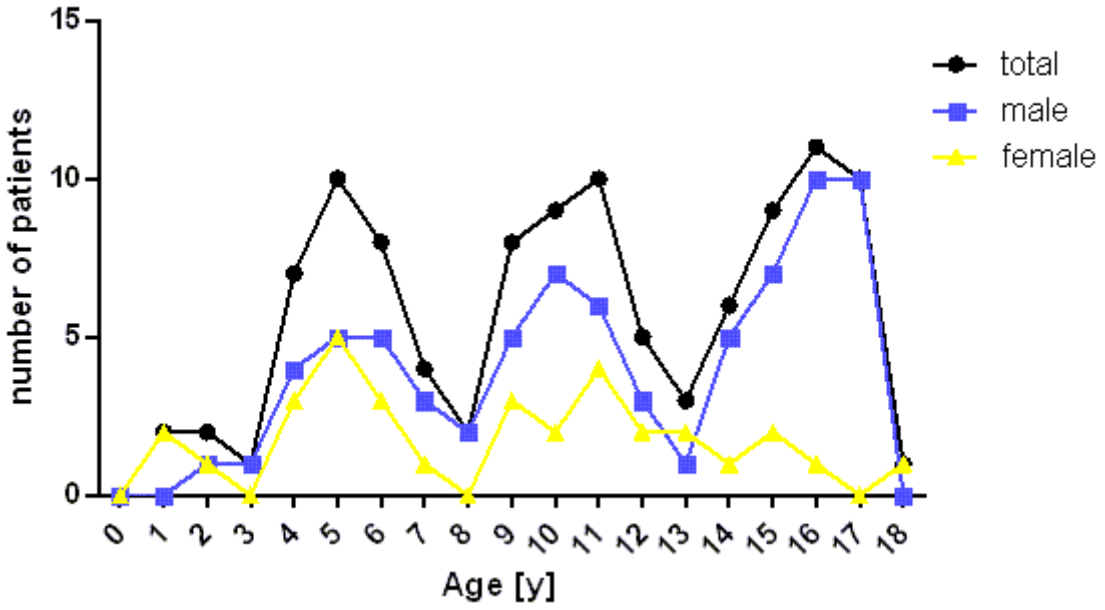

Figure 6: Facial bone fractures. Note the peaks at 5, 11 and 16 years of age.

Nearly one third of these fractures were related to sports (n=33; 30.6%) followed by accidents at home (n=23; 21.3%), in the yard (n=16; 14.8%) and traffic (n=15; 13.9%).

Contact with a person or object caused facial bone fractures in 48 patients (44.4%). In detail, children got hit by footballs or other sports equipment, or sustained a fracture during a scuffle. Falls on a level surface caused 28.7% (n=31) of these fractures while the children and adolescents had contact to furniture in most cases. However, bicycle related accidents or accidents with inline skates and non motorized scooters were recorded in 10.2% (n=11) of these fractures.

The first peak of incidence was found at the age of about 5 years and was related to accidents at home (fall on a level surface with contact to furniture), while children between 9 and 12 as well as adolescents between 14 and 18 suffered the fracture during sports.

3.3.3 Clavicle

We recorded 232 (6.8%) children and adolescents with fractures of the clavicle. The male to female ratio was 2:1 (male: 146 cases; 62.9%, female 86 cases; 37.1%). The average age was 6.8 years with boys being older (8.1 years) compared to girls (4.7 years). Most fractures occurred in preschool children, the peak incidence was between two and four years of age.

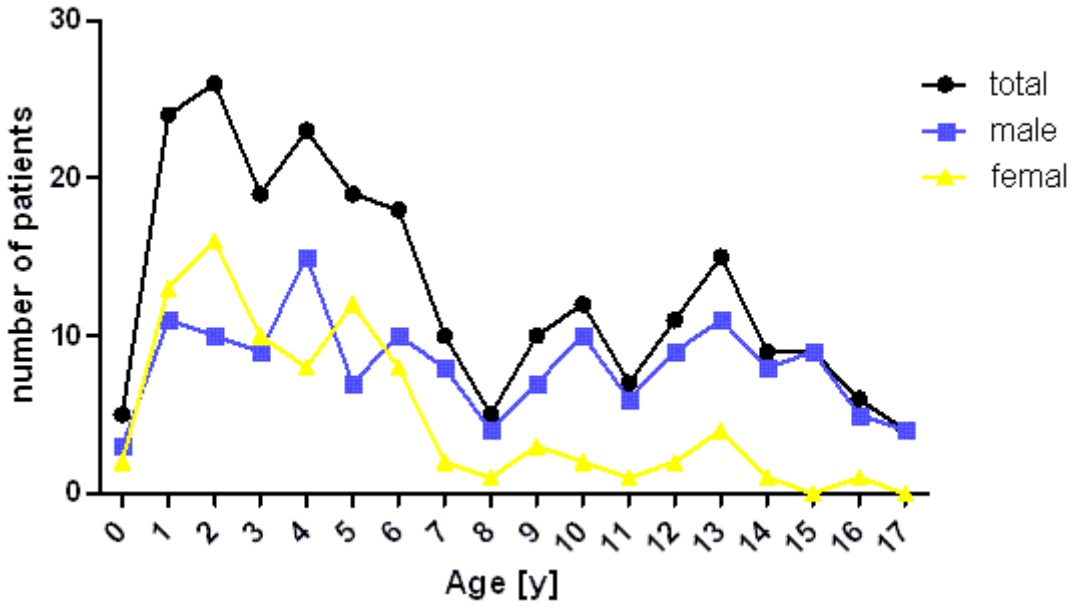

Figure 7: Fractures of the clavicle

The most common accident site was at home (n=61; 26.3%), at sports facilities (n=60; 25.9%), during outdoor activities (n=30; 12.9%) and traffic accidents (n=29; 12.5%).

Falls on level surface (n=102; 44.0%) were very common, mainly while stumbling at home but also during soccer playing or winter sports. A significant number of children had fractures of the clavicle during falls from heights of less than 3 meters (n=77; 33.2%), such as falls from the bed, armchairs, slides and other playground equipment. In 28 cases (12.1%) cycling or skating was the cause of such fractures.

3.3.4 Thorax

Fractures of the ribs and the sternum are rare in childhood; only 13 patients (11 boys and 2 girls) were documented being 5 to 17 years of age (12.4 years mean). Most fractures of the thorax were the consequence of high speed accidents such as road traffic accidents (n=5; 38.5%), at sports facilities (n=4; 30.8%). In two children the injury happened at home when children were falling at the staircase or the edge of a wooden bed, respectively (n=2; 15.4%).

Though the absolute number of fractures was low, the most common mechanism of accident was a car-, bike- or motorbike-accident (n=5; 38.5%) and falls on a level surface with contact (n=4; 30.8%). The children fell against furniture or were injured while skiing or playing football. In single cases, fractures were caused by falling from a height less than 3 meters (from a horse or while climbing a rope at school-sports) and contact with a person or an object (flowerpot) (n=4; 30.8%).

3.3.5 Spine

Similar to thoracic fractures, only 21children had a vertebral fracture and girls were more frequently affected compared to boys (m: 8; f: 13). We could not find spinal fractures under the age of 5 and the mean age was at 12.4 years. The peak incidence was 15 years with 5 recorded fractures.

The accidents happened at sports facilities (n=8; 38.1%), in the yard (n=6; 28.6%), or were associated to road traffic (n=4; 19.0%). Spinal fractures were the consequence of a fall from height in the majority of the cases (horse riding, ski-jumping and snow boarding-exhibitions).

3.3.6 Scapula

Five fractures of the scapula were recorded during the study period. The patients´ age ranged from 8 to 15 years (12 years mean), the male to female ratio was 4:1. All of these fractures happened at a sports facility during skiing, snow boarding, karate, or playing football. Four of the children fell on a level surface while the remaining child had a collision with another person.

3.3.7 Humerus

The upper arm was divided into three types:

- proximal humerus
- humerus shaft and
- distal humerus.

Proximal humerus

Fractures of the proximal humerus were documented in 72 children (10.1 years mean). About two thirds of these fractures occurred in girls (n=47; 65.3%) and 34.7% (n=25) in boys.

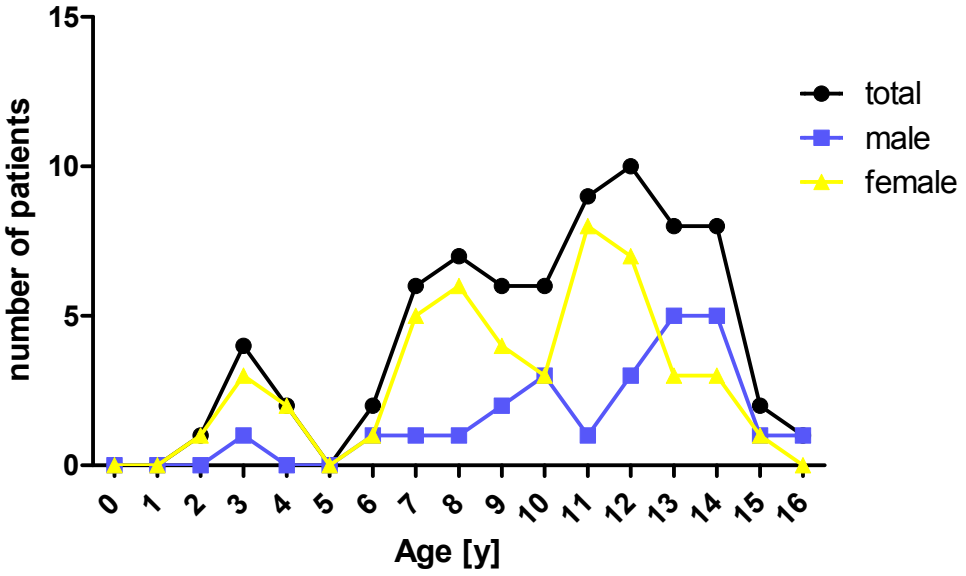

Figure 8: Proximal humerus fractures

More than the half of the accidents happened at sports facilities (n=37; 51.4%) followed by accidents at the playground (girls only; n=10) and road traffic (n=10, m:f = 1:1). Children fell on level surface (n=31; 43.1%) or from heights (n=28; 38.9%). Skiing, snowboarding, ice skating were typical activities associated with subcapital humerus fractures, similar to falls from horses and playground equipment like slides and swings.

Humerus shaft

Fractures of the humerus shaft are uncommon (n=17) and children presented at an average age of 10.4 years. Boys and girls were equally affected (m: 9; f: 8). More than one third of these fractures happened in the yard (n=6; 35.3%), followed by accidents at home, at playgrounds, and in traffic (3 cases each; 17.6%).

The most common mechanism for a fracture of the humerus shaft is to fall from a height less than 3 meters (n=7; 41.2%) followed by falls on a level surface (n=3; 17.6%). Children were falling from slides, ladders, or during ice skating, skiing, snowboarding, and cycling.

Distal humerus

The distal humerus is the most common fracture location of the upper arm (n=246; 7.2% of all fractures). Most fractures (n= 134; 54.5%) occurred in boys and 112 fractures (45.5%) in girls. The average patient's age was 6.4 years. The fracture peak was noted at the age of 6, when compulsory education starts in Austria.

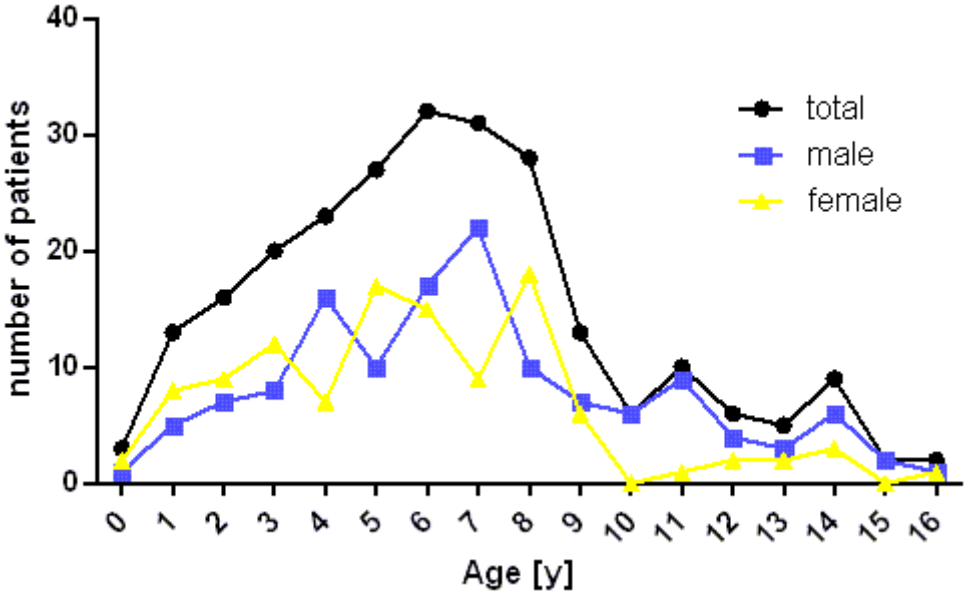

Figure 9: Age and gender distribution of distal humerus fractures

Most accidents were related to leisure activities, either on the playground (28.9%; n =71) or at the yard (22.0%, n=54). Accidents at home accounted for 15.9% (n=39) of the distal humerus fractures.

Since the playground was a common accident site, the most common mechanism of accident was a fall from heights less than 3 meters (n=116; 47.2%), e.g. from playground equipment such as swings, slides and monkey bars. Falls on level surface (n=78; 31.7%), and accidents associated to biking and skating (n=29; 11.8%) were less common.

3.3.8 Radius

Similar to the humerus, fractures of the radius were classified in

- proximal radius fractures
- radius shaft fractures and
- distal radius fractures.

Proximal radius

Fractures of the proximal radius were documented in 47 patients (22 m; 46.8%, 25 f; 53.2%) with an average age of 9 years **(Figure 10).**

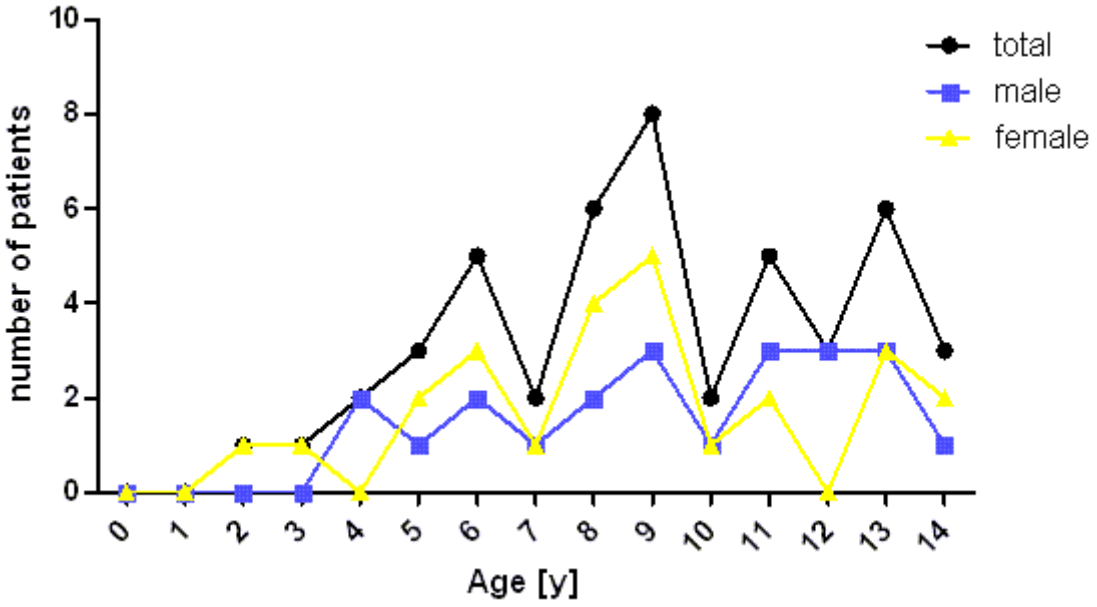

Figure 10: Fractures of the proximal radius

Twelve of these fractures happened in the yard, another 12 at the playground (25.5% each). Accidents at home or at school/kindergarten were half as frequent (n=6; 12.8% each).

Falling on a level surface (n=20; 42.6%) represented the most frequent mechanism of injury, mainly as a consequence of falls while running, playing soccer, or related to trampolines. Falling from a height less than 3 meters (mainly

from playground equipment) caused proximal radius fractures in 17 children (36.2%) and cycling or skating. Less frequent were accidents related to cycling, skating and falls from bunk-beds (n=10, 21%).

Radius shaft

In 9 children (7 boys and 2 girls) isolated fractures of the radius shaft were caused by accidents in the yard (n=3; 33.3%), at sports facilities, and in traffic (each n=2; 22.2%). The children fell from a height less than 3 meters, were skating and cycling, or falling on a level surface. Falls from monkey bars on playgrounds, from fences, and grappling caused these fractures.

Distal radius

The distal radius fracture was the most common single fracture (n=525; 15.4%). While we recorded 312 cases (59.4%) in boys, girls presented with 213 fractures (40.6%). The mean age was 9.2 years; a peak of incidence was noted with 11 years **(Figure 11)**.

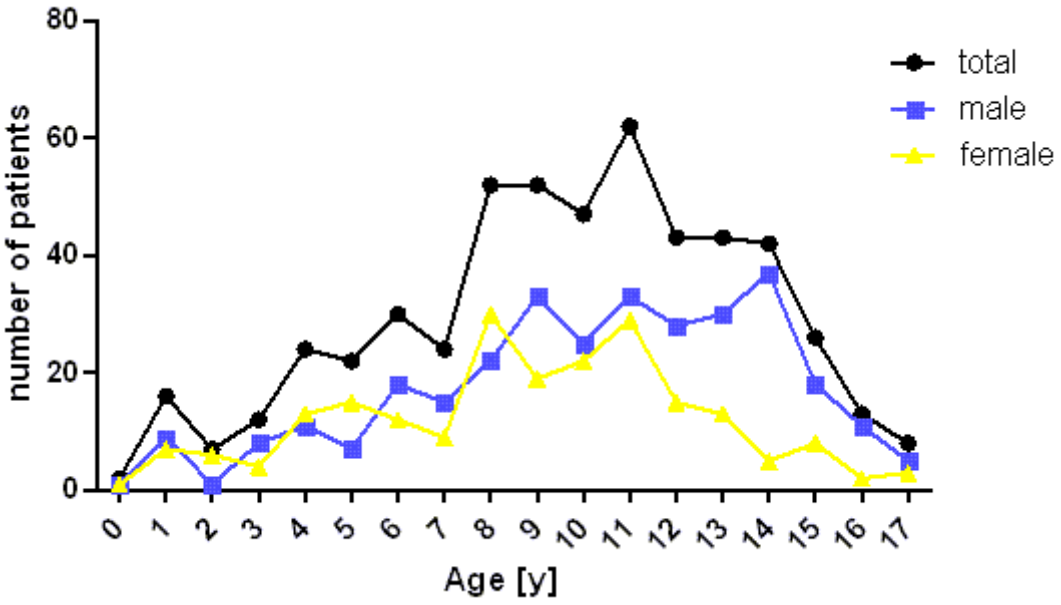

Figure 11: Distribution of the distal radius fracture

Almost half of these fractures occurred during sport activities (43.4%; n=228), followed by accidents in the yard (n=94; 17.9%), at home (n=55; 10.5%), and in traffic (n=54; 10.3%).

More than the half of the accidents (51.8%) happened when children were falling unintentionally on level surface (n=272; 51.8%), for example while playing soccer, during winter sports and while running. Another frequent mechanism of accident were falling from a height less than 3 meters (n=102; 19.4%) from chairs, sofas, beds, staircases, slides, swings or monkey bars. Accidents related to cycling or skating were also very common (n=77; 14.7%).

3.3.9 Ulna

Fractures of the ulna were sub-grouped in

- proximal ulna fractures
- ulna shaft fractures and
- distal fractures of the ulna

Proximal ulna

Isolated fractures of the ulna were rare (n=22): The accidents of 16 boys (72.7%) and 6 girls (27.3%) were recorded (mean age 8.3 years). A peak of incidence was noted at 5 years of age.

Accident sites were outdoors in the yard (n=8; 36.4%), at playgrounds, and road traffic as pedestrians (each n=4; 18.2%). Children frequently fell from a height less than 3 meters (n=8; 36.4%) and on level surface (n=7; 31.8%). These accidents include falls from staircases, swings, trampolines as well as running and stumbling, especially in preschool children. In 4 cases (18.2%) bicycle or skates related accidents were filed.

Ulna shaft

Similar to proximal ulna-fractures, ulna shaft fractures were documented in 25 cases with a male to female ration of 54% to 44% (n=14: 11). The average age of these children was 6.8 years.

The most common accident sites of this fracture type were sport facilities and play grounds (each n=5; 20%), followed by accidents in the yard and in traffic (each n=4; 16%). Children were falling from heights less than 3 meters (n=10; 40%) e.g. from slides, swings, monkey bars, fences, beds, and horses. Falls on a level surface in 8 children (32%) were related to running and playing soccer. Accidents during bicycling or skating caused 4 fractures (16%); less frequent was unintentional contact with a person or an object (n=3; 12%).

Distal ulna

Only eight children (5 boys and 3 girls) presented with isolated fractures of the distal ulna (mean age 13.4 years). Half of these (n=4; 50%) were injured in the yard. Two children (25%) had accidents at sports facilities and in traffic, respectively.

Half of these fractures (n=4; 50%) were caused by simple falls on level surface with contact to an object (e.g. road curbs). Children were falling while ice skating, running and stumbling. Another two accidents were related to motorbikes.

3.3.10 Radius/Ulna

Proximal Radius/Ulna

Fractures of the proximal forearm were recorded in 16 patients with an average age of 5.8 years. The fractures were equally distributed between genders (n=8 each).

Nearly one third of the cases (n=5; 31.3%) happened at playgrounds, followed by accidents in the yard and in traffic (each n=3; 18.8%). Accidents at home and at sport facilities were documented in 2 children each (12.5%).

The injuries were caused by falls from a height less than 3 meters in 7 children (43.8%). These falls were related to swings, slides, climb poles, and beds.

In 31.3% of the cases (n=5) fractures of the proximal lower arm were a result from falls on a level surface. Injuries while skating and riding the bicycle caused 4 fractures (18.2%).

Radius/Ulna shaft

Almost two thirds (n=68; 65.4%) of the 104 fractures of the radius and ulna shaft were recorded in boys while about one third (n=36; 34.6%) was documented in girls. We were not able to identify any specific peaks of age in children sustaining injuries to the shaft of the radius and ulna.

The main activities resulting in this type of lesion were in the yard (27.9%), at sports facilities (25.0%) and playgrounds (23.1%).

The most commonly seen mechanism was a fall from a height less than 3 meters (n=47; 45.2%) such as falls from slides, swings, fences, beds, horses, and trampolines. Almost one third of the cases were caused by falls on a level surface (n=34; 32.7%) like falls during playing football, snowboarding, and stumbling. 12.5% (n=13) were cycling or rollerskates related accidents.

Distal Radius/Ulna

Of the 273 children sustaining a fracture of the distal forearm 171 (62.6%) were boys and 102 (37.4%) girls. The average age was 8.5 years. Until the age of 10 years there is no specific difference between boys and girls. At puberty, the number of fractures increased markedly in boys, while the number in girls decreased **(Figure 12).**

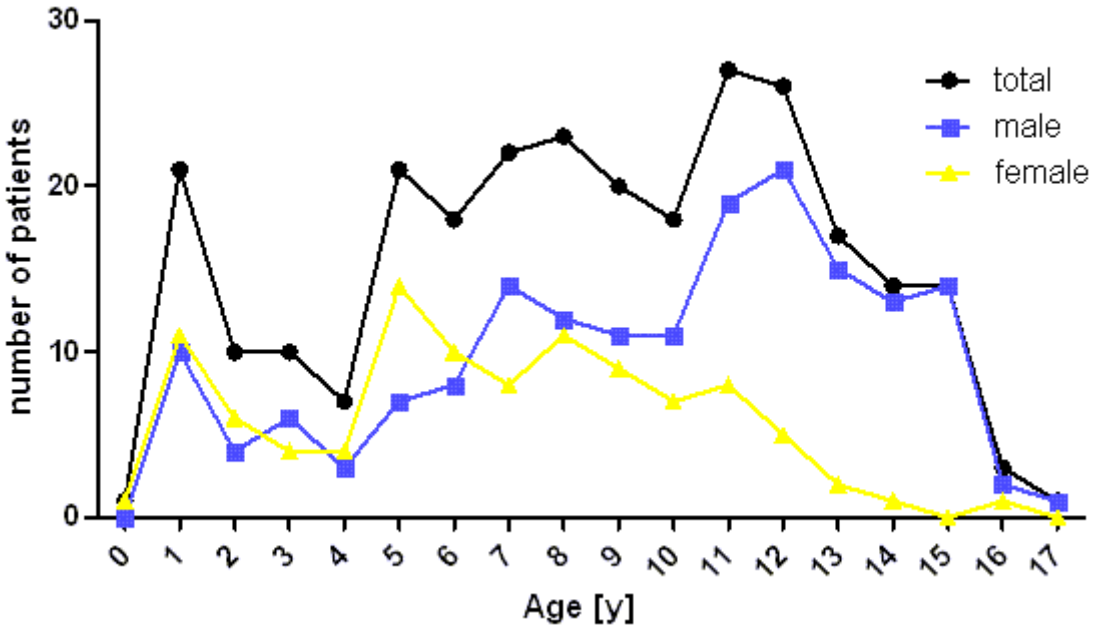

Figure 12: Distal radius/ulna fractures

The most common sites of accident were sports facilities (n=79; 28.9%), the yard (n=53; 19.4%) and playgrounds (n=52; 19.0%).

Falls on a level surface were documented in 107 children (39.2%) as a consequence of falling while playing football, winter sports activities, running, and stumbling. In 94 cases (34.4%) falls from a height less than 3 meters were the cause of fractures. In 13.9% (n=38) the fracture was caused by cycling and skating accidents.

3.3.11 Carpal bones

Fractures of the carpal bones were a less commonly seen injury. In as few as 22 children with an average age of 13.3 years (range 10-17a) we noted this type of fracture. Interestingly, a male to female ratio of 4.5:1 was noted (boys n=18; 81.8% and girls n=4; 18.2%).

Almost one third of the fractures (n=7; 31.8%) occurred during activities in the yard, followed by road traffic accidents (n=6; 27.3%) and accidents sustained at sports facilities (n=5; 22.7%).

The most common mechanism causing fractures of the carpal bones were falls on a level surface and accidents with bicycles or skates (each n=9; 40.9%). These falls were mostly related to skiing, running, playing football and simple stumbling. In contrast to many other fractures in this series falls from a height less than 3 meters occurred in only 3 children (n=13.6%) while falling out of beds, of the bus and from wall bars. One child (4.5%) had an accident on a motorbike.

3.3.12 Metacarpal bones

Fractures of the metacarpal bones were the second most prevalent fracture of the pediatric hand. In 112 cases (92 boys (82.1%) and 20 girls (17.9%)) fractures of single or multiple metacarpal bones were recorded. The average age of the patients was 11.4 years. A striking peak was noted at the age of 12 and 13 years in both girls and boys.

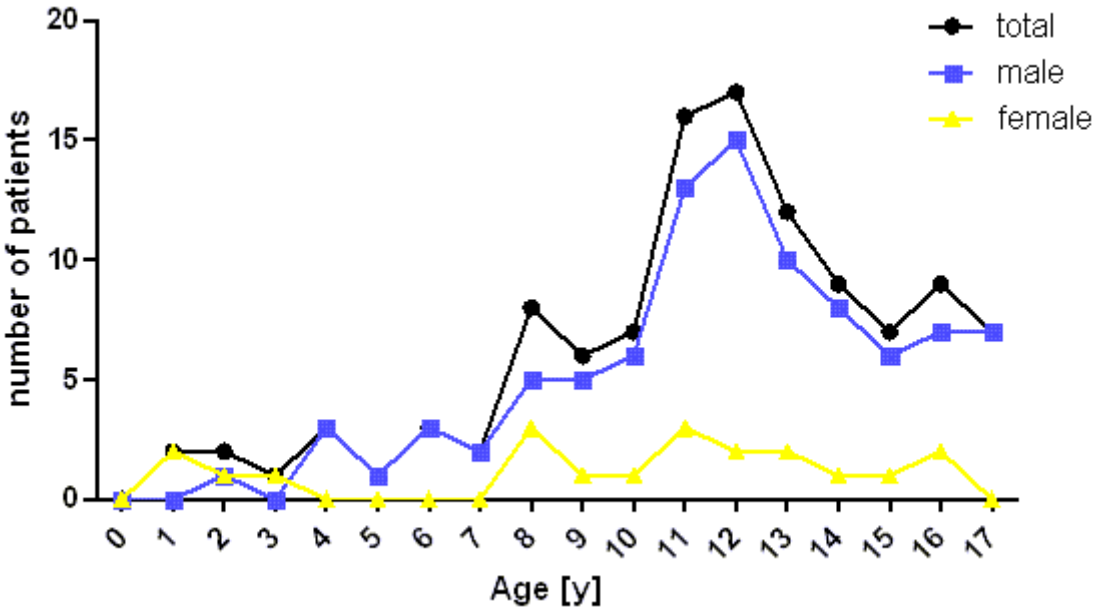

Figure 13: Distribution of fractures of metacarpal bones

More than a third of the fractures (n=41; 36.6%) happened at sports facilities, followed by accidents in traffic (n=23; 20.5%) and in the yard (n=17; 15.2%). In 12.5 % of the cases (n=14) fractures occurred at home.

The most common mechanism of these fracture type was falls on a level surface (n=49; 43.8%) while playing football, skiing, and sledging. In 24 cases (21.4%) children got hit by a person or an object e.g. during fights or judo. Accidents on bicycles or skates were documented in 20 children (17.9%).

3.3.13 Thumb

85 children sustained fractures of the thumb (54 boys; 63.5% and 31 girls; 36.5%). The average age of these patients was 9.8 years. A peak of incidence was seen in both male and female patients between 9 and 12 years of age **(Figure 14)**.

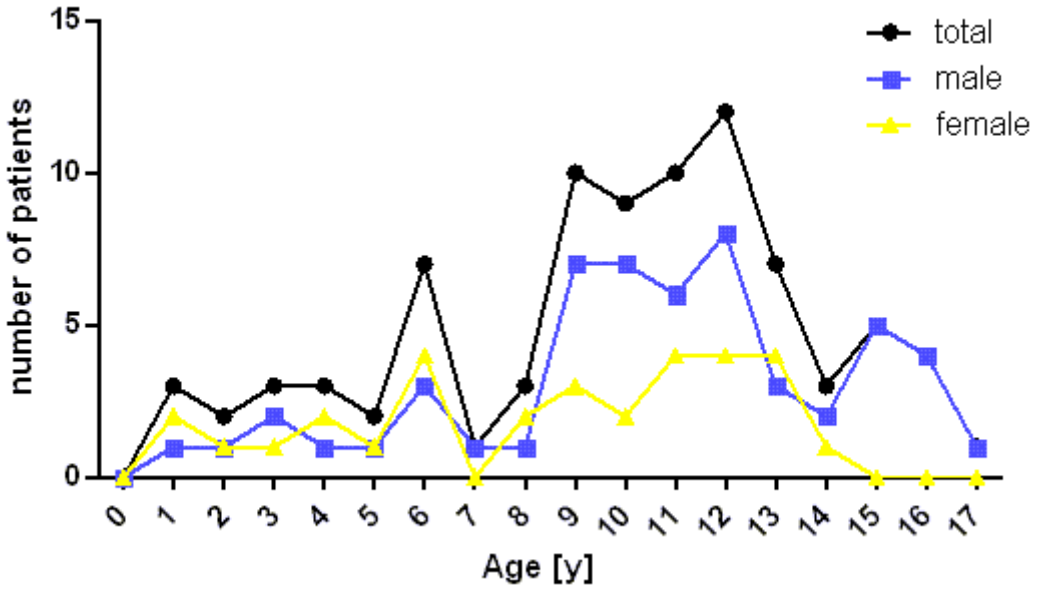

Figure 14: Fractures of the thumb

Almost half of the accidents causing these fractures occurred at sports facilities (n=35; 41.2%), followed by injuries at home (n=18; 21.2%) and in schools or kindergartens (n=9; 10.6%).

Falls on a level surface occurred while playing foot-, basket-, and volleyball, skiing, sledging, ice skating, and running (n=37; 43.5%). In more than a third of the cases (n=33; 38.8%) children got injured by contact with a person or an object. They were hit by balls or trapped their fingers in doors. In 8 children (9.4%) fractures were documented as a consequence of falling from a height less than 3 meters e.g. from wall bars, beds, hammocks, and trampolines.

3.3.14 Fingers

Phalangeal fractures of the hand (excluding the thumb) were the most common fractures of the pediatric hand. They were noted in as many as 477 children and adolescents with 273 being male (57.2%) and 204 female patients (42.8%). The average age was 10.2 years. The age distribution was strikingly similar to the patients who sustained fractures of the thumb with a peak at 10 years of age **(Figure 15)**.

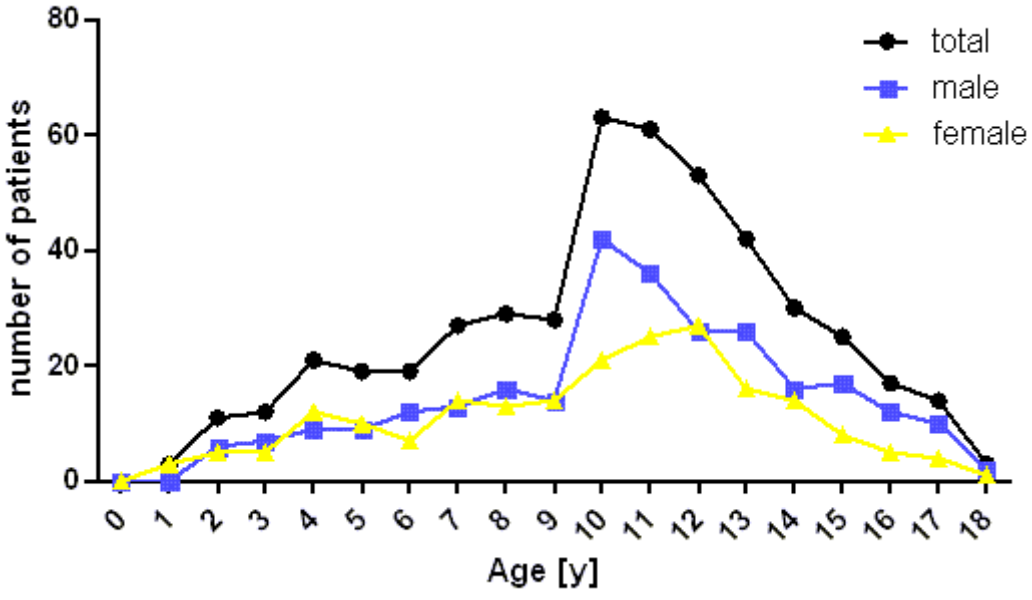

Figure 15: Finger fractures

The accident sites were sports facilities (n=221; 46.3%), at home (n=84; 17.6%) and in the yard (n=80; 16.8%).

Half of the cases (n=240; 50.3%) were related to falls on level surface during foot-, basket-, and volleyball, and running. More than a third of the fractures (n=183; 38.4%) resulted from a contact with a person or an object. Children were hit by balls, stones, and during fights and they trapped their fingers in doors. In 5% of the cases children fell from a height less than 3 meters and had accidents on bicycles or skates, respectively.

3.3.15 Pelvis

Fractures of the pelvis were rare and typical “male” injuries. Only 15 children aged between 5 and 16 years with an average age of 13.2 years sustained this type of fracture. The male to female ratio was 6.5:1 (boys: n=13; 86.7%; girls: n=2; 13.3%).

60% of the fractures (n=9) occurred at sports facilities, followed by injuries in the yard (n=4; 26.7%) and in traffic (n=2; 13.3%).

Interestingly, the majority of the patients (n=11; 73.3%) fell on level surface while playing football and running. The remaining mechanisms causing fractures of the pelvis occurred as consequence of falling from heights less than 3 meters, falls as a pedestrian, an accident with a motorbike, and skates (each n=1; 6.7%).

3.3.16 Femur

Proximal femur

Fractures of the proximal femur were documented in 9 children aged between 5 and 16 years with an average age of 13.1 years. The male to female ratio was 3.5 to 1(boys n=7; 77.8%; girls n=2; 22.2%).

More than the half of the cases (n=5; 55.6%) occurred at sports facilities, followed by accidents in traffic (n=3; 33.3%) and in the yard (n=1; 11.1%).

The most common mechanism of fractures of the proximal femur were falls on a level surface (n=4; 44.4%) while playing football and running. A third of the children (n=3; 33.3%) sustained accidents on motorbikes. Two children fractured their proximal femur as a consequence of falls from heights less than 3 meters; in particular, one child was falling from a tractor, another was injured while snowboard jumping.

Femur shaft

Fractures of the femur shaft were diagnosed in 21 children. The group of patients consisted of 15 boys (71.4%) and 6 girls (28.6%). The average age was 7.1 years. A peak was noted at the age of 1 year when children start to walk.

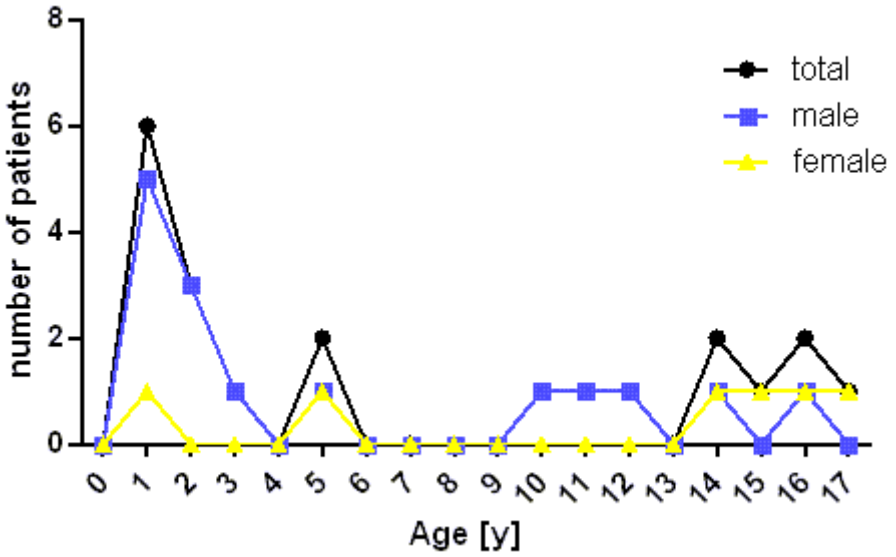

Figure 16: Distribution of gender and age in femur shaft fractures

The most common accident sites were at home and in traffic with both contributing 33.3% (n=7), followed by accidents in the yard (n=3; 14.3%), sports facilities and playgrounds (each n=2; 9.5%).

Falls on a level surface (n=5; 23.8%) such as stumbling, running at an early age and sledging was a commonly described mechanism. Falls from a height less than 3 meters like falls from ladders, beds, staircases, and horses were documented in 4 cases as well as accidents with bicycles or skates and motorbikes (n=4; 19.0%).

Distal femur

The male to female ratio of patients with fractures of the distal femur was 60% to 40% in a collective of 10 children. The average age in this group was 9.4 years with a peak of incidence at 8 years of age.

Most of the accidents happened at sports facilities (n=6; 60%), followed by accidents in traffic (n=2; 20%) and playgrounds (n=1; 10%).

Falls on a level surface were documented in 4 children (40%). Examples for this mechanism were accidents during skiing, sledging, and even an epileptic seizure in one patient. In two cases falls from a height caused fractures of the distal femur as well as contacts with persons or objects, and accidents with bicycles or skates (each n=2; 20%).

Overall, fractures of the distal femur were caused by high speed trauma in most cases.

3.3.17 Patella

Fractures of the patella were very uncommon; we documented only 10 children aged between 7 and 16 years. Interestingly only one of these patients was female. The average age for patella fractures was 12.8 years and the peak of incidence was at the age of 16 years **(Figure 17)**.

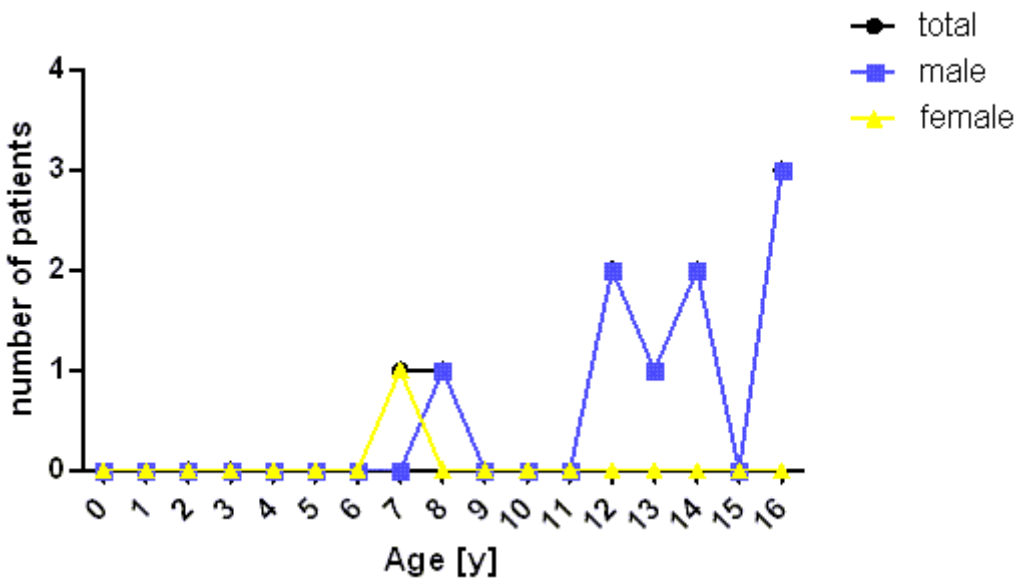

Figure 17: Male to female distribution of patella fractures

In 4 patients (40%) accidents causing fractures of the patella occurred in traffic, another 3 had sports related injuries (30%). The remaining accident sites were documented at home, in the yard, and in school or kindergarten (each n=1; 10%).

The most common mechanism was a fall on level surface during snowboarding, stumbling, running; playing football, and ice hockey (n=6; 60%). Accidents on motorbikes happened in 3 children (30%), while cycling caused the remaining fracture of the patella.

3.3.18 Tibia

Proximal tibia

In 34 children aged between 1 and 16 years fractures of the proximal tibia were documented. The male to female ratio was nearly 1:1 (44.1% male, 55.9% female). The average age was 6.6 years.

In approximately one third of the cases (n=11; 32.4%) the accidents occurred at playgrounds, while in 17.6% (n=6) children got injured at home. Sports and traffic related fractures were contributing 14.7% (n=5) each.

Falls from a height less than 3 meters (falling from beds, slides, trampolines and sofas) represented the most common mechanism (44.1%). 9 children (26.5%) got injured by falls on a level surface. Examples for this kind of mechanism were skiing, sledging, running, playing football and rugby. Cycling caused 3 fractures of the proximal tibia (8.8%).

Tibia shaft

Fractures of the tibia shaft were documented in 78 children and adolescents aged between 1 and 16 years with an average age of 7.5 years. While 46 patients (59.0%) were male, 32 patients (41.0%) were female.

The majority of tibia shaft fractures (n=44; 56.4%) happened at sports facilities, followed by accidents in traffic and playgrounds (both n=10; 12.8%). Eight children (10.3%) sustained the injury at home.

The leading mechanism of accident (n=48; 61.5% of the patients) was falling on a level surface while playing football, skiing and sledging. Falls from a height less than 3 meters caused 15.4% (n=12) of the fractures. Examples for this mechanism were falls from slides, swings, staircases, sofas, and trampolines. Accidents related to bicycles, skates, and scooters were documented in 9 children (11.5%).

Distal tibia

Fractures of the distal tibia were diagnosed in 84 children until the age of 18 years. Almost two thirds of the patients were male (n=54, 64.3%). While one peak of incidence occurred in patients one year of age, a second peak was seen in patients between 10 and 15 years of age.

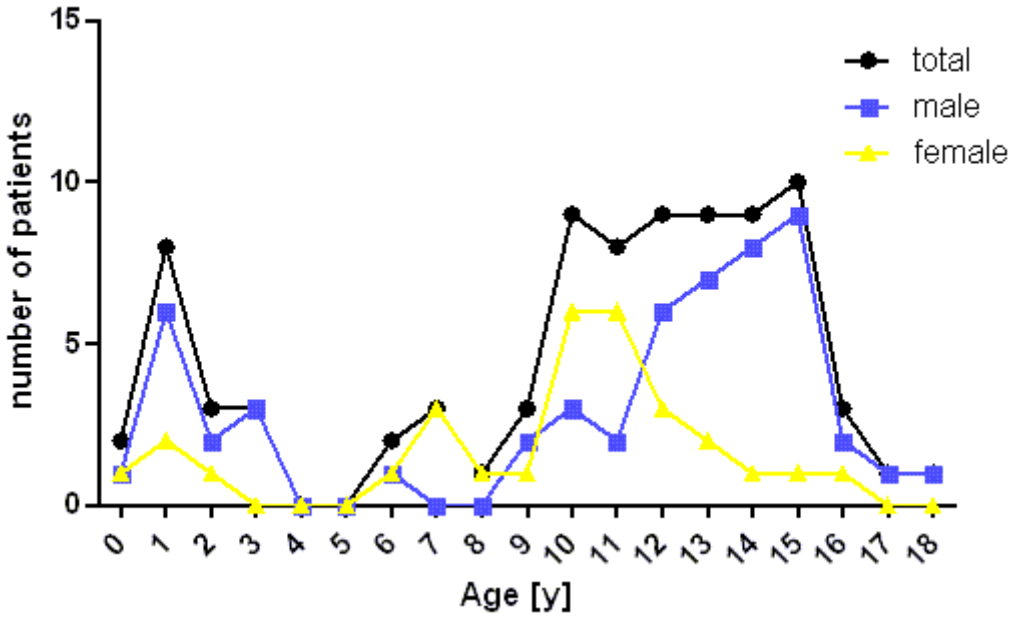

Figure 18: Fractures of the distal tibia

More than a third of the fractures (n=31; 36.9%) occurred at sports facilities, followed by accidents in the yard (n=15; 17.9%), and at home (n=12; 14.3%). Traffic accidents caused 11 (13.1%) fractures of the distal tibia.

In about half of the cases (47.6%, n=40) the fractures were caused by falls on a level surface during skiing, snowboarding, ice skating, sledging, and running. 19% of the patients fell off slides, swings, staircases, trampolines, climbing walls and chairs. In 10 cases (11.9%) children got hit by objects or got hurt during fights. Cycling and skating accidents were documented in 10 children.

3.3.19 Fibula

Proximal fibula

Fractures of the proximal fibula were extremely rare injuries. In only 3 children (2 boys and 1 girl) we were able to diagnose this injury. The accidents happened at home, in the yard and in traffic. The mechanism causing these injuries was direct trauma by falling from a bed on the edge of a table, getting hit by a sledge or a car.

Fibula shaft

In 4 children (3 boys, 1 girl) fractures of the fibula shaft were diagnosed as a consequence of accidents at home, in the yard and in traffic. The children fell from a tree, got involved in an accident with a motorbike or collided with another person.

Distal fibula

Fractures of this part of the fibula were the most common injury of this bone. 55 children and adolescents aged between 2 and 18 years (32 boys (58.2%) to 23 girls (41.8%)) sustained this type of lesion. The average age was 11 years and two peaks of incidence at 8 and 14 to 15 years could be identified **(Figure 19)**.

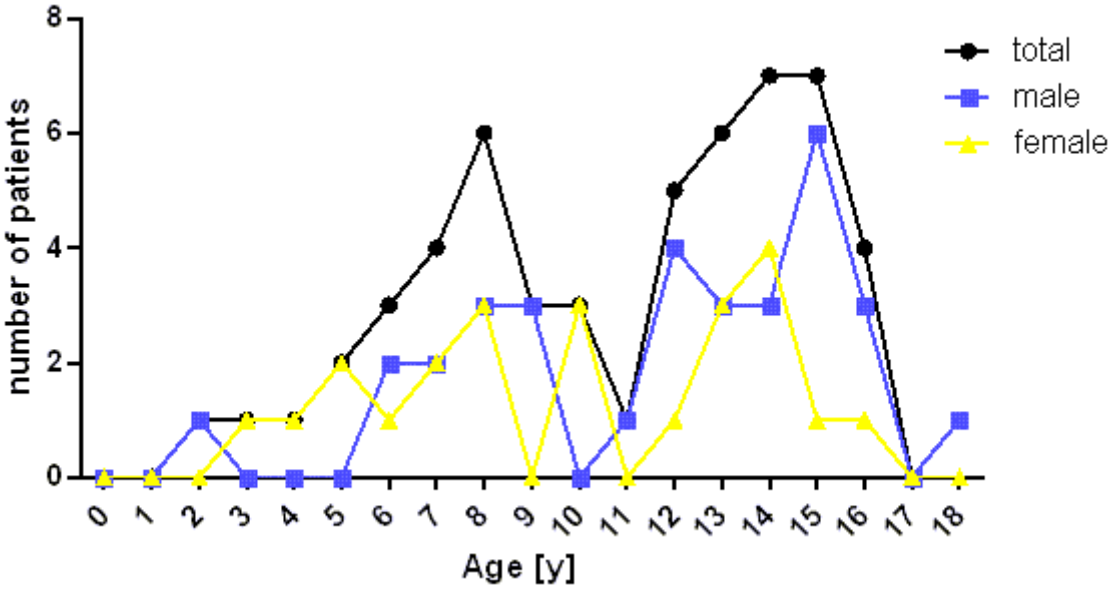

Figure 19: Two peaks of incidence in distal fibula fractures

The most common accident sites were sports facilities and the yard each contributing 29.1%. In 8 children (14.5%) accidents causing fractures of the distal fibula occurred at home, followed by 7 accidents (12.7%) in traffic.

Falls on a level surface were responsible for 60% of the fractures (n=33). Examples for this mechanism were playing football, volleyball, and tennis, as well as running and stumbling. In 23.6% (n=13) children fell of a height less than 3

meters like trampolines or got hurt while jumping. Cycling and skating caused 5 fractures of the distal fibula (9.1%).

3.3.20 Tibia/Fibula

Proximal Tibia/Fibula

Fractures of the proximal lower leg were diagnosed in 2 boys and 2 girls aged between 1 to 10 years. Sports related fractures occurred in 3 children. The mechanisms causing fractures were collisions with a person and during sledging.

Tibia/Fibula shaft

In 23 patients (14 (60.9%) boys and 9 (39.1%) girls) fractures of the shaft of the lower leg were diagnosed. The average age of the patients was 10.4 years.

The most common accident sites were sports facilities (n=9; 39.1%). Accidents in the yard and in traffic were diagnosed in 5 cases (21.7%) each. Accidents at home and playgrounds were rare (each n=2; 8.7%).

Skiing and running caused 9 fractures (39.1%) while falls from a height less than 3 meters were responsible for 5 of those fractures (21.7%).

Distal Tibia/Fibula

The most common fractures of the lower leg were fractures of the distal part of the tibia and fibula. In 44 children and adolescents with an average age of 11.0 years this type fractures was diagnosed. The majority of the patients were male (n=33; 75%) and only a quarter of the patients (n=11) were female. A gender independent peak of incidences was documented at the age of 15 years.

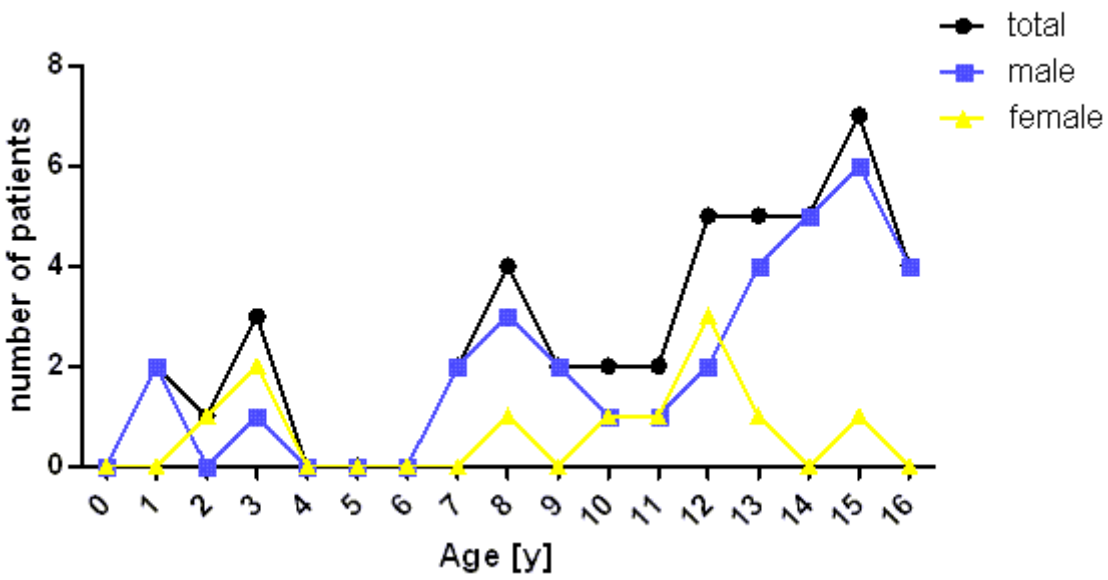

Figure 20: Distribution of distal lower leg fractures

Accidents at sports facilities causing fractures of the distal tibia/fibula were recorded in 18 children and adolescents (40.9%), followed by 15 cases (34.1%) in traffic and 6 cases (13.6%) in the yard.

More than the half of the documented patients (n=24; 54.5%) got injured by falling on a level surface during skiing, sledging, playing football, running, and stumbling. Seven children (15.9%) got involved in an accident with a motorbike, followed by 6 (13.6%) accidents involving non motorized bikes.

3.3.21 Tarsal bones

Fractures of one or more tarsal bones were recorded in 21 children aged between 6 to 16 years. This type of fracture represented an injury of older children with an average age of 12.6 years and two peaks of incidence at 12 and 16 years. The vast majority of the patients were male (71.4%; female: 28.6%).

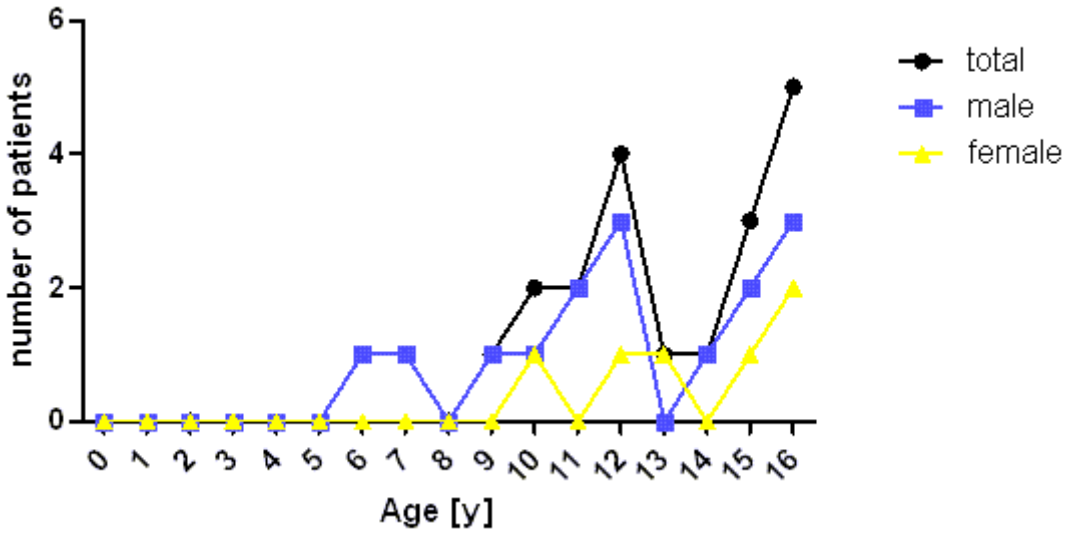

Figure 21: Tarsal bone fractures

In one third of the cases (n=7; 33.3%) children got injured at sports facilities, followed by accidents in traffic (n=5; 23.8%) and at home (n=4; 19.0%).

Crushes with horses, other persons, and furniture caused 7 (33.3%) fractures in this group. Five (23.8%) fractures were caused by falls on a level surface while playing football, skiing, and stumbling. Falls from a height more than 3 meters (waterfalls, fall out of the window, roping down) and accidents with motorbikes occurred in 3 cases each (14.3%).

3.3.22 Metatarsal bones

Fractures of the metatarsal bones were recorded in 164 children and adolescents aged between 1 and 17 years. 103 fractures (62.8%) were diagnosed in boys and 61 (37.2%) in girls. The average age of the patients was 8.8 years.

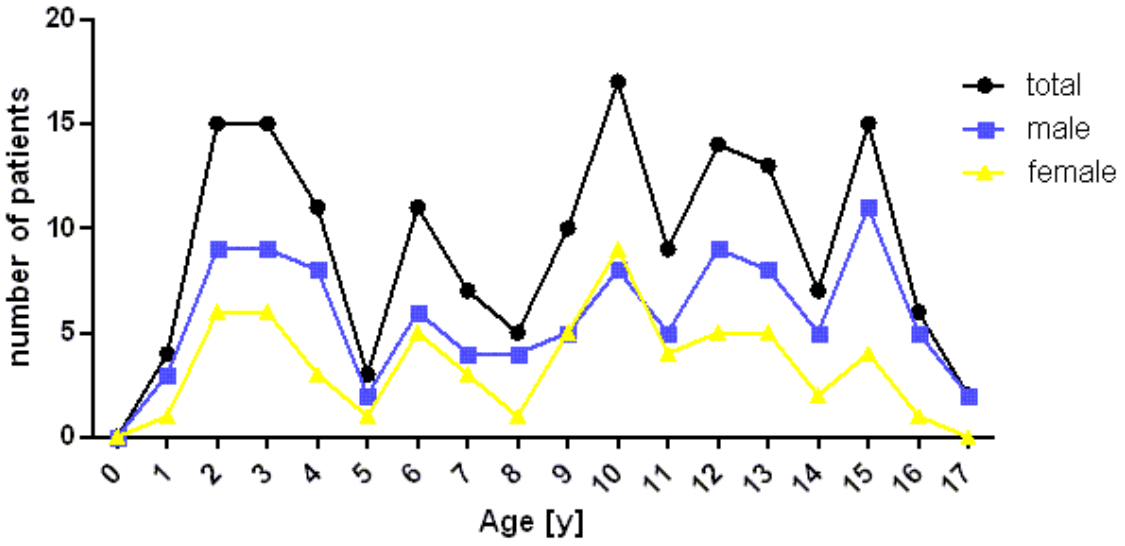

Figure 22: Fractures of metatarsal bones

Approximately a third of the fractures (n=56; 34.1%) of metatarsal bones occurred at sports facilities, while accidents happened at home in 23.8% (n=39). Accidents outdoors in the yard caused 25 fractures (15.2%).

Falls on a level surface while playing football, running, stumbling, and jumping were responsible for 71 fractures (n=43.3%), while falls from a height less than 3 meters were recorded in 31.1% of the cases (n=51). Examples for this mechanism were falls from beds, chairs, staircases, and playground equipment. In 14.0% (n=23) children get hit by a crush with a person or an object.

3.3.23 Hallux

Fractures of the big toe were diagnosed in 96 patients aged between 1 and 17 years with an average age of 10.9 years and a main peak at the age of 13 years. More than half of the fractures were recorded in boys (n=61; 63.5%). The remaining 35 fractures were seen in girls (36.5%).

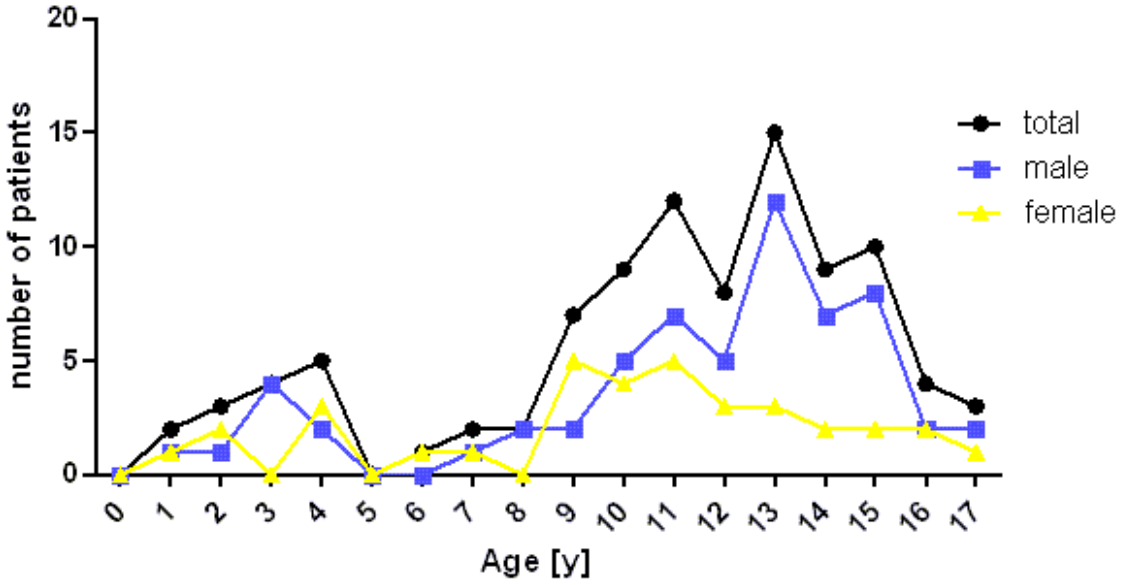

Figure 23: Gender and age distribution of big toe fractures

Exactly half of the fractures (n=48; 50%) happened at sports facilities, followed by 22 cases (22.9%) occurring at home. Accidents at home, at playgrounds, and in traffic were each responsible for 6 fractures (6.3%).

Nearly half of the fractures (n=47; 49.0%) were caused by crushes with furniture, playthings, horses, and kicks. In about a third of the cases (n=33; 34.4%) falls on a level surface such as falls while playing football, basketball, or running were the responsible mechanism of accident.

3.3.24 Toes

Similarly to fractures of the fingers, fractures of the toes were the most frequent injury of the pediatric foot skeleton. 213 patients (135 boys; 63.4% and 78 girls; 36.6%) aged between 2 and 18 years sustained a single or multiple fractures of the toe. The main peak of incidence was seen at the age of 12 years **(Figure 24)**.

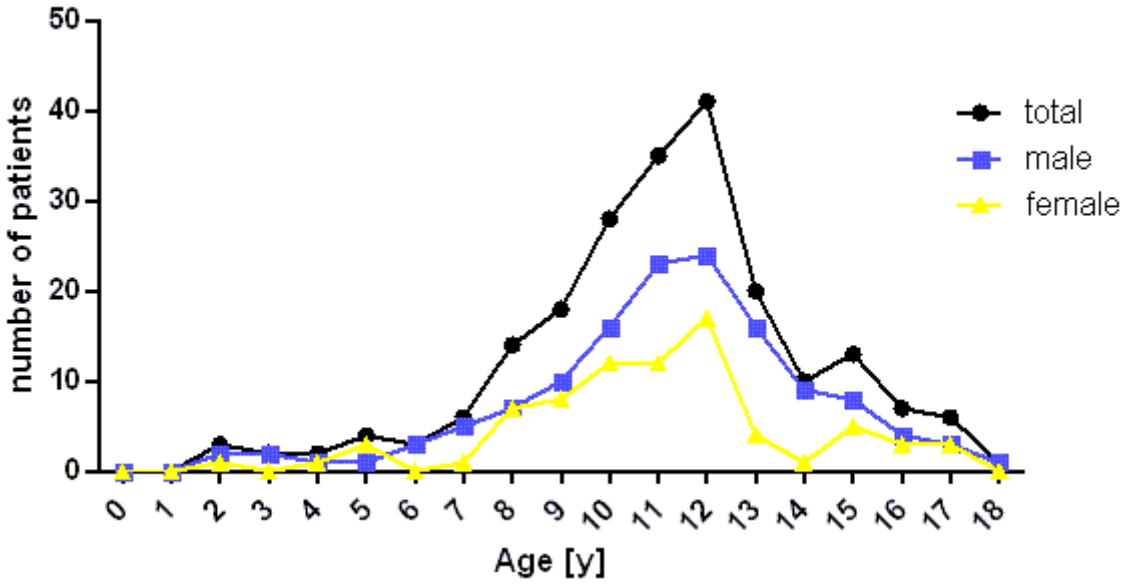

Figure 24: Fractures of the toes in girls and boys

Accidents at sports facilities occurred in 85 patients (39.9%), while 31.9% of the children got injured at home. Fractures happening at school or kindergarten were recorded in 26 cases (12.2%).

In 59.2% the fractures happened as a consequence of contact with persons or objects. Examples for this mechanism were crushes with chairs and desks, football and martial arts associated accidents. Falls on a level surface occurred in 67 patients (31.5%) such as falls during football and running. Falls from a height less than 3 meters rarely (5.6%) were responsible for this type of fracture:

3.4 Sports related fractures

A significant portion of the recorded fractures in this study happened during sports activities. Therefore the characteristics of the most common sports activities causing fractures in children and adolescents were analyzed separately.

Accidents related to playing *soccer* were recorded in 427 patients (12.7% of all patients included in the analysis). A male predominance was obvious, with 90% of the patients sustaining a fracture while playing soccer beeing male. The most common fractures in this group were fractures of the distal radius (n=111), fingers (n=64), toes (n=40), and the big toe (n=34).

Other ball sports accidents (basket-, volley-, handball, tennis, and bowling) were more frequently related to girls and occurred in 168 children (97 girls and 71 boys, respectively). The fingers (n=122), the thumb (n=9) and the distal radius (n=9) represented the most commonly affected bones.

Cycling accidents caused 232 fractures in 159 boys and 73 girls. Most of fractures occurred in the upper extremity. While 42 fractures of the distal radius could be recorded, fractures of the distal radius/ulna (n=25), clavicle (n=24) and the distal humerus (n=23) were also very common.

121 patients (71 boys and 50 girls) sustained a fracture during *gymnastics*. The most common fractures of this group were fractures of the distal radius (n=22), distal radius/ulna and toes (both n=12), and fingers and metatarsal bones (both n=10).

Due to geographic circumstances, *skiing* is a very common sport in Austria. Fractures related to this sport were documented 119 patients. Again a male predominance was obvious (82 male and 37 female patients). The most common fracture was the tibia shaft fracture (n=36). Fractures of the metacarpal bones (n=11) and the proximal humerus (n=10) were also caused by skiing (**Figure 25**).

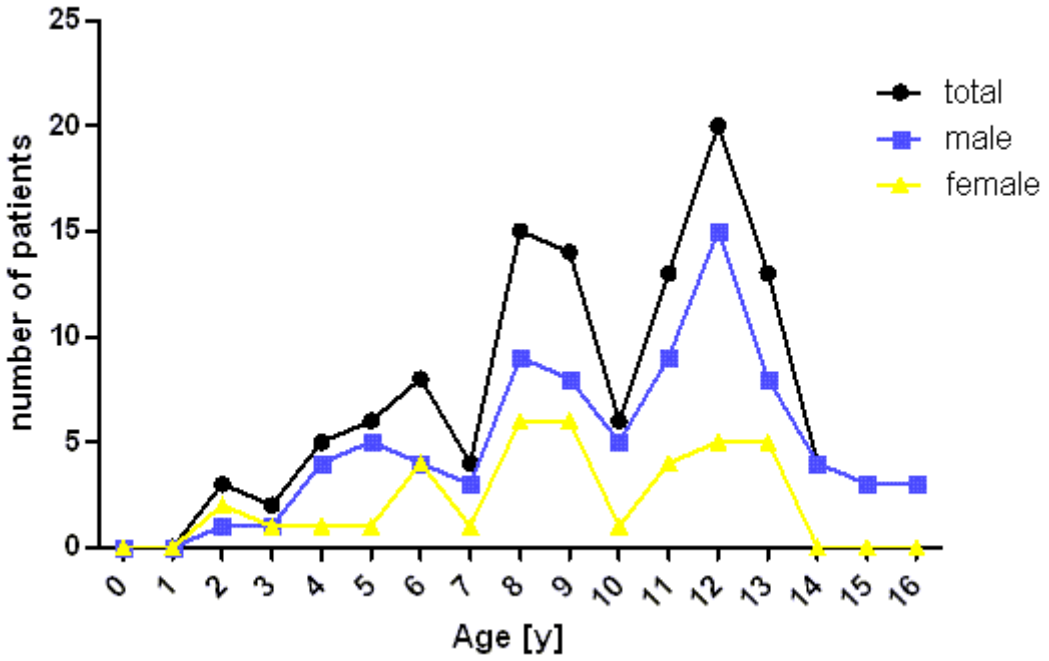

Figure 25: Distribution of gender and age in skiing fractures

Furthermore 71 fractures in 47 boys (66.2%) and 24 girls (33.8%) were related snowboarding. The distal radius (n=34) and the distal forearm were most commonly fractured (n=12), followed by fractures of the proximal humerus (n=9).

4 Discussion

Trauma still is the leading cause of death in children and adolescents. One in four children will sustain an unintentional injury requiring medical care each year [3]. A large proportion of pediatric trauma consists of fractures. About a third of all boys and girls can expect to have a fracture before the age of 16 [6]. In order to prevent fractures and to reduce the costs, the knowledge of the epidemiology of pediatric fractures plays a pivotal role. The aim of this study was to describe the demographics, circumstances of injury and distribution of fractures in a cohort of pediatric patients treated at our Department in a period of 23 months. 3,339 children sustaining 3,421 fractures were included.

It has been shown previously that fractures in children exert significant differences to fractures in adults [18]. Firstly, fractures in children have twice the incidence of fractures in adults. Secondly, in adults an equal distribution between the male and female gender can be found, while in children there is a strong male predominance [18]. A previously undertaken study including 2,168 children sustaining a fracture in Edinburgh, Scotland showed that 61% of the included subjects were male [6]. Rennie and coworkers reported a gender ratio of 51:49% of males to females in their census area. In our respective census area the distribution is equal with 51% male (n=914,367) and 49% female (n=869,900) children and adolescents aged between 0 and 19 years [19]. Also, we can confirm the distribution described by Rennie et al. and other studies with 61% of the patients in our study group being male [6, 20, 21]. However, our results show that certain fracture types such as proximal fractures of humerus, radius and tibia are typical “female fractures”.

A noteworthy difference between the results of the present study and the results of the study describing the epidemiology of fractures in Edinburgh may be the distribution of lower and upper limb fractures. While Rennie and coworkers describe a strong tendency towards upper limb fractures in children (80% upper limb versus 20% lower limb fractures), we can not confirm this finding. In our group of patients 60% of all fractures affected the upper limb therefore making this

distribution comparable to results found in adults. Another study describing 2,477 fractures in children of up to 12 years of age confirmed the findings of the present manuscript and found upper limb fractures in 60% of the affected subjects [20]. Hence, the meta-analysis of the fracture distribution demonstrates incoherent data which may be attributed to causalities in the local regions. However, the following five fractures (distal radius, fingers, distal forearm, distal humerus and clavicle) represent more than 50% of all fractures in our study group which is similar to previously published reports [6, 21].

Starting with birth and extending to the age of 12 years, all major series have demonstrated a linear increase in the incidence of fractures by age [6, 20, 21]. The peak of fracture incidence in our group of patients was at the age of 11 and 12 years. While up to this age an almost equal distribution between males and females can be seen, the percentage of injured boys versus girls continues to be significantly different in the older age groups. These differences can be explained with fracture-causing activities in which there is a male dominance in participation such as soccer and bicycle riding [22]. However, the incidence of fractures can not be explained by differences in the rate of exposure alone. Therefore, behavior may also play a certain role. The difference in the rates of fractures occurs at an age when behaviors change and boys develop a more aggressive and risk-taking behavior. At puberty leisure time-activities get more gender specific. Therefore, remarkable differences between boys and girls occur. Boys most often get hurt in competitive sports like football while girls fracture their bones during non-competitive sports like horse riding or ice skating. The difference in injury rates between genders may change in the future since girls will participate more often in activities with increased physical risks [22].

Recently, a lot of attention has been devoted to finding a correlation between bone mineral density and bone turnover and the occurrence of fractures in children. Goulding stated that the peak in early puberty may be correlated to the high bone turnover at this age [23]. Michalus and coworkers have shown that a decreased bone mineral density measured by DXA densitometry is the most frequent risk factor for bone fractures in children [24]. It has been reported that the mean bone mineral density (BMD) measured with DXA in girls with forearm

fractures has been found lower than the respective values in control girls without a history of a fracture. According to Baroncelli et al. the mean BMD values assessed by ultrasound in children with bone and mineral disorders are lower in patients with fractures compared with patients without fractures [25]. A study from our institution confirmed these results in a group of healthy school-age children [26]. It is still controversial, however, to what extent exogenous and endogenous factors influence bone quality [27, 28] According to Cvijetic et al., [29] body weight and physical activity correlate positively with BMD. On the other hand, other authors [30] found no correlation between dietary intake, physical activity, and bone mineralization values. One limitation of our survey is that these factors were not documented in our group of patients.

In children younger than one year of age fractures of the skull caused by falls were recorded most frequently. Other authors exclude skull fractures from their analysis because in their institutions skull x-rays are not performed routinely. Since it has been shown that the relative risk for intracranial injury is increased almost fourfold in the presence of a skull fracture [31], it is the local policy to include skull x-rays in the initial examination of children with a history of trauma to the head. Therefore, we have included skull fractures into our analysis. A possible explanation for the noteworthy frequency of skull fractures in children younger than one year of age (65% skull fractures) is the relative size of the cranium. The cranium in children is larger related to the rest of their body and already at the age of 2 years it reaches 80% of its mature size making the head an exposed part of the body for injuries [32]. This anatomic correlation of larger head size in young children when compared to the torso combined with the lack of defense movements is responsible for the high incidence of skull fractures in this age group.

Sports related fractures represent a large number of cases in this study. Obviously, these injuries vary between different countries. Rennie and coworkers have shown that soccer, skiing and rugby were the most common sports that cause fractures in children [6]. A strong male predominance of sports injuries (male to female ratio of 2:1) has been described in the literature. While we were able to confirm soccer and skiing as typical activities causing pediatric fractures,

rugby did not play a role in our patients due to the under-representation of this sport in our country.

Among boys soccer injuries and among girls netball injuries were the most common causes of fractures in a survey of 255 children with sports related injuries [33]. Confirming these findings, we found soccer related fractures as typical male injuries, while netball injuries like basket-, volley- and handball were a girls´ domain.

Skiing and snowboarding are very popular winter sports in Austria. Rennie et al. [6] have shown that children in Edinburgh sustain skiing related fractures at an average age of 11.5 years compared to 9.6 years in our patients. This lower age of our age may be related to the fact that nearly every child in Austria learns to ski already at a young age. However, skiing injuries still may be under-represented in this study because of the geographical position of our Department where no skiing-area is in close proximity. Most children get treated in hospitals near skiing-area and therefore we are not able to draw a firm conclusion about fractures related to skiing from our data.

5 Conclusion

In this study 3,421 fractures of 3,339 children and adolescents are documented in a trauma surveillance system. We demonstrated the distribution of gender, age, causes, and circumstances of injuries. The distal radius, the phalanges of the fingers, the distal forearm, the distal humerus, and the clavicle were most commonly fractured bones. Similar to previously published literature we showed an increase in the incidence of fractures starting at an age of 11 and 12 years. Moreover, we confirmed a male predominance commenced at the same age. This phenomenon may be related to leisure time behavior with boys preferring riskier activities and taking part in competitive sports more often. Sports in general and especially competitive sports were one of the most common activities were children and adolescents get injured. The results of this study may help to set priorities for injury prevention in childhood and may help to develop future prevention strategies. These prevention strategies should not aim to reduce the level of exposure but should increase the risk-awareness and encourage young people and their parents to use safety equipment.

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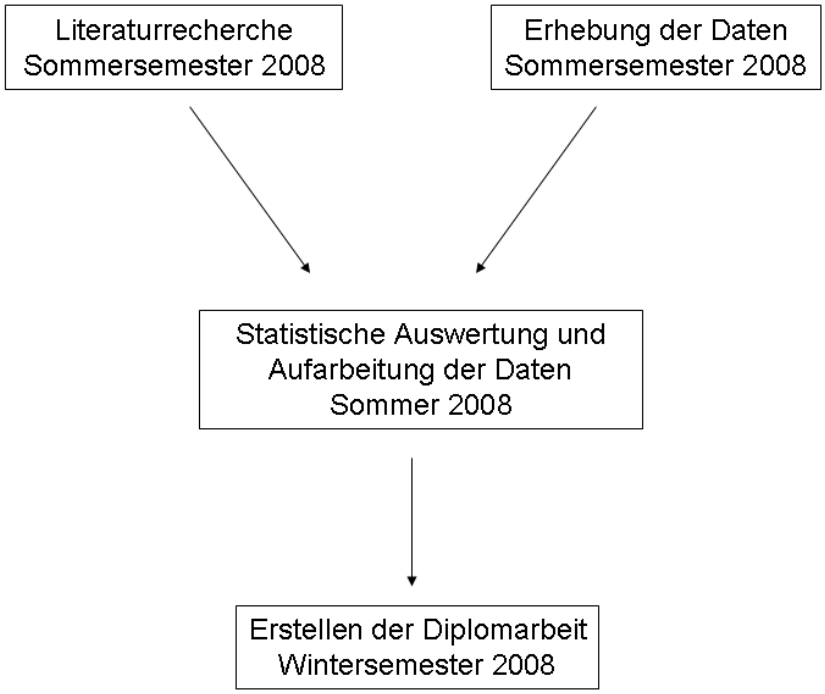
Appendix A: Project Plan



Appendix B: Location and Circumstances of Accidents

Location

at work	construction site	outdoor (forest/meadow)	garden
home	kindergarten (outdoor)	kindergarten (indoor)	farm
school (outdoor)	school (indoor)	school (gym)	playground
sports facility	Traffic	way to school	others (specify):

Circumstances

Swimming

collision in pool	fall near the pool	diving platform	changing room
water slide	others (specify):		

Bites (animal/human) + injuries by animals

Dog bite	cat-bite	paw	human bite	horse bite
horse-kick	rodent	others (specify):		

Foreign bodies

aspiration	swallowed	soft tissue	others (specify):

Farm accidents

fall from height	tractor	other machines	others (specify):

Violence

hit by object	hit by opponent	others (specify):

Cut/stab/soft-tissue

car door	garden tools	glass	folding chair	explosives
kitchen food processor	knife	lawn mower	saw(circular)	weapon
tools (hammer..)	others (specify):			

Other play/sports injuries

tricycle	golf	bouncy castle	inline skater	bowling
running	rollerblades	scooter	trampoline	athletics
collision	others (specify):			

Playground

carousel	junglegym	slide	sandbox	swing
seesaw	others (specify):			

Fall

pram	baby carrier	baby-walker	bunk bed	height (window…)
level surface without contact		level surface against object		stairs
high chair	diaper changing table	others (specify):		

Ingestion of chemical substances

drug	base	acid	others (specify):

Active traffic participant

car	bicycle	pedestrian	motorcycle	others (specify):

Passive traffic participant

car passenger	bicycle passenger	motorcycle passenger	train/tram
bus	others (specify):		

Ball sports

badminton	basketball	soccer	handball	tennis
volleyball	dodgeball	others (specify):		

Winter sports

bob	cross-country skiing	sledge	ice skating	skiing
snowboard	others (specify):			

Toys

jam	cut	stumbling	others (specify):

Hit by object

Others (specify):

Curriculum Vitae

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Birth date:	18th August 1983
Place of birth:	Graz

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10/2003 –	course studies for human medicine at the Medical University of Graz
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09/2007	**Department of Internal Medicine**, LKH Fürstenfeld
09/2006	**Department of Internal Medicine**, LKH Fürstenfeld
09/2005	**Department of Orthopaedics,** LKH Bad Radkersburg

FOREIGN LANGUAGES, SOCIAL INTERESTS

Languages	English, French and Latin
Social interests	Scouting (leading between 6 and 10 years old boy scouts for 5 years and organising several scout camps)
Music	playing drums and guitar