Observational Study

Medicine®

OPEN

Epidemiological evaluation of traumatic lower limb fractures in children

Variation with age, gender, time, and etiology

Huan Liu, PhD[a], Hongwei Wang, PhD[b,c,d,e,*], Bing Shao, MD[f], Han Lu, PhD[b], Song Zhang, PhD[g], Lan Ou, MD[h], Yu Chen, PhD[b,*], Liangbi Xiang, MD[b]

Abstract

To investigate the age, gender, time, and etiology differences of traumatic lower limb fractures (TLLFs) in a population of children (≤18 years old), we retrospectively reviewed 936 children who had TLLFs and who came to our university-affiliated hospitals from 2001 to 2010. This study enrolled 657 males (70.2%) and 279 females (29.8%) aged (11.6 ± 4.9) years old. The most common etiologies and fracture sites were motor vehicle collisions (MVCs, 440, 47.0%) and tibias (376, 40.2%). A total of 126 (13.5%) patients suffered neurological deficits (NDs), 127 (13.6%) patients sustained associated injuries (ASOIs), and 78 (8.3%) patients sustained complications. During all periods the occurrence increased with increasing age group and a male preponderance was observed in all age groups. With increasing age, the proportion of injuries due to different etiologies increased and the proportion of femur fracture decreased from 65.2% to 34.5%. With increasing year of admission, the proportion of injuries due to MVCs decreased. The most common fracture sites were tibias in MVCs, femurs in low fall, high fall, and struck by object, feet in sprain. Male patients presented with significantly higher proportions of injuries due to struck by object and sprain, significantly lower proportions of pelvis fracture than the female patients. MVCs and tibias were the most common etiologies and fracture sites. Prevention and treatment should be taken according to the pattern of TLLFs which have specific annual, gender, and age characteristics.

Abbreviations: ASOIs = associated injuries, CT = computed tomography, MRI = magnetic resonance imaging, MVCs = motor vehicle collisions, ND = neurological deficit, PNI = peripheral nerve injuries, SD = standard deviation, TLLFs = traumatic lower limb fractures.

Keywords: children, fracture, lower limb, traumatic

1. Introduction

Pediatric fractures are common among all age groups and comprise about 15.8% in China.[1] Among patients presented with lower limb fractures, fractures in children and adolescent (0–19 years) accounted for about 19.2%,[2] and the incidence of pediatric fractures increased with year of admission.[3] Lower limb fractures account for approximately 20% of all fractures in children and may result in substantial mortality and morbidity.[4,5] During 2005 to 2006 in Sweden, 1692 fractures (66% boys) happened in 1615 children (<16 years), 19.5% were in the lower extremities.[4] For a total of 2716 patients (60% boys) in Switzerland, 2807 accidents with 2840 long bone fractures, tibia, fibula, and femur accounted for about 20%.[5] Some studies have shown the incidence of specific lower limb fracture sites and specific etiology in pediatric patients,[3–13] the patterns of fractures vary between countries and even regions within a

Editor: Ediriweera Desapriya.

HL, HW, and BS contributed equally to this work.

This work was supported by the Foundation of applied basic research of Sichuan province (2018JY402), the Liaoning Provincial Natural Science Foundation of China (201901389), the State Key Laboratory of Robotics (2017-O01), the Open Project Program of the State Key Laboratory of Trauma, Burn and Combined Injury (SKLKF201705) and the State Key Laboratory of Materials Processing and Die and Mould Technology (P2018-011).

The authors have no conflicts of interests to disclose.

[a] Department of Orthopedics, Affiliated Traditional Chinese Medicine Hospital, Southwest Medical University, Luzhou, [b] Department of Orthopedics, General Hospital of Northern Theater Command of Chinese PLA, Shenyang, Liaoning, [c] State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Science, Shenyang, Liaoning, [d] State Key Laboratory of Materials Processing and Die and Mould Technology, Huazhong University of Science and Technology, Wuhan, Hubei, [e] State Key Laboratory of Trauma, Burn and Combined Injury, Third Military Medical University, Chongqing, [f] Department of Anesthesia, General Hospital of Northern Theater Command of Chinese PLA, Shenyang, Liaoning, [g] Department of Nuclear Medicine, Xinqiao Hospital, the Third Military Medical University, Chongqing, [h] Department of Radiology, Southwest Hospital, the Third Military Medical University, Chongqing, China.

[*] Correspondence: Hongwei Wang, Yu Chen, Department of Orthopedics, General Hospital of Northern Theater Command of Chinese PLA, Shenyang, Liaoning 110016, China (e-mail: cplawhw@163.com, chenyumd@126.com).

How to cite this article: Liu H, Wang H, Shao B, Lu H, Zhang S, Ou L, Chen Y, Xiang L. Epidemiological evaluation of traumatic lower limb fractures in children. Medicine 2019;98:38(e17123).

Received: 12 March 2019 / Received in final form: 15 August 2019 / Accepted: 19 August 2019

http://dx.doi.org/10.1097/MD.0000000000017123

country, depending on the local climate, culture, and leisure-time activities,[6–13] but data on the overall patterns and epidemiologic trends of traumatic lower limb fractures (TLLFs) has not been studied extensively in Chongqing, China.

In the present study, we reviewed a multicenter (2 tertiary hospitals in Chongqing, China) database of TLLFs in a population of children ≤18 years of age that occurred over a 10-year period between 2001 and 2010 to address these deficiencies and to provide comprehensive information on this important childhood public health problem in China. The incidence and patterns were summarized with respect to the different age groups, the year of admission and etiologies were investigated.

2. Materials and methods

2.1. Study population

Our study included 936 patients in a population of children (≤18 years old) who had TLLFs between January 2001 and December 2010 and who came to our university-affiliated hospitals. We made definitive diagnoses of TLLFs in patients who were children (≤18 years old) using X-rays, computed tomography (CT) and/or magnetic resonance imaging (MRI). The patients were grouped in four age groups: ≤3 years old, 3 to 6 years old, 6 to 12 years old and 12 to 18 years old. The patients were grouped in 5 year of admission range groups: 2001–2002, 2003–2004, 2005–2006, 2007–2008, and 2009–2010. The etiologies were grouped in 5 groups: MVCs, high fall (≥2m), low fall (<2m), mechanical injury, struck by object, sprain and others. Sites of TLLFs were divided into femur, tibia, fibula, pelvis, and foot. The study protocol and this manuscript were approved by the committee on ethics and the institutional review board of our institution.

2.2. Statistical analysis

All statistical analyses were performed using SPSS version 22.0 (SPSS, Inc., Chicago, IL). We used Pearson chi-square tests to assess differences in age, sex distribution, and clinical characteristics between the 2 groups. Differences in the continuous variables between the 2 groups were evaluated using independent samples *t* tests. The variables are expressed as mean ± standard deviation (SD).

3. Results

3.1. Age, gender, and year of admission distributions

The study included 657 male and 279 female patients with a mean age of 11.6 ± 4.9 years and a sex ratio of 2.4 (Table 1). The incidence peaked around the periods of 12 to 18 years in both male and female patients. Patients in ≤3 years old group accounted for 4.9%, whereas 3 to 6 years old patients accounted for 16.6%, 6 to 12 years old patients accounted for 28.0%, 12 to 18 years old patients accounted for 50.5% (Table 2). As shown in Figure 1, the number of children diagnosed was increased with the year of admission. During all periods the

Table 1

The epidemiology of traumatic lower limb fractures according to different etiologies.

Etiologies	MVCs	Low fall	High fall	Struck by object	Sprain	Others	Total
Total	440	243	140	41	37	35	936
Male/female	299/141 (2.1)	170/73 (2.3)	101/39 (2.6)	36/5 (7.2)	33/4 (8.3)	18/17 (1.1)	657/279 (2.4)
Mean age	10.4 ± 5.1	12.3 ± 4.3	13.1 ± 4.7	11.1 ± 5.0	14.4 ± 2.9	14.5 ± 3.7	11.6 ± 4.9
Age range							
≤3	25 (5.7)	12 (4.9)	6 (4.3)	3 (7.3)	0	0	46 (4.9)
3–6	113 (25.7)	20 (8.2)	13 (9.3)	5 (12.2)	1 (2.7)	3 (8.6)	155 (16.6)
6–12	133 (30.2)	75 (30.9)	27 (19.3)	16 (39.0)	8 (21.6)	3 (8.6)	262 (28.0)
12–18	169 (38.4)	136 (56.0)	94 (67.1)	17 (41.5)	28 (75.7)	29 (82.9)	473 (50.5)
Fracture sites							
Femur	166 (37.7)	107 (44.0)	67 (47.9)	18 (43.9)	9 (24.3)	8 (22.9)	375 (40.1)
Tibia	209 (47.5)	98 (40.3)	37 (26.4)	15 (36.6)	7 (18.9)	10 (28.6)	376 (40.2)
Fibula	133 (30.2)	45 (18.5)	24 (17.1)	9 (22.0)	5 (13.5)	6 (17.1)	222 (23.7)
Pelvis	44 (10.0)	7 (2.9)	21 (15.0)	3 (7.3)	5 (13.5)	8 (22.9)	88 (9.4)
Patellar	10 (2.3)	14 (5.8)	5 (3.6)	0	3 (8.1)	3 (8.6)	35 (3.7)
Foot	79 (18.0)	20 (8.2)	38 (27.1)	13 (31.7)	13 (35.1)	9 (25.7)	172 (18.4)
ND	78 (17.7)	6 (2.5)	35 (25.0)	4 (9.8)	0	3 (8.6)	126 (13.5)
PNI	30 (6.8)	4 (1.6)	4 (2.9)	3 (7.3)	0	3 (8.6)	44 (4.7)

MVCs = motor vehicle collisions, ND = neurological deficit, PNI = peripheral nerve injuries.

Table 2

The epidemiology of traumatic lower limb fractures according to different age range groups.

Age range	≤3	3–6	6–12	12–18	Total
Total	46	155	262	473	936
Male/female	32/14 (2.3)	102/53 (1.9)	178/84 (2.1)	345/128 (2.7)	657/279 (2.4)
Mean age	2.3 ± 0.8	5.1 ± 0.8	9.6 ± 1.7	15.9 ± 1.7	11.6 ± 4.9
Fracture sites					
Femur	30 (65.2)	76 (49.0)	106 (40.5)	163 (34.5)	375 (40.1)
Tibia	11 (23.9)	71 (45.8)	110 (42.0)	184 (38.9)	376 (40.2)
Fibula	5 (10.9)	49 (31.6)	67 (25.6)	101 (21.4)	222 (23.7)
Pelvis	3 (6.5)	8 (5.2)	20 (7.6)	57 (12.1)	88 (9.4)
Patellar	0	0	7 (2.7)	28 (5.9)	35 (3.7)
Foot	4 (8.7)	28 (18.1)	38 (14.5)	102 (21.6)	172 (18.4)
ND	6 (13.0)	15 (9.7)	29 (11.1)	76 (16.1)	126 (13.5)
PNI	2 (4.3)	10 (6.5)	8 (3.1)	24 (5.1)	44 (4.7)

ND = neurological deficit, PNI = peripheral nerve injuries.

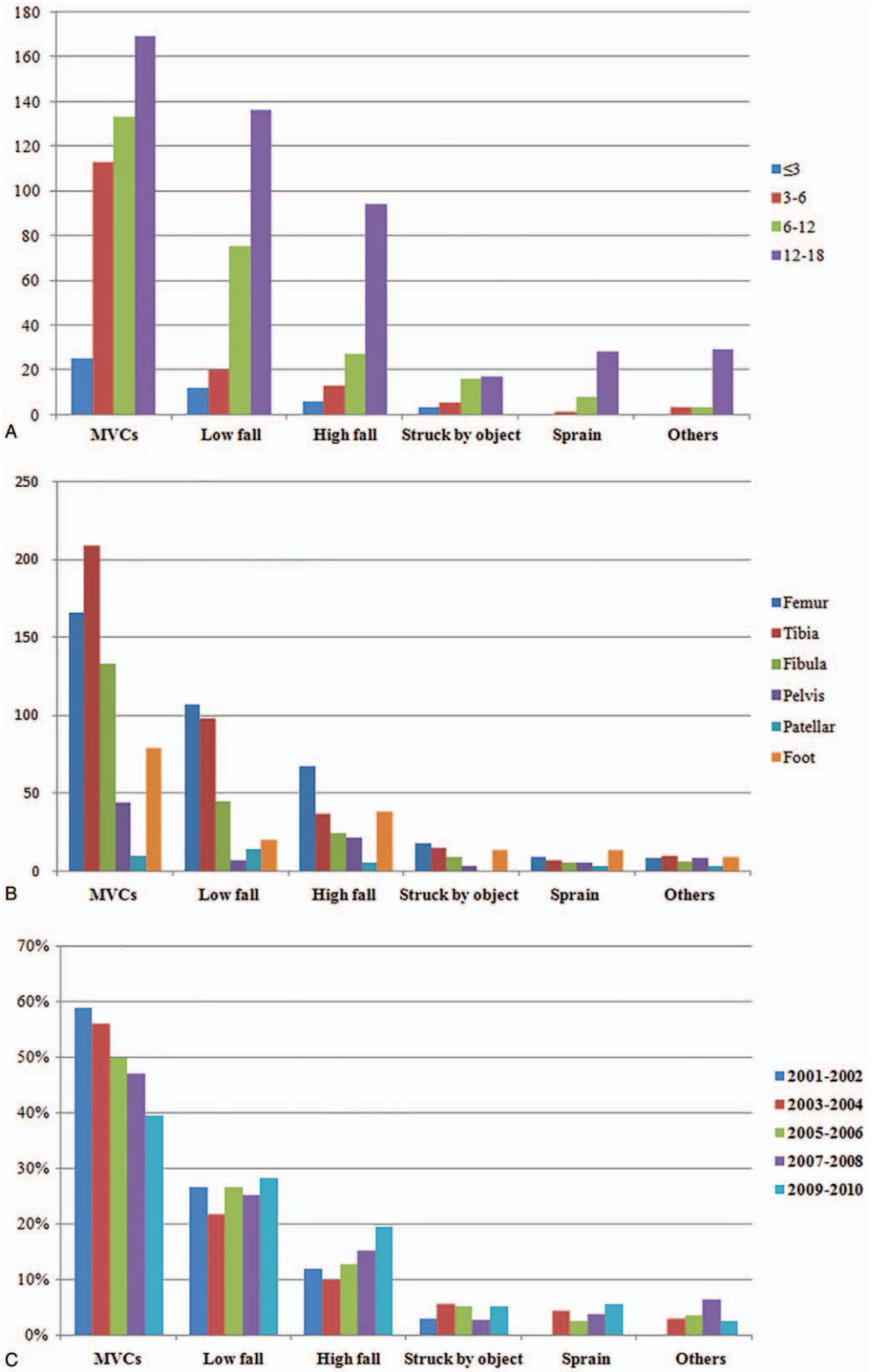

Figure 1. Age, fracture site distribution according to different etiologies (A, B) and etiology distribution according to different year of admission (C).

occurrence increased with increasing age group and a male preponderance was observed in all age groups (Table 2). The overall annual incidence of TLLFs was (89.1 ± 34.8) patients per 100,000 hospital admissions per 2-year period. Annual incidence rates increased from 28.8 patients (2001–2002) to 113.5 patients (2007–2008) and then decreased to 94.0 patients (2009–2010) with year of admission per 100,000 hospital admissions per 2-year period.

3.2. Etiology

Overall, the most common etiologies were MVCs (47.0%), followed by low falls (26.0%), high falls (15.0%) and struck by object (4.4%). Among children of all different age range groups and both gender groups, the most common causes of injury were MVCs and low falls. With increasing year of admission, the proportion of injuries due to MVCs decreased (Table 3). The proportions of injuries due to struck by object and sprain were significant higher in the male than female patients (Table 4).

3.3. Fracture sites and time

Among all the patients, the most common fracture sites were tibias (40.2%) and femurs (40.1%), followed by fibulas (23.7%) (Fig. 2). In children injured by MVCs, we predominantly observed tibia (47.5%) and femur fractures (37.5%). In children who suffered low falls, we mainly observed femur fractures (44.0%) and fractures of the tibia (40.3%). In children who suffered high fall, we predominantly noted fractures of the femur (47.9%) and foot (27.1%). In patients struck by an object, we predominantly observed fractures of the femur (43.9%) and tibia (36.6%). In patients who sustained sprains, we most frequently noted fractures of the foot (35.1%) and femur (24.3%).

The proportion of femur fractures was the largest in the high fall group (47.9%) and lowest in the sprain group (24.3%). The proportion of tibia fracture was the largest in the MVCs group (47.5%) and lowest in the sprain group (18.9%). The proportion of fibula fracture was the largest in the MVCs group (30.2%) and lowest in the sprain group (13.5%). The proportion of pelvis fracture was the largest in the high fall group (15.0%) and lowest in the low fall group (2.9%). The proportion of foot fracture was the largest in the sprain group (35.1%) and lowest in the low fall group (8.2%).

The most common fracture sites were femurs (65.2%) in the $\leq$3 years old patients, femurs (49.0%) and tibias (45.8%) in the 3 to 6 years old patients, tibias (42.0%), and femurs (40.5%) in the 6 to 12 years old patients, tibias (38.9%) and femurs (34.5%) in the 12 to 18 years old patients. With increasing age, the proportion of femur fracture decreased from 65.2% to 34.5%. The proportion of pelvis fracture was significant higher in the female than the male patients (Table 4). The incidences had an obvious seasonal, time variation and a little week variation, with peaks in Autumn (28.0%), Monday (15.1%), Tuesday (15.1%), and 16:00 to 20:00 PM (31.2%) (Fig. 3).

3.4. Neurological deficits (NDs), associated injuries (ASOIs), and complications

A total of 126 (13.5%) patients suffered NDs, 127 (13.6%) patients sustained ASOIs, and 78 (8.3%) patients sustained complications (Fig. 4). Among the patients who presented with NDs, peripheral nerve injuries (PNI) were seen in 44 patients.

Table 4

The epidemiology of traumatic lower limb fractures according to different genders.

Genders	Male	Female	P
Total	657	279	
Mean age	11.9±4.9	11.2±4.9	.051
Age range			
≤3	32 (4.9)	14 (5.0)	.924
3–6	102 (15.5)	53 (19.0)	.191
6–12	178 (27.1)	84 (30.1)	.347
12–18	345 (52.5)	128 (45.9)	.063
Year range			
2001–2002	23 (3.5)	11 (3.9)	.741
2003–2004	101 (15.4)	42 (15.1)	.901
2005–2006	129 (19.6)	70 (25.1)	.062
2007–2008	185 (28.2)	81 (29.0)	.786
2009–2010	219 (33.3)	75 (26.9)	.052
Etiologies			
MVCs	299 (45.5)	141 (50.5)	.159
Low fall	170 (25.9)	73 (26.2)	.926
High fall	101 (15.4)	39 (14.0)	.584
Struck by object	36 (5.5)	5 (1.8)	.012
Sprain	33 (5.0)	4 (1.4)	.010
Others	18 (2.7)	17 (6.1)	.013
Fracture sites			
Femur	269 (40.9)	106 (38.0)	.399
Tibia	273 (41.6)	103 (36.9)	.186
Fibula	151 (23.0)	71 (25.5)	.417
Pelvis	52 (7.9)	36 (12.9)	.017
Patellar	26 (4.0)	9 (3.2)	.589
Foot	114 (17.4)	58 (20.8)	.214
ND	90 (13.7)	36 (12.9)	.744
PNI	32 (4.9)	12 (4.3)	.706

MVCs = motor vehicle collisions, ND = neurological deficit, PNI = peripheral nerve injuries.

4. Discussion

Lower limb fractures account for approximately 20% of all fractures in children and may result in substantial mortality and morbidity.[4,5] Some studies have shown the incidence of specific lower limb fracture sites and specific etiology in pediatric patients,[3–14] but data on the overall patterns and epidemiologic trends of TLLFs have not been studied extensively in China. In the current study, pediatric and adolescent traumatic fractures were evaluated in 2473 children of 18 years of age or less with a total of 936 lower limb fractures (37.8%) over a 10-year period. Of the patients with TLLFs, 473 (50.0%) could be found in the

Table 3

The etiology distribution according to different year of admission.

Year range	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010
MVCs	20 (58.8)	80 (55.9)	99 (49.7)	125 (47.0)	116 (39.5)
Low fall	9 (26.5)	31 (21.7)	53 (26.6)	67 (25.2)	83 (28.2)
High fall	4 (11.8)	14 (9.8)	25 (12.6)	40 (15.0)	57 (19.4)
Struck by object	1 (2.9)	8 (5.6)	10 (5.0)	7 (2.6)	15 (5.1)
Sprain	0	6 (4.2)	5 (2.5)	10 (3.8)	16 (5.4)
Others	0	4 (2.8)	7 (3.5)	17 (6.4)	7 (2.4)
Total	34	143	199	266	294

MVCs = motor vehicle collisions.

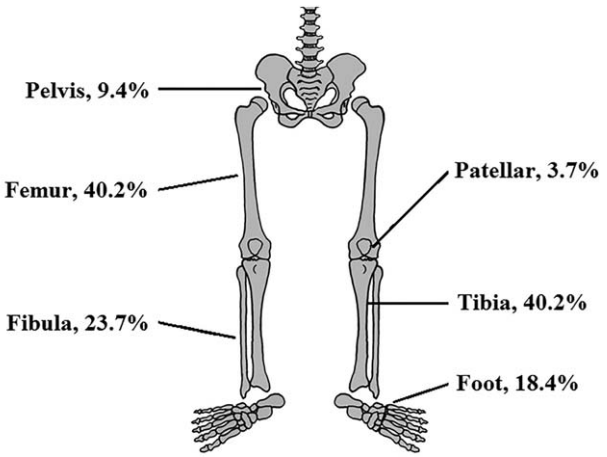

Figure 2. Fracture site distribution of all 936 patients.

age group of 12 to 18 years of age with the largest proportion. During all periods the occurrence increased with increasing age group and a male preponderance was observed in all age groups. This statistic finding can be explained by increased activity, and by more aggressive sports activities with increasing age. Our data confirm that there is considerable variation in the incidence of lower limb fractures by age and sex.

The most common causes were MVCs (47.0%), followed by low falls (26.0%). Among children of all different age range groups and both gender groups, the most common causes of injury were MVCs and low falls. Previous studies showed that the leading cause of femur shaft fractures was fall of <1 m in children younger than 4 years of age, sports accidents in children 4 to 12 years of age, and traffic accidents in children 13 to 14 years of age.[14] With increasing age the proportion of injuries due to different etiologies increased and the proportion of femur fractures decreased from 65.2% to 34.5%, which was consistent with previous studies which showed that the number of femur fractures decreased with increasing age.[14,15] The most common fracture sites were the tibia (40.2%) in the current study. Similar to previous reports, tibia shaft was the most common fracture site in the lower limb region.[16,17] Therefore, we can see that the pattern of TLLFs among the patients has its own characteristics and that targeted intervention methods should be considered to decrease the incidence and burden of TLLFs.

The incidences had an obvious seasonal variation, with peak in autumn (28.0%). Cheng et al reported that femoral shaft fractures and tibia shaft fractures showed a peak incidence in winter.[16] The incidences demonstrated a time variation, with peaks in 16:00 to 20:00 PM (31.2%). These are the seasons and times of great opportunity for outdoor and sports activities, short trips and recreation in general, thus tending to a higher chance of trauma. We believe that the pattern of traumatic fractures among children and adolescents is partly explained by changes in the activity patterns of children over time. The peak time was during rush hour or dismissal times. The study we presented here may be useful to public health program planners in prioritizing funding and developing approaches for the prevention and treatment of lower limb fractures such as building a home management program for stable pediatric fractures and a pediatric virtual fracture clinic.[18]

This study has several limitations. First, it was limited by the retrospective study design and by the small sample size. Second, there may be selection bias because this study includes patients who were referred to our teaching hospitals.

5. Conclusion

During all periods the occurrence increased with increasing age group and a male preponderance was observed in all age groups. With increasing age, the proportion of injuries due to different etiologies increased and the proportion of femur fracture decreased from 65.2% to 34.5%. With increasing year of admission, the proportion of injuries due to MVCs decreased. The most common fracture sites were tibias in MVCs, femurs in low falls, high falls and struck by object, feet in sprain. Male patients presented with significantly higher proportions of injuries due to struck by object and sprain, significantly lower proportions of pelvis fracture than the female patients. Prevention and treatment should be taken according to the pattern of TLLFs which have specific annual, gender and age characteristics.

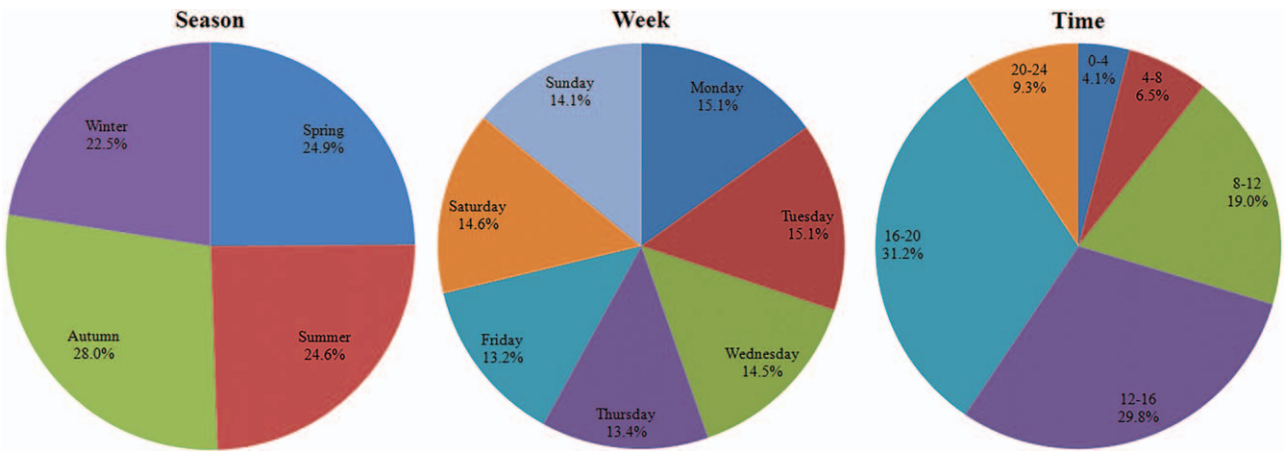

Figure 3. Season, week, and time distribution of all 936 patients.

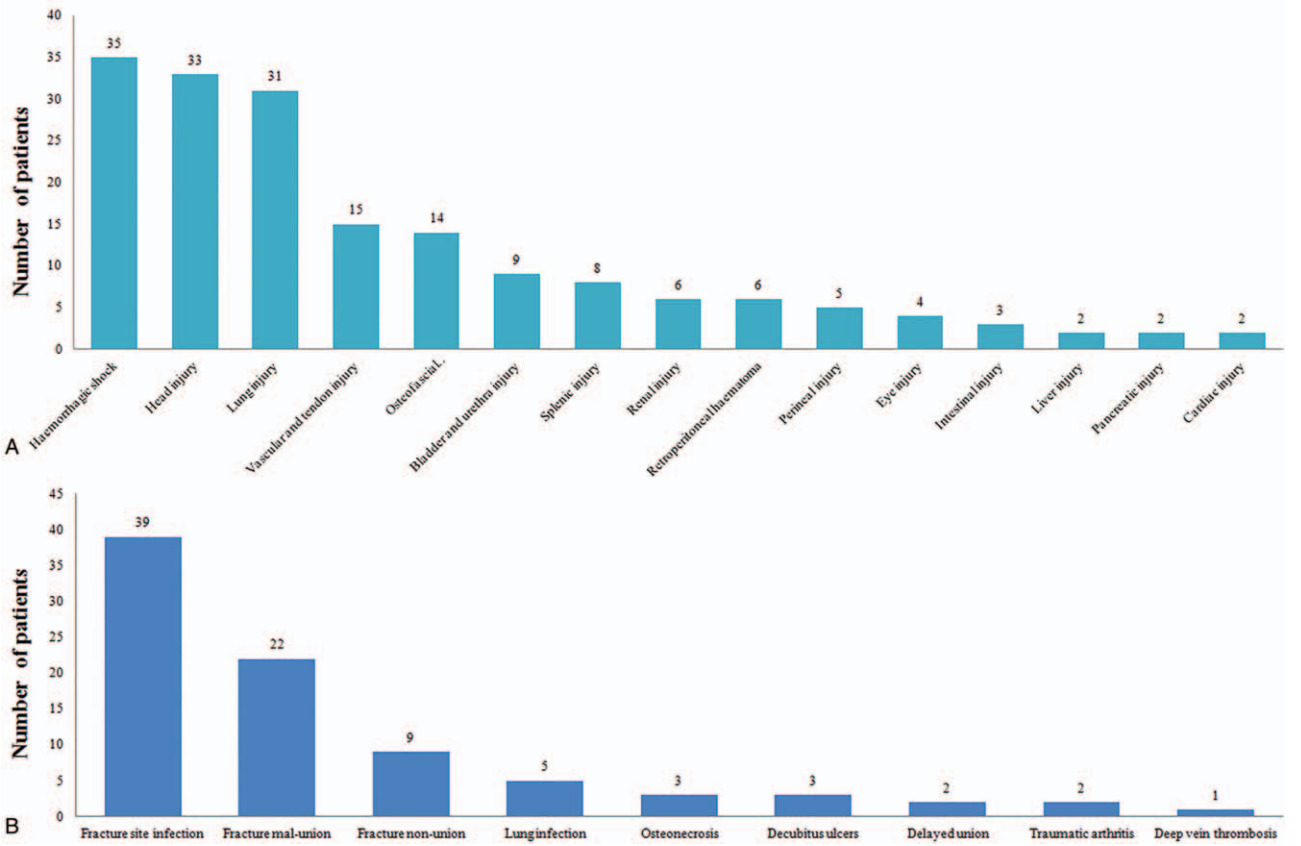

Figure 4. Number of patients presented with associated injuries (A) and complications (B).

Author contributions

Conceptualization: Huan Liu, Hongwei Wang.
Data curation: Hongwei Wang, Han Lu, Song Zhang, Lan Ou.
Formal analysis: Huan Liu, Hongwei Wang, Bing Shao, Lan Ou, Yu Chen, Liangbi Xiang.
Funding acquisition: Hongwei Wang.
Supervision: Huan Liu, Liangbi Xiang.
Visualization: Yu Chen.
Writing – original draft: Huan Liu, Hongwei Wang, Bing Shao, Han Lu, Song Zhang, Lan Ou.
Writing – review & editing: Hongwei Wang, Yu Chen, Liangbi Xiang.

References

[1] Chen W, Lv H, Liu S, et al. National incidence of traumatic fractures in China: a retrospective survey of 512 187 individuals. Lancet Glob Health 2017;5:e807–17.
[2] Kaye JA, Jick H. Epidemiology of lower limb fractures in general practice in the United Kingdom. Inj Prev 2004;10:368–74.
[3] Hedström EM, Svensson O, Bergström U, et al. Epidemiology of fractures in children and adolescents. Acta Orthop 2010;81:148–53.
[4] Lempesis V, Rosengren BE, Nilsson JÅ, et al. Time trends in pediatric fracture incidence in Sweden during the period 1950–2006. Acta Orthop 2017;88:440–5.
[5] Joeris A, Lutz N, Wicki B, et al. An epidemiological evaluation of pediatric long bone fractures – a retrospective cohort study of 2716 patients from two Swiss tertiary pediatric hospitals. BMC Pediatr 2014;14:314.
[6] Wang H, Yu H, Zhou Y, et al. Traumatic fractures as a result of falls in children and adolescents: a retrospective observational study. Medicine (Baltimore) 2017;96:e7879.
[7] Wang H, Zhou Y, Liu J, et al. Traumatic fractures as a result of motor vehicle collisions in children and adolescents. Int Orthop 2018;42:625–30.
[8] Cooper C, Dennison EM, Leufkens HG, et al. Epidemiology of childhood fractures in Britain: a study using the general practice research database. J Bone Miner Res 2004;19:1976–81.
[9] Spady DW, Saunders DL, Schopflocher DP, et al. Patterns of injury in children: a population-based approach. Pediatrics 2004;113:522–9.
[10] Moon RJ, Harvey NC, Curtis EM, et al. Ethnic and geographic variations in the epidemiology of childhood fractures in the United Kingdom. Bone 2016;85:9–14.
[11] Curtis EM, van der Velde R, Moon RJ, et al. Epidemiology of fractures in the United Kingdom 1988-2012: variation with age, sex, geography, ethnicity and socioeconomic status. Bone 2016;87:19–26.
[12] Christoffersen T, Ahmed LA, Winther A, et al. Fracture incidence rates in Norwegian children, The Tromsø Study, Fit Futures. Arch Osteoporos 2016;11:40.
[13] Koga H, Omori G, Koga Y, et al. Increasing incidence of fracture and its sex difference in school children: 20 year longitudinal study based on school health statistic in Japan. J Orthop Sci 2018;23:151–5.
[14] Heideken JV, Svensson T, Blomqvist P, et al. Incidence and trends in femur shaft fractures in Swedish children between 1987 and 2005. J Pediatr Orthop 2011;31:512–9.
[15] Talbot C, Davis N, Majid I, et al. Fractures of the femoral shaft in children: national epidemiology and treatment trends in England following activation of major trauma networks. Bone Joint J 2018;100-B:109–18.
[16] Cheng JC, Shen WY. Limb fracture pattern in different pediatric age groups: a study of 3,350 children. J Orthop Trauma 1993;7:15–22.
[17] Park MS, Chung CY, Choi IH, et al. Incidence patterns of pediatric and adolescent orthopaedic fractures according to age groups and seasons in South Korea: a population-based study. Clin Orthop Surg 2013;5:161–6.
[18] Robinson PM, Sim F, Latimer M, et al. Paediatric fracture clinic re-design: Incorporating a virtual fracture clinic. Injury 2017;48:2101–5.