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Multicenter epidemiological analysis of related factors in 10,808 hospitalized children with lower limb and pelvic fractures in China

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To analyze the causes, locations, associated injuries, and relevant factors of lower limb and pelvic fractures in hospitalized children in China to provide a theoretical basis for reducing the incidence of such fractures. A retrospective analysis of children with lower limb and pelvic fractures admitted to 27 tertiary children's hospitals affiliated with China's Futang Research Center of Pediatric Development between December 1, 2015, and December 31, 2019, was conducted. Inpatient cases were analyzed in the following age groups: Infants (< 2 years), Preschool children (2–5 years), School children (6–11 years), and Adolescents (12–18 years). This study included 10,808 pediatric patients (7152 males, 3656 females). The proportion of preschool children of lower limb and pelvic fractures was the highest. The 10,808 patients sustained a total of 14,398 fractures. The shafts of the femur, tibia, and fibula, the distal tibia, distal fibula, and the pelvis were the six most common locations. Of the 734 pelvic fractures in children and adolescents, the top three locations were the ilium, pubic bone, and the ischium. Of the total patients, 9599 underwent surgery, while 1209 received non-surgical treatment. The three most common causes of pediatric lower limb and pelvic fractures were falling over, traffic accidents, and falling from a height. Among the 1806 concomitant traumas, respiratory traumas was the most common, mainly pulmonary contusion. The most common concomitant traumas of nervous, digestive and urinary system were scalp hematoma, liver injury and kidney injury respectively. The analysis of the location, age, causes, and concomitant injuries of lower limb and pelvic fractures showed that the most common fracture requiring hospitalization was tibia fracture, which was most common in preschool children. The most common cause of injury in preschool children was traffic accident. In addition, children are susceptible to accidental injuries from multiple sources in life, which can cause serious consequences of multi-system injuries.

Keywords Children, Injury, Lower limb, Pelvic fracture, Concomitant trauma

Unintentional childhood injuries have become a primary global public health concern, with a significant number of children and adolescents succumbing to accidental injuries worldwide[1]. Fractures are the most common type of unintentional injuries in children, accounting for 10–25%[2], with an increasing incidence of childhood fractures as they grow[3]. In addition, among patients of various age groups with lower limb fractures, children

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and adolescents account for approximately 19.2%[4], with potential consequences leading to higher mortality rates in children[5,6]. Childhood fracture types vary according to local climate, culture, and recreational activities, resulting in diverse causative factors for fractures in different countries or regions within a country[7,8]. Sweden reported that 19.5% of childhood fractures occurred in the lower limbs[5]. Similarly, in Switzerland, among 2716 patients (60% male), there were 2840 cases of long bone fractures, with tibia, fibula, and femur fractures accounting for approximately 20%[9].

In addition, trauma leading to pediatric pelvic fractures is rare, occurring only in 0.5–7.0% of children[10–13]. For immature skeletal structures in children, pelvic fractures typically occur following high-energy impacts such as traffic accidents or falling from a height. In such cases, the injuries will likely extend to other body parts. Therefore, surgeons treating pediatric pelvic fractures should be vigilant about concomitant trauma extending to other systems, including the abdomen, genitourinary system, spine, or head[14]. However, there is currently limited research on lower limb and pelvic fracture-associated injuries in children.

China has the second largest children population globally, accounting for 12.9% of the world's total children[15]. However, research on the overall patterns and trends of lower limb and pelvic fractures in Chinese children and adolescents is limited. We conducted a retrospective analysis of epidemiological information of lower limb and pelvic fractures in children from 27 tertiary pediatric hospitals in China. This study aims to collect information on fracture sites, causes, and concomitant injuries, describe the epidemiological characteristics of lower limb and pelvic fractures in children, and improve the awareness of scientific researchers on accidental injuries in children.

Materials and methods

We conducted a retrospective analysis of the medical records of hospitalized children with lower limb and pelvic fractures at the FuTang Research Center for Pediatric Development (FRCPD)[16,17] in 27 tertiary children's hospitals in China between December 1, 2015, and December 31, 2019. Using the International Statistical Classification of Diseases and Related Health Problems coding 10, we collected data on age, sex, causes of injury, fracture sites, treatment modalities, concomitant trauma to other systems from the medical record index of pediatric inpatients with lower limb and pelvic fractures.

We categorized all enrolled patients into the following age groups: Infants (< 2 years), Preschool children (2–5 years), School children (6–11 years), and Adolescents (12–18 years), the causes of fractures were classified based on the injury mechanism: falling over, falling from a height, traffic accidents, being struck or hit, other reasons, and unknown reasons[18].

The fracture sites were anatomically classified into the patella, proximal fibula, fibula shaft, distal fibula, proximal tibia, tibia shaft, distal tibia, proximal femur, femur shaft, distal femur, and pelvis (including the ilium, pubis, ischium, sacrum, and acetabulum).

Concomitant systemic trauma was divided into nervous, respiratory, digestive, urinary, and circulatory system traumas.

Statistical methods

All statistical analyses were performed using SPSS version 26.0 (IBM Corporation, Armonk, NY, USA) for Windows (Microsoft Corporation, Redmond, WA, USA). Categorical variables were expressed as numbers and percentage. The chi-squared test was used for categorical variables. Differences with P value < 0.05 were considered to be statistically significant.

Results

Age and sex

In total, 10,808 pediatric patients were included in this study, with 7152 males and 3656 females. In all age groups, the number of males exceeded that of females. The preschool children and infants had the highest and lowest incidences of fractures, respectively. Among the pediatric patients in the four age groups, the infant group had 1562 individuals with fractures, including 965 males and 597 females. In the preschool group, the number of fractures increased to 3720 cases (2419 males and 1301 females). Subsequently, the number of fractures decreased, with 3144 individuals in the school children group, including 1948 males and 1196 females, and a further decline in the adolescent group, accounting for 2382 individuals, including 1820 males and 562 females. In the adolescent group, the sex ratio difference was the largest, with a male-to-female ratio of 3.24:1 (Table 1).

Fracture site and treatment

Among the 10,808 pediatric patients, there were 14,398 lower limb and pelvic fracture sites. The fracture sites included the iliac, pubic, ischial, sacrum, acetabular, femur, patella, tibia, and fibula. The three most commonly fractured bones were the tibia, femur, and fibula. In the three long bones, the incidence of shaft fractures was higher than proximal and distal fractures. In the tibia and fibula, distal fractures were higher than proximal fractures. But in the femur, proximal fractures higher than distal fractures. In addition, there were 152 cases of patellar fractures. There were 734 cases of pelvic fractures, including 25 acetabular fractures, 208 iliac, 151 pubic, 74 ischial, 55 sacral bone fractures, and 221 unknown pelvic fractures (Figs. 1 and 2).

Femur shaft fracture was commonly seen in preschool children (1699 cases). The tibia shaft fracture was also most common in preschool children (1163 cases). For the fibula shaft fractures, it was most common in school children (812 cases). Patellar fractures were most common in school children(82 cases). For the 734 pelvic fracture cases, the most common age group was preschool children (267 cases), followed by adolescents (218 cases) (Table 2 and Fig. 3). The highest incidence of femoral fractures occurs during infants and preschool children, while the highest incidence of tibia fractures occurs during school children and adolescents (Fig. 3).

Parameter	Patients n(%)
Numbers	10,808
Age class	
Infants	1562(15%)
Preschool children	3720(34%)
School children	3144(29%)
Adolescents	2382(22%)
Sex	
Female	3656(34%)
Male	7152(66%)
Sex ratio (male:female)	
Infants	1.62:1
Preschool children	1.85:1
School children	1.63:1
Adolescents	3.24:1

Table 1. Demographics of patients with 10,808 fractures.

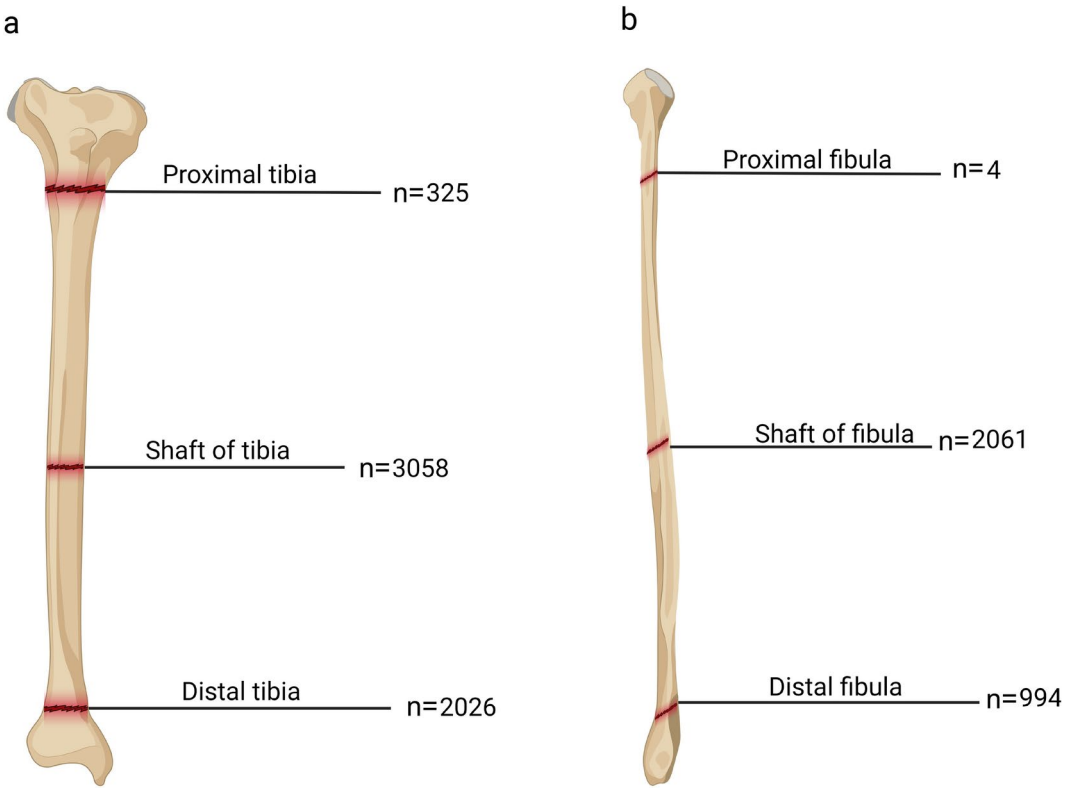

Fig. 1. Fracture sites of the tibia and fibula in pediatric lower limb and pelvic fractures. (**a**) Specific Details of tibial fracture site. (**b**) Specific Details of fibula fracture site.

Among the included 10,808 children, 9599 underwent surgery, while 1209 were treated with non-surgical therapy. The ratio of surgical to non-surgical treatments was 8:1. Of the 9599 children who underwent surgery, 4781 underwent open reduction, and 4818 underwent closed reduction. The results of the chi-square test showed that there were statistically significant differences in the number of conservative and surgical treatments in different age groups and different fracture sites($P < 0.001$) (Table 3 and Fig. 4).

Cause of injury

In children with lower limb and pelvic fractures, the leading cause of injury was falling over in 4629 children (43%), followed by traffic accidents in 3434 children (32%), falling from a height in 1115 children (10%), other reasons in 573 children(5%), unknown reasons in 573 children (5%), and being struck or hit in 484 children (4%). Regarding the common causes of injuries in the different age groups, the most common cause of lower

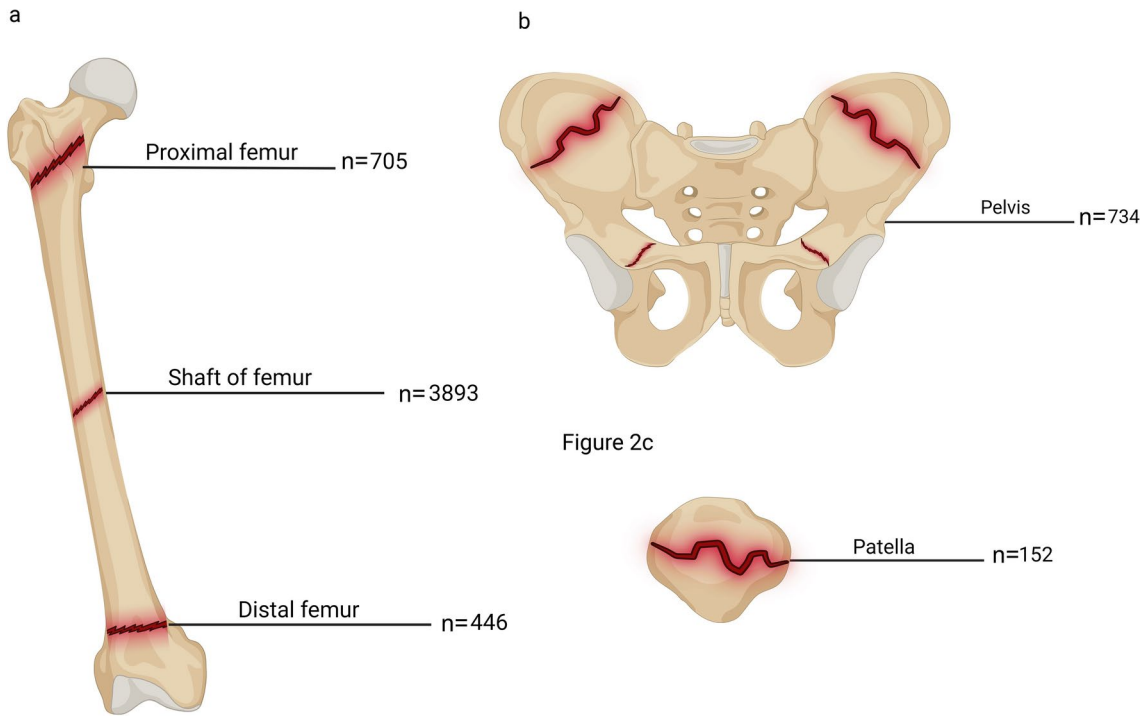

Fig. 2. Fracture sites of the femur, patella, and pelvis in pediatric lower limb and pelvic fractures. (**a**) Specific Details of femur fracture site. (**b**) Specific Details of pelvis fracture site. (**c**) Specific Details of patella fracture site.

Fractures sites	Infants	Preschool children	School children	Adolescents	χ^2	*P* value
Fibula					129.61	< 0.001
Proximal fibula	0	1	1	2		
Shaft of fibula	93	718	812	438		
Distal fibula	28	226	339	401		
Tibia					447.51	< 0.001
Proximal tibia	25	37	80	183		
Shaft of tibia	165	1163	1121	609		
Distal tibia	73	409	728	816		
Femur					513.10	< 0.001
Proximal femur	61	215	201	228		
Shaft of femur	1139	1699	793	262		
Distal femur	93	169	106	78		
Patella	0	3	82	67	122.34	< 0.001
Non-patellar area	1769	4904	4338	3235		
Pelvis	92	267	157	218	38.51	< 0.001
Non-pelvis area	1677	4640	4263	3084		

Table 2. The epidemiology of age group according to different fractures sites. χ^2 and *P* value represent the differences in the following fracture sites among age groups: (1) the proximal end, shaft and distal end of the fibula; (2) the proximal end, shaft and distal end of the tibia; (3) the proximal end, shaft and distal end of the femur; (4) the patella and non-patellar area; (5) the pelvis and non-pelvic area.

limb and pelvic fractures among children in the infant, school child, and adolescent groups was falling over, and the most common cause of injury in the preschool children group was traffic accidents (Table 4).

For falling over, the adolescents had the most significant number (1344 cases, 29%), followed by the school children (1300 cases, 28%), and the preschool children (1205 cases, 26%). In the infant group, 780 children(17%) were injured due to falls (Table 4).

Secondly, traffic accidents (3434 cases) was the second-largest cause of injury. The Preschool children group had the most children (1553 cases, 45%), followed by the school children group (1118 cases, 33%), the adolescent

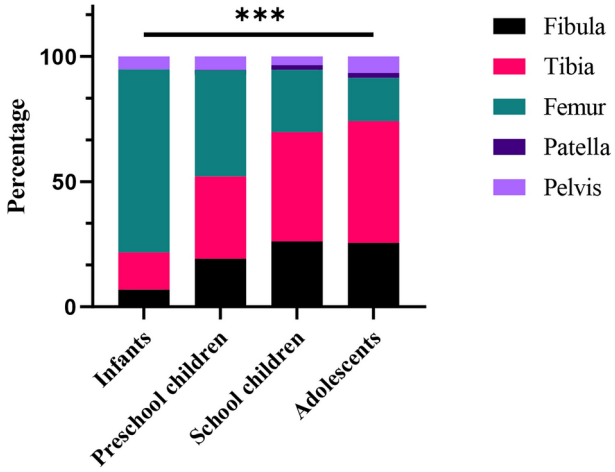

Fig. 3. Stack bar graph of different fracture sites in four age groups. The results of the chi-square test show that there are statistically significant differences in the incidence rates of different age groups for all fracture sites ($P < 0.001$).

Parameter	Surgery	Conservative treatment	χ^2	*P* value
Age class			802.54	< 0.001
Infants	1075	487		
Preschool children	3319	401		
School children	2920	224		
Adolescents	2285	97		
Fractures sites				
Fibula			43.94	< 0.001
Proximal fibula	0	4		
Shaft of fibula	466	1595		
Distal fibula	337	657		
Tibia			13.56	0.001
Proximal tibia	297	28		
Shaft of tibia	2783	275		
Distal tibia	1901	125		
Femur			53.10	< 0.001
Proximal femur	654	51		
Shaft of femur	3225	668		
Distal femur	398	48		
Patella	125	27	7.05	0.008
Non-patellar area	10,341	3905		
Pelvis	280	454	464.90	< 0.001
Non-pelvis area	10,186	3478		

Table 3. Differences in surgical and conservative treatments among age groups and fracture sites. χ^2 and *P* value represent the comparison results between surgical treatment and conservative treatment for the following: (1) each age group; (2) the proximal end, shaft and distal end of the fibula; (3) the proximal end, shaft and distal end of the tibia; (4) the proximal end, shaft and distal end of the femur; (5) the patella and non-patellar area; (6) the pelvis and non-pelvic area.

group (418 cases, 12%), and the infant group with the smallest number of children with injuries due to traffic accidents (345 cases, 10%) (Table 4).

There were 1115 cases of high-energy injuries from falling from a height. Among them, preschool children had the most significant number of 413 cases(37%). There were 282 cases(25%) in the school children group and 255 cases(23%) in the adolescent group. Similarly, the infant group had the lowest number of children whose injuries were caused by falling from a height (165 cases, 15%) (Table 4).

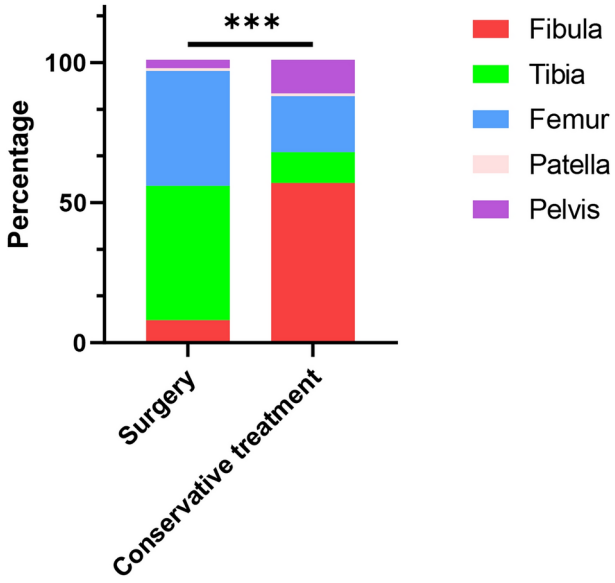

Fig. 4. Stacked bar graph of surgical and conservative treatments for different fracture sites. The results of the chi-square test showed that there were statistically significant differences in the percentage of surgical and conservative treatments for different fracture sites ($P < 0.001$).

Cause of injury	Infants	Preschool children	School children	Adolescents
Falling over	780(50%)	1205(32%)	1300(41%)	1344(56%)
Falling from a height	165(11%)	413(11%)	282(9%)	255(11%)
Traffic accident	345(22%)	1553(42%)	1118(36%)	418(18%)
Being struck or hit	84(5%)	219(6%)	132(4%)	49(2%)
Other reasons	81(5%)	114(3%)	142(5%)	236(10%)
Unknown	107(7%)	216(6%)	170(5%)	80(3%)
Total	1562(100%)	3720(100%)	3144(100%)	2382(100%)

Table 4. The epidemiology of age group according to different etiologies.

Concomitant trauma

Among the 10,808 children with lower limb and pelvic fractures, 1806 presented with concomitant trauma to other systems. Among them, concomitant respiratory trauma was the most common, with 721 cases; concomitant nervous trauma occurred in 539 cases, concomitant digestive trauma (260 cases), concomitant urinary trauma (250 cases), and concomitant circulatory trauma was observed in 36 cases. (Supplementary Tables 1–4).

Regarding the most common concomitant respiratory trauma, the top five were pulmonary contusion, traumatic pneumonia, pneumothorax, pleural effusion, and hemothorax. The top five cases of concomitant nervous trauma were scalp hematoma, intracerebral hemorrhage, subarachnoid hemorrhage, traumatic paralysis, and subdural hemorrhage. The top five concomitant digestive traumas were traumatic liver, splenic, pancreatic, and gallbladder injuries and small bowel injuries. The top five concomitant urinary traumas were traumatic renal, urethral, perineal, genital, and bladder injuries. (Fig. 5).

Discussion

Currently, there are few studies on the overall pattern and prevalence of lower limb and pelvic fractures in Chinese children and adolescents and the concomitant trauma to other systems with lower limb and pelvic fractures in children due to high-energy trauma. By analysing hospitalized children, this study found that (1) the number of males among hospitalized children with fractures of all ages was higher than that of females for lower limb and pelvic fractures in children, and the number of children in the preschool age group was the highest. (2) For lower limb and pelvic fractures in children, the most common fracture site was the femur shaft, with 2594 cases in males and 1299 cases in females. (3) The most common age group for pelvic fractures was preschool children. (4) The characteristics of common fracture sites differed in different age groups; the femur shaft was the most common lower limb fracture site in the infant (1139 sites) and preschool children groups (1669 sites). The tibial shaft was the most common lower limb fracture site in the schoolchildren (1121 sites) and adolescent groups (609 sites). (5) For children with lower limb and pelvic fractures requiring hospitalization, surgery is the primary treatment, and the ratio of surgical to non-surgical treatment is 8:1. For surgical treatment, the ratio between the open and closed reductions was 1:1. (6) For lower limb and pelvic fractures in children, the most

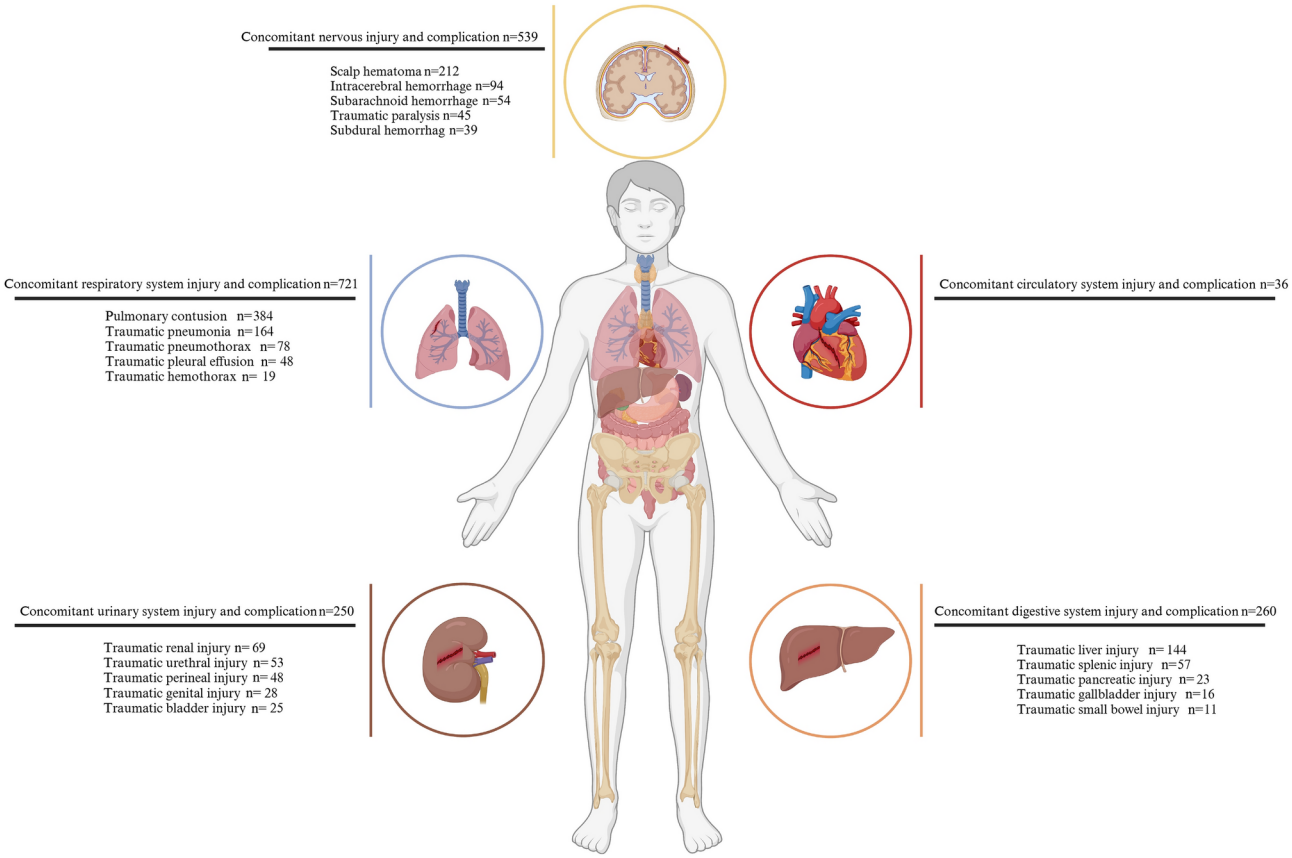

Fig. 5. The concomitant trauma and complications associated with pediatric lower limb and pelvic fractures (This figure was created by Biorender).

common cause of injury was falling over. (7) Among the 10,808 patients who experienced lower limb and pelvic fractures associated with trauma to other systems, concomitant respiratory trauma was the most common, with pulmonary contusion accounting for the highest proportion (53.26%).

Age and sex

One study reported that 2473 children and adolescents aged < 18 years with traumatic fractures were studied over 10 years and observed 936 lower limb fractures (37.8%). In addition, 473 of the 936 lower limb fractures (50.0%) accounted for the most significant proportion in the 12–18 year-old age group, and in all age groups, the number of males exceeded that of females[9]. Similarly, an Israeli study reported that the peak number of female fractures occurred between ages 10 and 11 years, and the peak number of male fractures occurred between ages 12 and 13 years. In addition, the number of fractures in males was more significant than that in females in all age groups[19]. In addition, a United States study reported that the peak incidence of fractures in children occurred between ages 10 and 14 years[20].

In contrast with the current research results, we found that the most common age group for lower limb and pelvic fractures in children was the Preschool children group aged 2–5 years, and in all age groups, the number of male children was higher than that of female children. This study's results are consistent with those of previous studies[18,21–23]. Males are naturally active and curious and prefer high-risk outdoor activities. Therefore, even if male children have stronger bones, the incidence of lower limb and pelvic fractures is higher than that in female children of all ages. Therefore, monitoring and prevention efforts should be strengthened for males, particularly children aged 2–5 years.

Fracture site

The tibial shaft is the most common fracture site in the lower extremity regions[24–26]. However, a study in Saudi Arabia showed that among 217 children with lower limb fractures, 141, 47, and 50 had femoral, tibial, and pelvic fractures, respectively[27]. Studies have also reported that the femur (25.9%) is the most common site of lower limb fractures in children[28]. In addition, the proportion of fractures in various parts of the lower limbs changes with increasing age, with the proportion of femoral fractures decreasing from 65.2 to 34.5%[29,30]. Other epidemiological studies reported similar rates of femoral fractures in children[29]. This finding is consistent with the results of the present study. The most common fracture site among children with lower limb and pelvic fractures was the femur shaft, followed by the tibia shaft. In addition, the incidence of femoral shaft fractures decreased with age, except in the infant group. The preschool children had the most significantly higher number

of fractures. Children in this age group often ignore their surroundings due to their lively and active nature. They are prone to risky behaviors during play or activities due to the environment's potentially hazardous nature. These behaviors may involve high-risk activities such as jumping, climbing, and running, which increase the risk of injury[31], especially if there is insufficient supervision and guidance. In particular, the lack of safety guidance from schools or community education results in a lack of the ability to identify and avoid potential dangers.

Cause of injury

Fractures in children can be caused by various injury mechanisms, such as sprains, falls from bed height or below (< 1 m), falls from stairs or slopes, blunt trauma, sports injuries, and traffic accidents[32]. A Chinese study reported that the common causes of lower limb fractures in children are motor vehicle accidents (47%) and falls (26%), followed by falls from heights (15%) and injury from a hit (4.4%). In addition, motor vehicle accidents (47%) were the most common cause of injury among all age groups and children of both sexes[33]. Similarly, the most common cause of lower limb fractures in children was car accidents, followed by falls[34]. A study conducted in the United States reported that two-thirds of injuries were caused by motor vehicle accidents and falls, with falls being more common in younger children and motor vehicle accidents in older children[35].

In contrast to our research results, falling over was the leading cause of lower limb and pelvic fractures in children, followed by traffic accidents. In addition, for children in the infant, school, and adolescent groups, the most common cause of lower limb fractures was falling over, and the most common cause of injury in the preschool children group was traffic accidents. Regarding fracture patterns of the lower limbs and pelvis in children of different ages, there were differences in injury causes. Therefore, targeted preventive interventions based on the specific characteristics of each age group should be developed urgently to reduce the occurrence and related burden of lower limb and pelvic fractures in children, considering the characteristics of each age group and the exposure risks in daily activities in the design of personalized, scientific and effective prevention strategies.

Pelvic fractures and concomitant trauma

A few studies have investigated the impact of pelvic fractures in children. The anatomical and biological characteristics of the pelvis in children are significantly different from those in adults. In children, the bones are more flexible and mineralized. This makes them relatively less likely to fracture when exposed to stress[36]. We collected data on 734 pelvic fractures in children and adolescents. The top three fracture locations were iliac (208), pubic (151), and ischial (74) areas. In addition, studies have pointed out that the incidence of pelvic fractures is higher in older children. As children grow older, their bones become more mineralized, challenging, and fragile. However, in the present study, pelvic fractures were lower in the adolescent group than in the preschool group. This may be because increased age in older children positively impacts their risk perception and coping ability, making them more vulnerable to potential dangers. Precautions should also be taken independently to reduce the occurrence of pelvic fractures.

In addition, in skeletally immature children, pelvic fractures, which usually occur after a sustained high-energy impact such as a car accident or a fall from a height, are likely to be transmitted to other parts of the body. When children present with complaints of lower limb and pelvic fracture injuries, surgeons should be aware of concomitant trauma to other systems, including the abdomen, genitourinary system, spine, or head (14). Similarly, the genitourinary system is more likely to be injured after trauma than any other area. Pelvic fracture is accompanied by hematuria, dysuria, and urinary retention[37,38]. Children's organs, such as the kidneys, that are more important than other body parts, and the fat around the waist is underdeveloped and does not cushion injuries well[39]. The incidence of urinary tract or bladder injury is 1.5–3.7% in patients with pelvic fractures[40].

However, in the present study, respiratory trauma was the most common concomitant systemic trauma in patients with pelvic fractures. Therefore, in children with pelvic fractures due to high-energy trauma, a first examining physician should perform a detailed respiratory physical examination. For children with suspected pulmonary contusions or traumatic pneumothorax, comprehensive computed tomography scan and other imaging examinations should be performed to ensure a timely and accurate diagnosis of respiratory system injuries. For children with confirmed respiratory system injuries, timely and effective treatment methods such as tracheal intubation, mechanical ventilation, and chest drainage are vital to ensure adequate oxygenation and ventilation. This series of measures is crucial to prevent the progression of respiratory system complications, help slow the development of complications to the greatest extent and improve children's recovery and survival rates.

The limitation of this study is that although we have tried our best to collect information about the causes of injury and the fracture locations, there is still a small number of patients whose information is unclear, which has some impact on the accuracy of the research results.

Conclusion

We should strengthen health and safety education for children, parents, communities, and schools based on distribution characteristics such as age, sex, and causes of injuries. Protective measures for children's activities should also be increased. The incidence of lower limb fractures in children can be reduced and healthy growth through comprehensive intervention measures can be ensured.

High-energy trauma in children resulting in pelvic fractures and concomitant multi-system injuries is challenging, and its treatment and management require interdisciplinary teamwork. Therefore, comprehensive and individualized treatment plans for pelvic fractures and multi-system accompanying injuries due to high-energy trauma in children through close cooperation should be provided among pediatric orthopedics, critical care medicine, pediatric surgery, pediatric internal medicine, and other specialties, minimizing the risk of death in children.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Author contributions
Xin Qiu, Tianfeng Zhu, Hansheng Deng, Jianlin Chen and Haoran Feng conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript. Xin Qiu, Guoshuang Feng, Leonardo Antonio Sechi, Gianfilippo Caggiari, Chao You and Guibing Fu designed the data collection instruments, coordinated and supervised data collection and critically reviewed the manuscript. Zilong Huang, Jiahui Li, Xinyu Wang, Shizhe Liu, Shuaiyin Wang, Zhenkun Gu, Zhengyu Wu, Qisong Yang and Gen Liu collected data, carried out the initial analyses, and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Declarations

Competing interests
The authors declare no competing interests.

Ethics approval
This study was carried out in full compliance with the Declaration of Helsinki. This study has been approved by the Medical Ethics Committee of the Shenzhen Children's Hospital (No. 202000302).

Consent to participate
Informed consent was waived because of the register design of this study, which did not involve any additional risk for patients. The need for written informed consent was waived by the Shenzhen Children's Hospital ethics committee due to retrospective nature of the study.

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