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Using macroscopic and ultrafast spectroscopic approaches to decouple the effect of structural properties on the (photo)reactivity of manganese oxides

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Épidémiologie des fractures des membres inférieurs en pédiatrie dans un centre de soins tertiaires en Suisse.

Epidemiology of paediatric lower extremity fractures in a tertiary care center in Switzerland.

THESE

préparée sous la direction du Professeur Pierre-Yves ZAMBELLI
(avec la collaboration du Docteure Sophie MERCKAERT)

et présentée à la Faculté de biologie et de médecine de
l'Université de Lausanne pour l'obtention du grade de

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Objectif

20% de toutes les fractures de l'enfant surviennent sur le membre inférieur. Cet article observe l'épidémiologie et les différents types de fractures du membre inférieur dans la population pédiatrique, venant consulter dans un hôpital de référence tertiaire suisse.

Méthode

Il a été étudié une population de patients âgés de moins de 16 ans, présentant une fracture du membre inférieur, sur une période d'une année. Les données analysées étaient l'âge, le genre, le côté atteint, la saison de l'année, le mécanisme, le type de fracture et le traitement prescrit.

Résultats

Les fractures du membre inférieur représentent 23% du total de toutes les fractures rapportées, avec une moyenne d'âge de neuf ans et six mois. Le tibia, avec 94 fractures (38%), est l'os le plus atteint. Un pic d'incidence peut être observer en hiver et 24% des fractures du tibia sont dues aux sports de glisse. Au total, 82% des fractures ont été traitées par immobilisation plâtrée avec ou sans réduction fermée préalable, et seulement 18% ont nécessité une chirurgie.

Conclusion

Les sports de glisse semblent être le plus grand pourvoyeur de fractures du tibia dans notre région. Néanmoins, seulement 18% des fractures nécessitent l'intervention d'un chirurgien orthopédique, démontrant l'importance de former les assistants/internes en Pédiatrie dans la prise en charge conservatrice des fractures de l'enfant.

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ORIGINAL ARTICLE

Epidemiology of paediatric lower extremity fractures in a tertiary care center in Switzerland

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Abstract

Purpose About 20% of all fractures in children occur at the lower extremity. This study aims to investigate the epidemiology and injury pattern of lower extremity fractures within the pediatric population consulting a tertiary referral hospital in Switzerland.

Methods Study population included all patients up to 16 years presenting with a lower extremity fracture over a period of one year.

Recorded data were age, gender, side, season of the year, mechanism, type of fracture and applied treatment.

Results Fractures of the lower extremity represent 23% of all fractures with a mean age of 9 years and 6 months.

The tibia, with 94 fractures (38%), represents the most frequently injured bone. Peak incidence is seen in winter and 24% of tibia shaft fractures were due to board sports.

Overall, 82% of fractures were treated by cast with or without closed reduction, and only 18% requested surgery.

Conclusion Board sports seems to be a leading cause of tibial shaft fracture in our region. Nevertheless, only 18% of fractures had recourse to an orthopedic surgeon, hence the importance of the teaching quality of pediatric residents for conservative fracture treatment.

Keywords Fractures · Epidemiology · Pediatric injuries · Lower extremity

Introduction

Pediatric fractures account for 10–25% of injuries in children and are a common reason for emergency consultation [1, 2]. The life-time risk to sustain a fracture from birth to the age of 16 years is up to 49% for boys and 40% for girls [1, 3] with considerable activity restriction and subsequent high socio-economic impact [4, 5].

Data from the federal department of statistics in Switzerland related to 2016 confirmed that traumatic injuries represented the first reason for hospital admission in children aged between 6 and 10 years and accounted for 9.2% of all diagnosis in children aged between 0 and 14 years old [6]. In this population, lower extremity injuries represent about 20% of all fractures, the large majority occurring at the tibia [7–9].

Few reports have analyzed the epidemiologic data of pediatric fractures within the Swiss population, especially if there is a correlation between the high activity in board sport and the prevalence of lower extremity fractures [7]. Most available data come from other European countries [5, 8–11].

Epidemiology and injury pattern analysis are fundamental to improve prevention and optimize treatment options [8, 12].

The present paper aims to investigate the epidemiology and injury pattern of lower extremity fractures within the pediatric population consulting a tertiary referral hospital in Switzerland.

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Materials and methods

The present study was approved by the Human Research Ethics for analysis and subsequent publication of the identified data.

We performed a monocentric retrospective data collection of all pediatric traumatic injuries referred to the Children's University Hospital of Lausanne between May 2017 and May 2018. The Children's University Hospital of Lausanne is a primary care hospital for the surrounding population, as well as a tertiary referral hospital for pediatric orthopedics. The hospital drains a large part of pediatric trauma in the French speaking region of Switzerland.

Study population included all patients up to 16 years old presenting with a lower extremity fracture.

Radiographic and clinical data were recorded by a resident and verified by a pediatric orthopedic surgeon (EC, SM).

Recorded data were age, gender, side, season of the year, mechanism, type of fracture and applied treatment. Femoral and leg fractures were classified according to the AO classification system [13]. Open fractures were classified according to the Gustilo classification [14].

The following definition of the seasons was used: Winter (21st of December till 20th of March); spring (21st of March till 20th of June); summer (21st of June till 20th of September) and fall (21st of September till 20th of December).

Fracture treatment were: cast with or without closed reduction, closed reduction with internal fixation and open reduction with internal fixation.

Initiation of treatment by cast without reduction was mostly done by the emergency department after approval by a pediatric orthopedic surgeon. Follow-up was done by the pediatric orthopedic team at the outpatient clinic. All other treatment options were done by the orthopedic team.

The mechanisms of fracture and treatments were recorded and extracted from digitalized patient's charts.

Study parameters were analyzed and tabulated using standard descriptive statistics.

Results

Study population

We analyzed data of 1008 patients consulting our emergency department for an overall number of 1066 of fractures; overall mean age was of nine years and seven months (2 months–16 years). Boys accounted for 57% of all fractures. Lower extremity fractures represented 23% (246 fractures in 226 patients) with a mean age of 9.5 years (7 months–16 years). Girls/male ratio was 0.8/1 (44% and 56%) with a mean age of 9.8 years (9 months–16 years) and 9.4 years (7 months–16 years), respectively. Compared to girls, boys have a risk ratio of 1.25 of having a traumatic injury. 19 patients (8%) suffer from more than one fracture. The right side accounts for 55% ($n = 135$) of all fractures.

Overall, peak age for fracture occurrence is 11–12 and 14–15 years in girls, and 11–13 years in boys (Fig. 1).

Open fractures occurred in only three patients and all of them were Gustilo type I fractures (one tibia fracture and two toe fractures).

30% of fractures occurred during the winter season, 29% in spring, 23% in fall and only 18% were observed in summer time.

Proximal femur and tarsal bone fractures accounted for 2% of all lower extremity fractures and represented the rarest injury within our population (Table 1).

The tibia, with 94 fractures (38%), is the most injured bone mostly at its shaft segment (41%), followed by toe fractures diagnosed in 24% of patients. 45% of all tibia fractures occurred during the winter months (Fig. 2).

Fractures around the ankle represent 26% of all fractures with a mean age of 10.4 years (11 months; 16.7 years). Within this group, the most encountered fracture types, according to the Salter and Harris classification, were Salter type II (30%), followed by Salter type IV (10%) and Salter type III (3%); triplane and Tillaux fractures were classified as juvenile fracture and represented 8%.

Femur shaft fractures represent 50% of all femur fractures, with a mean age of 8.3 years (1.8–14 years). Patella fractures and dislocations represent only 4% (10) of all lower extremity lesions with femoro-patellar dislocation as the most encountered lesion (60%) followed by sleeve and transverse fractures (20% each) (Table 2).

Clinical and classification data for every specific fracture are described in Tables 2 and 3.

Figure 3 shows the peak age incidence according to gender for the most frequent fractures.

Ankle injuries due to inversion trauma and simple fall, followed by soccer-related traumatisms represented the main injury mechanisms in lower extremity fracture accounting for 17%, 13% and 11% of injuries, respectively (Fig. 4). However, tibia and leg shaft fractures showed somewhat different injury patterns with a higher prevalence of ski- and tobogganing accidents accounting for an average 24% each (Fig. 5). Of the 39 tibia shaft fractures, 11 (28%) were toddler fractures with a mean age of 2.2 years (1–4.2 years). 10 of the 11 fractures (90%) were due to twisting in the toboggan. 28 (72%) fractures were transverse, oblique or spiroid shaft fractures (AO classification type 42t-D/4.1, 5.1 or 5.2, respectively) with a mean age of 7.44 years (1.2–16 years), Of them, 10 fractures (36%) were due to board sport (Fig. 5).

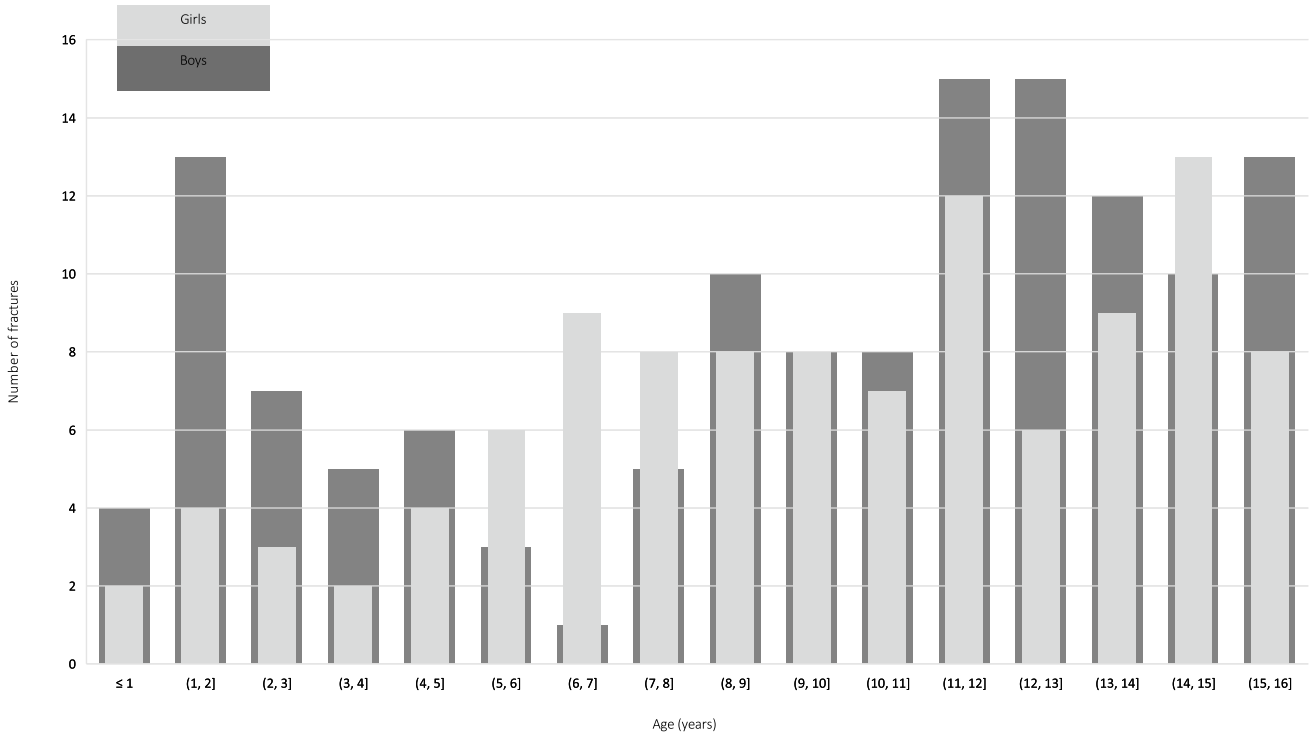

Fig. 1 Peak age of all children suffering from fractures of the lower extremities

Table 1 Localization of lower extremity fractures

Fractures	Number (%)	Age (years) (range)	Boys:Girls (%)
Femur	24 (10)	8.7 (7 months; 15.7 years)	58:42
Proximal	5 (2)		
Shaft	12 (5)		
Distal	7 (3)		
Tibia/Fibula[a]	116 (47)	8.6 (10 months; 16 years)	59:41
Proximal	12 (5)		
Shaft	40 (16)		
Distal	64 (6)		
[Tibia isolated]	[71 (29)]		
[Fibula isolated]	[22 (9)]		
Patella	10 (4)	13.5 (8.6 years–16 years)	40:60
Tarsal bone	5 (2)	9.9 (8.8 years; 15.2 years)	60:40
Metatarsal bone	36 (15)	8.6 (1.7 years; 15.3 years)	62:38
Phalangeal bone	55 (22)	11.4 (11 months; 16 years)	55:45

The prevalence of different fractures together with the average age and gender of the patients is shown

[a]Concerning the 116 tibia/fibula fractures, 94 fractures involved the tibia and 22 fractures were isolated fractures of the fibula

82% (201) of all fractures were treated by cast with or without closed reduction, 11% of injuries (28) by closed reduction and pinning or elastic stable intramedullary nail fixation (ESIN) (mostly femur shaft fractures and tibia shaft fractures) (Fig. 6), and only 7% (17) of fractures were treated by open reduction and internal fixation.

Only 3 patients (8%) treated by cast for tibia shaft fracture underwent secondary cast wedging and one fracture had secondary surgery with an elastic stable intramedullary nail (ESIN) because of failed closed reduction.

Femur shaft fractures in children up to 2 years were all treated by spica cast.

Specific details about the different fractures treated by ORIF and the used devices can be found in Table 4.

Discussion

Epidemiological data in our series are comparable with data reported in literature with 23% of fractures involving the lower extremity with a mean age of children of 9 years and 6 months [7, 9].

As previously described in larger series [9, 15], we reported a greater prevalence in the male population (56%) [8, 10].

Regardless of sex, the risk of injury increased up to the age of 12–13 years and then diverged with greater risk recorded in boys [8].

According to literature, tibia fractures (38%) are the most encountered lesions followed by toe fractures (22%);

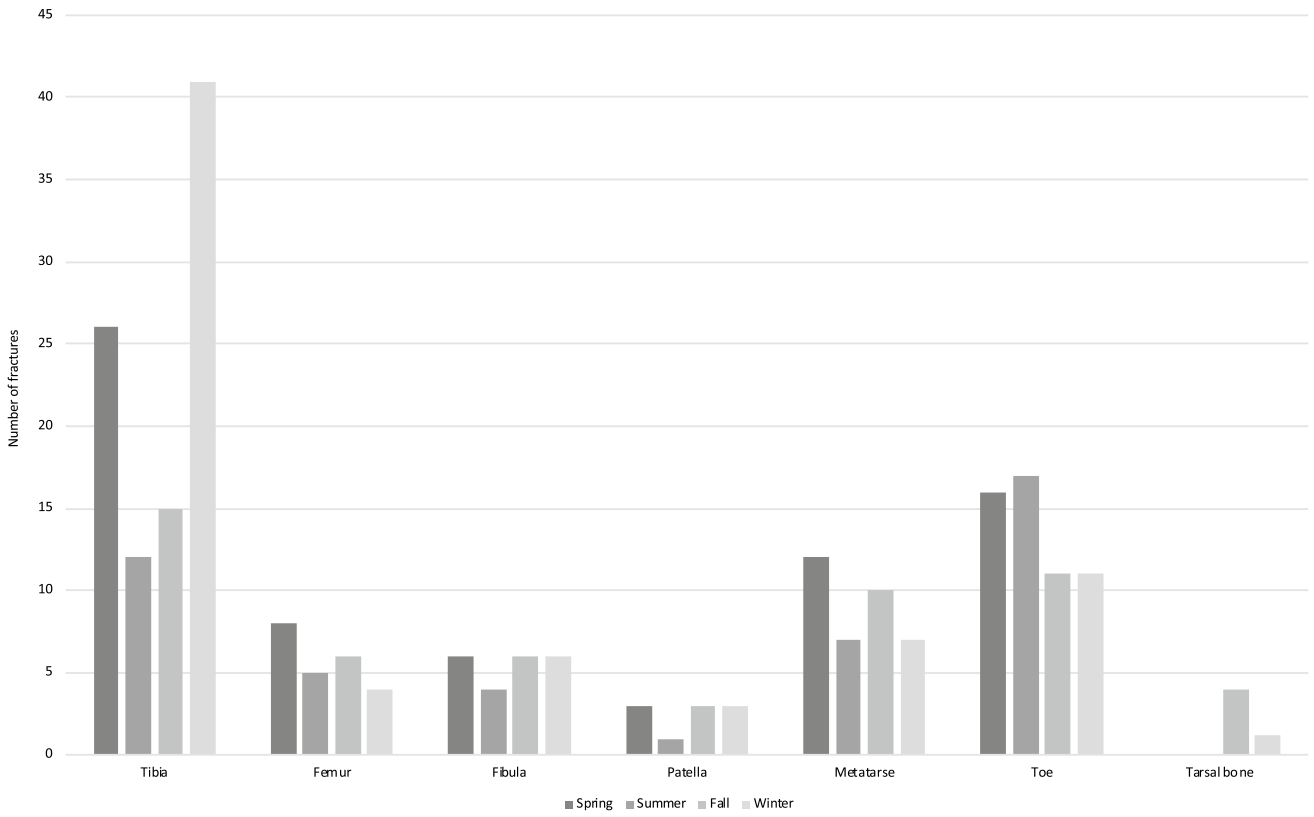

Fig. 2 Fractures by bone and season

whereas, lesions of the proximal femur are rare (2%) [7, 9, 16].

In our population, the right side was slightly predominant (right/left 1.2:1), in accordance with some previous studies [17, 18]. Unfortunately, due to the retrospective nature of the study, some data were not recorded and we were not able to correlate the dominant side with the injury side.

Season prevalence is multifactorial and tightly related to the different geographical and climatic regions as well as demographic predisposition and subsequent activities [8, 19, 20]. We recorded a higher incidence of injuries occurring during winter (30%) and spring (29%), especially tibia fractures, likely related to board sports and the rise in population during this season, being Switzerland a popular destination for winter holidays [7]. In a subgroup analysis according to age, ski accidents followed by twisting mechanism on toboggans were the main causes of tibia shaft fractures [21, 22]. Toddler fractures with a mean age of 2.2 years (1–4.2 years) represent 28% of all tibia shaft fractures and are typically stable sub-periosteal fractures seen in very young patients with a thick periosteum. In our series, 10 of the 11 fractures (90%) were due to twisting in the toboggan. The other 72% fractures were transverse, oblique or spiroid shaft with a mean age of 7.4 years (1.2–16 years) that were more likely due to high energy trauma in older children. Of them, 10 fractures (36%) were due to board sport [9].

Our results tend to confirm the higher prevalence of tibia fracture in our region due to ski accidents.

Furthermore, most of the tibia fractures occurred in the shaft region (41%) and 15% were associated to fibula fractures, this is somewhat lower than reported in literature [23, 24].

Despite increasing of intramedullary fixation of tibia shaft fractures in the last decade as a result of improved implant technology and the changing expectations of society [20, 25, 26], 85% (33/39) of all tibia shaft fractures in our series were treated by cast with or without closed reduction.

In case of secondary displacement of the tibia fractures, we have considered cast wedging in 3 of the 33 (8%) conservative treated fractures, as it is a valuable and simple treatment option [24, 25].

Our attitude is in line with clinical data, which have proven the high success of cast treatment for tibial shaft fractures, despite prolonged immobilization and in some case the need for cast wedging or changing [27].

Patella fracture are referred in the literature as a rare fracture with an incidence about 1% [28]. Our study presents a predominance of isolated patella-femoral dislocation (60%) during gymnastic activities (80%) at school.

Table 2 Incidence of different fractures for femur, tibia and fibula together with the average age, gender ratio of the patients, side and specific diagnosis according to the AO pediatric comprehensive classification of long-bone fractures [13]

Bone number/(incidence)	Localization/(incidence)	Number	Mean age (years)	Boys:Girls (%)	Right:left (%)	Diagnosis (number)	Classification
Femur 24 (10%)	Proximal (21%)	5	13.3 (min 12; max 16)	3:2 (60:40)	1:4 (20:85)	Pertrochanteric fracture (1) Infratrochanteric fracture (1) Mid cervical fracture (1) Basicervical fracture (1) Pipkin IV (1)	31-M/2.1 III 31-M/2.1 I 31-M/2.1 II 31-E/8.2
	Shaft (50%)	12	8.3 (min 1.8; max 14)	8:4 (75:25)	5:7 (42:58)	Spiroid/oblique fracture (8) Multifragmentary (2) Transverse (2)	32-D/5.1 32-D/5.2 32-D/4.1
	Distal (29%)	7	6.9 (min 7 months; max 12.6)	3:4 (43: 57)	2:5 (29:71)	Torus fracture (4) Transverse fracture (3)	33-M/2.1 33-M/3.1
Patella 10 (8%)	-	10	13.5 (min 8.6; max 16)	4:6 (40:60)	2:8 (20:80)	Osteochondral fracture (6) Sleeve fracture (2) Transverse (2)	–
Tibia/fibula 23 (9%)	Proximal (0%)	0	–	–	–	–	–
	Shaft (26%)	6	9.6 (min 1.7; max 13.7)	4:2 (66:33)	4:2 (66:33)	Plastique fracture (2) Transverse (2) Oblique fracture (2)	42-D/1.1 42-D/4.1 42-D/5.1
	Distal (74%)	17	10.9 (min 11 m; max 15.3)	12:5 (70:30)	12:5 (70:30)	Bimalleolar fractures -Salter Harris II Tibia (3) -Salter Harris IV Tibia (3) -Triplane (1) -Transverse fracture (8) -Torus fracture (2)	43-E/2.1 43-E/4.1 43-E/6.1 43-M/3.1 43-M/2.1
Tibia 71 (29%)	Proximal (17%)	12	9.8 (min 4.8; max 16)	6:6 (50:50)	9:3 (75:25)	Tibial spine fracture (5) Salter Harris II (1) Salter Harris IV (2) Transverse (2) Torus fracture (1) Tibial tuberosity (1)	41t-E/7 41-t/2.1 41t-E/4.1 41t-M/3.1 41t-M/2.1 41t-M/7
	Shaft (46%)	33	8.4 (min 1, max 16)	23:10 (70:30)	19:14 (58:42)	Transverse fracture (5) Oblique/spiroid fracture (16) Toddler's fracture (11) Spiroid multifragmentary (1)	42t-D/4.1 42t-D/5.1 – 42t-D/5.2
	Distal (37%)	26	9.3 (min 8 months, max 16)	11:15 (42:58)	13:13 (50:50)	Salter Harris II (12) Salter Harris III (1) Salter Harris IV (4) Tillaux (2) Triplane (3) Transverse (1) Torus fracture (3)	43t-E/2.1 43t-E/3.1 43t-E/4.1 43t-E/5.1 43t-E/6.1 43t-M/3.1 43t-M/2.1

Table 2 (continued)

Bone number/ (incidence)	Localization/(incidence)	Number	Mean age (years)	Boys:Girls (%)	Right:left (%)	Diagnosis (number)	Classification
Fibula 22 (9%)	Proximal (0%)	0					
	Shaft (5%)	1	14.1	0:1	1:0	Transverse (1)	42f-D/4.1
	Distal (95%)	21	9.3 (min 10, months; max 15.2)	13:9 (60:40)	10:12 (45:55)	Avulsion fracture (14) Torus fracture (1) Salter Harris I (2)[a] Salter Harris II (4) Salter Harris III (1)	43f-E/7 43f-M/2.1 43f-E/1.1 43f-E/2.1 43f-E/3.1

[a]Diagnosis was done by clinical findings

Table 3 Incidence of different fractures for tarsal, metatarsal and phalangeal bones together with average age, gender ratio, side and specific diagnosis

Bone number/ (incidence)	Localization/(incidence)	Number	Mean age (years) (range)	Boys:Girls (%)	Right:left (%)	Diagnosis (number)
Tarsal 5/(2%)	Talus (57%)	3	9.9 (min 8.8; max 16)	3:2 (60: 40)	3:2 (60: 40)	Osteochondral fracture (2) Hawkins I (1)
	Calcaneum (29%)	1				Sprain fracture (1)
	Cuboid (14%)	1				Fracture–dislocation (1)
Metatarsal 36/(15%)	First (19%)	7	8.6 (min 1.7; max 16)	17:19 (47: 53)	22:14 (61: 39)	Transverse metaphyseal fracture (2) Salter Harris II (3) Spiroid fracture (1) Subcapital fracture (1)
	Second (14%)	5				Salter Harris II (2) Subcapital (1) Transverse metaphyseal fracture (1) Transverse shaft fracture (1)
	Third (17%)	6				Salter Harris II (3) Transverse shaft fracture (2) Subcapital fracture (1)
	Fourth (11%)	4				Salter Harris II (3) Salter Harris IV (1)
	Fifth (39%)	14				Transverse fracture (5) Fracture—avulsion base (7) Subcapital fracture (2)
Phalanx 55/(22%)	D1 (40%)	22	11.4 (min 11 months; max 16)	30:25 (55: 45)	32:23 (58: 42)	Salter Harris II P1 (3) Salter Harris II P1 (7) Salter Harris III P1 (1) Salter Harris IV P1 (1) Shaft first phalanx (10)
	D2–D5 (60%)	33				2nd toe (10) 3rd toe (3) 4th toe (6) 5th toe (14)

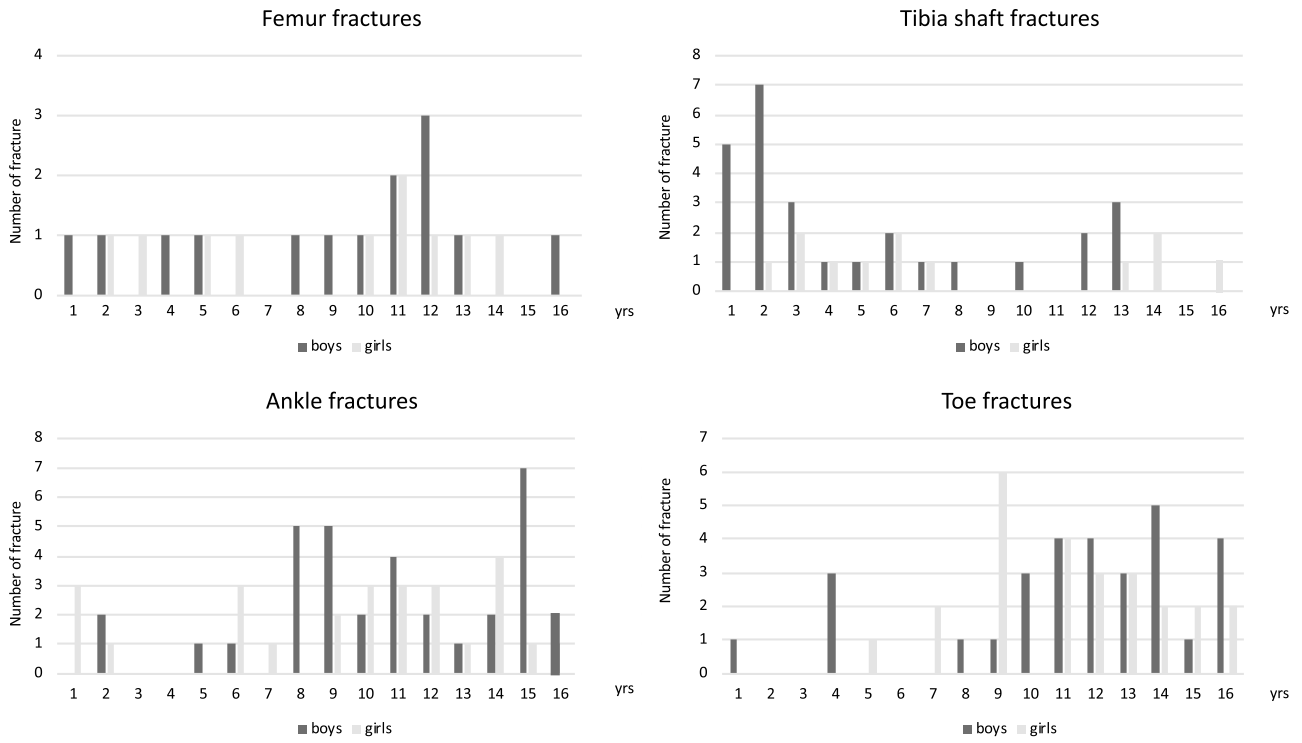

Fig. 3 Peak age of specific fractures (femur fractures, tibia shaft fractures, ankle fractures and toe fractures)

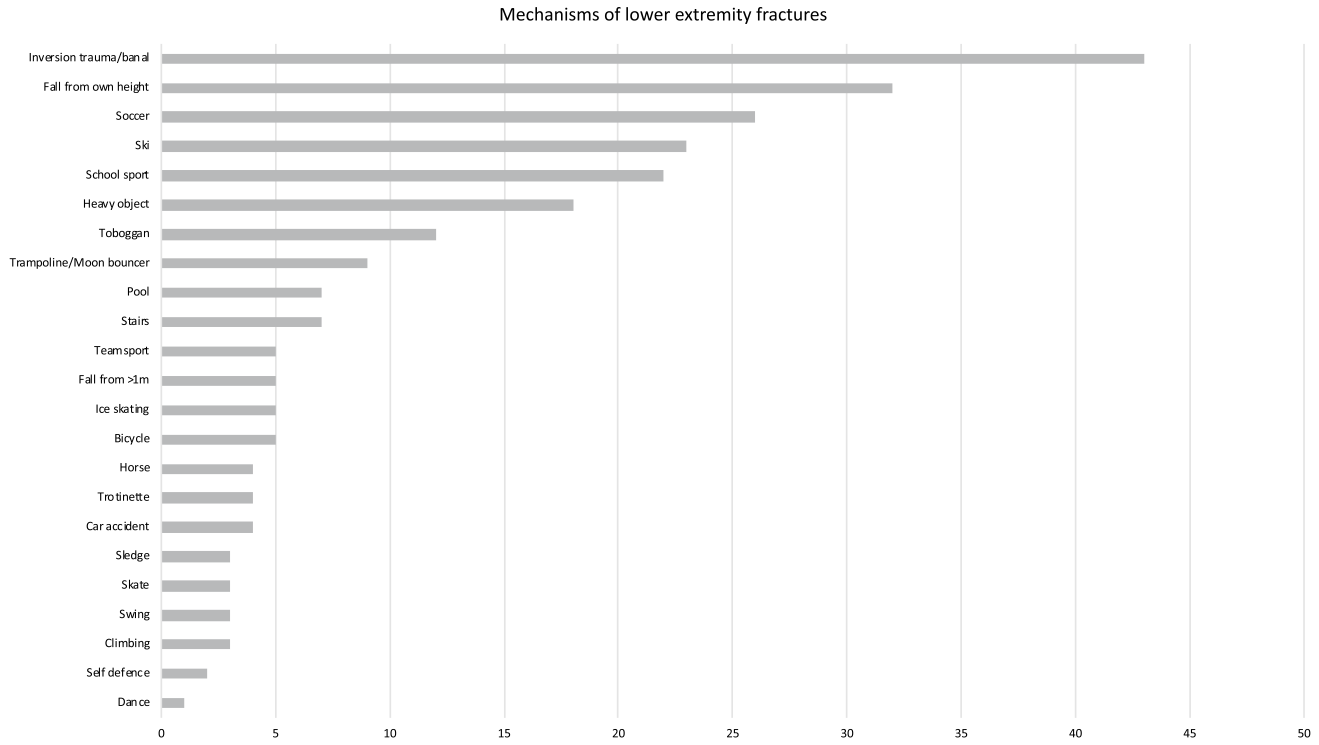

Fig. 4 Mechanisms for lower extremity fractures

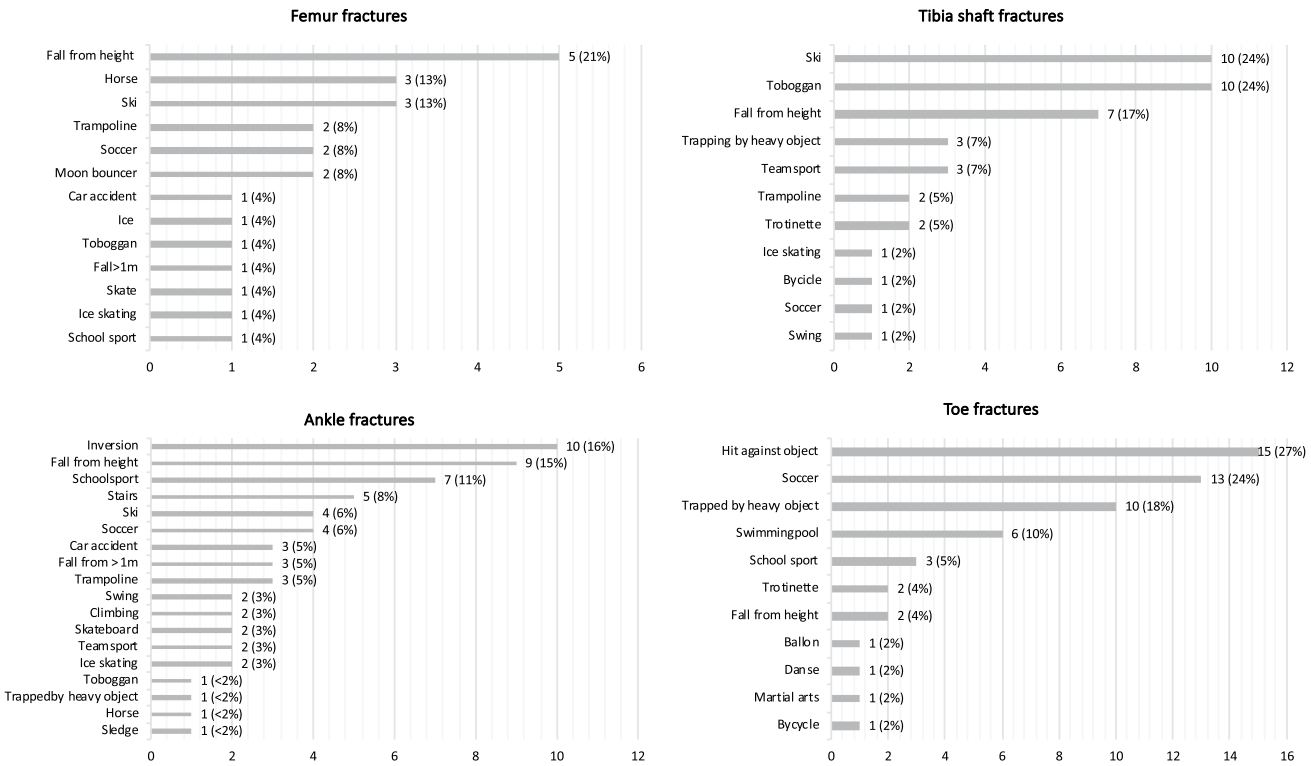

Fig. 5 Mechanisms for specific fractures (femur fractures, tibia shaft fractures, ankle fractures and toe fractures)

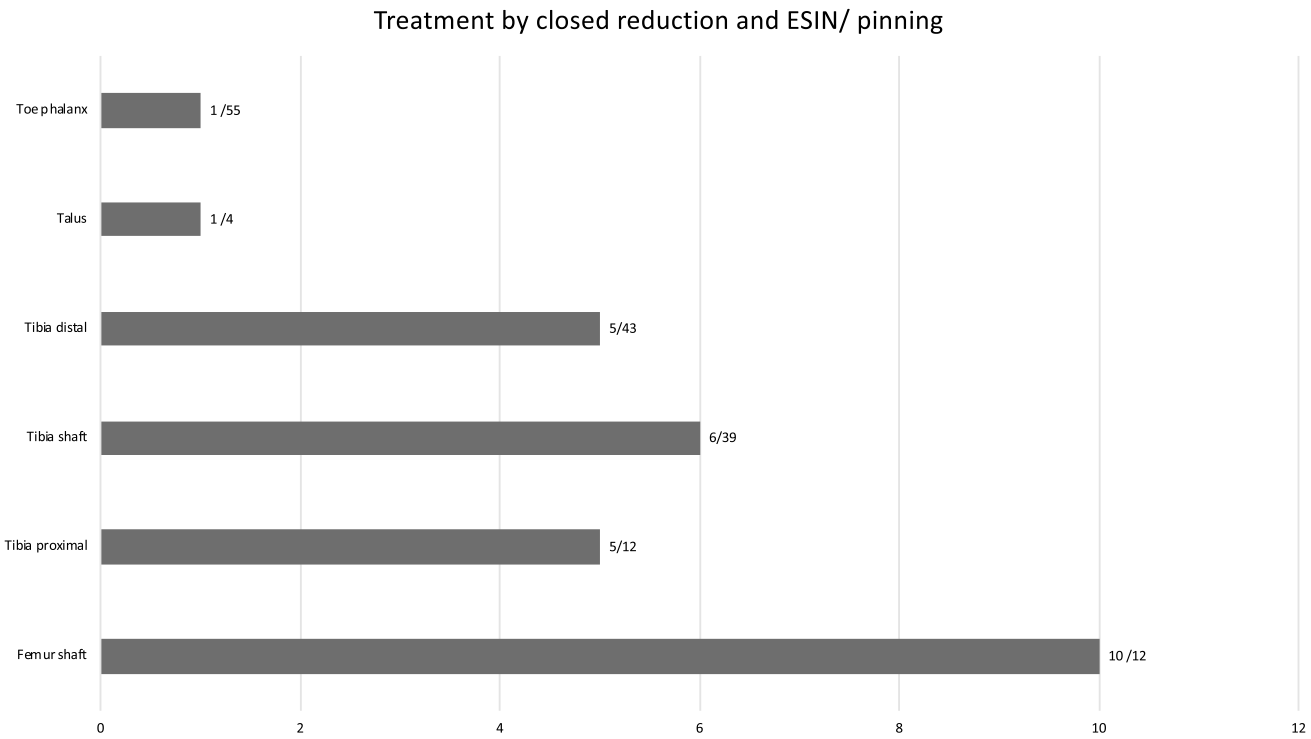

Fig. 6 Treatment by closed reduction and elastic stable intramedullary nailing (ESIN)/ pinning

Table 4 Overview of patients treated by open reduction and internal fixation

Diagnosis	Number	Mean age (years)	Treatment
Femur			
Proximal	1	13	Pertrochanteric fracture (1) (Pediatric hip plate)
Shaft	2		Multifragmentary shaft fracture (2) (plate)
Leg			
Proximal	1	13.4	Salter Harris IV proximal tibia (1) (cannulated screw)
Distal	8		Salter Harris IV distal tibia (6) (cannulatred screw and k-wire) Transverse metaphyseal fractures of distal tibia (2) (plate)
Foot			
Tarsal bone fractures	4	13.3	ORIF calcaneus (1) (plate) ORIF cuboid (fracture–disclocation) (1) (k-wire) Osteochondral fracture of talus (2) (resorbable pins)
Metatarsal bone	1	13.5	ORIF first metatarsal shaft fracture (plate)
Total	17	13.2	

Details of the 17 fractures treated by open reduction and internal fixation

ORIF open reduction and internal fixation

Considering isolated patellar fractures, as sleeve fractures or transverse fractures, those represent 1.5% of all fractures of the lower extremity in our series and is, therefore, similar to preexisting literature [29].

Ankle fractures represent in our study 26% and are mostly secondary to simple inversion/twist trauma followed by school-sport injuries [9]. Depending on the transmitted energy, those fractures go from simple torus fractures (8%) to more complex physeal fractures, mostly Salter Harris type II (30%). Typically, torus fractures are common in younger children due to a lower energy mechanism and to specific bone structure characteristics (thicker periosteum and higher elasticity of the bone). In counterpart, physeal and transverse fractures require a higher energy trauma and are mostly related to sport activities, and, therefore, more frequent in older children, especially adolescents [30]. The juvenile fractures, triplane and Tillaux fractures, represented in our study 8% of all ankle fractures with a mean age of 12.5 years and correlates with preexisting literature [31].

In accordance with the published data, toe fractures are the most common traumatic foot injuries for both gender together [32]. Typically, those fractures usually result by stubbing a toe (27%), soccer (24%) or from object falling on the foot (18%) [33]. Treatment was generally conservative with strapping immobilization in neutral position (98%) and surgical treatment was only necessary in rare cases of fractures of the hallux (2%), especially for fractures involving the physis, because of the first toe's role in weight bearing and balance [32].

Proximal femur fractures are with 2% the rarest injury in our series and result from high energy trauma. This is in line with the previously published studies [34, 35].

Femur shaft fractures represented 50% percent of all femur fractures. Main cause was simple fall, especially in younger children and 83% of cases were treated by elastic intramedullary nails or by open reduction and internal fixation. Conservatively treated femoral shaft fractures were restricted to children younger than 2 years of age, as retrograde flexible intramedullary nailing has proven to be a safe and more reliable treatment with early rehabilitation [36]. Those results are comparable with existing literature [37, 38].

In our series, 82% of the fractures benefited from conservative treatment, and only 18% were treated by surgery, mostly for femur, tibia shaft fractures and unstable displaced physeal fractures [39].

The present study confirms the high prevalence of fractures in children and adolescent. Epidemiology data are comparable to them published in literature. Comparing the fracture prevalence with its mechanisms, we can observe a higher prevalence of tibia shaft fractures during winter months probably due to the high activity of board sports in our region.

These data underline the importance of a proper basic training for junior residents in pediatrics assigned to the emergency department who could manage and treat a high percentage of lower limb traumatism without the presence of an orthopedic senior attending in the future.

The limit of this study is related to the retrospective nature of the data collection and the short-term follow-up of our cohort which does not allow a clinical outcome analysis. Other studies over a period of several years, ideally multi-centric, could reinforce our results.

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Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by EC and SM. The first draft of the manuscript was written by EC and accepted by P-YZ and SM. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability The data and materiel are securely hold by the main author and coded for ethical reasons. It is available on asking.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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