Age, gender, and etiology differences of sports-related fractures in children and adolescents

A retrospective observational study

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Abstract

To investigate the age, gender, and etiology differences of sports-related fractures in children and adolescents (6–18 years old). We retrospectively reviewed 410 child and adolescent patients (335 males and 75 females aged 13.5 ± 3.1 years old) with sports-related fractures admitted to our university-affiliated hospitals from 2001 to 2010. The incidence and pattern were summarized with respect to different age groups, genders, etiologies.

Playing basketball (97, 23.7%) and running (90, 22.0%) were the most common etiologies. Radius (102, 24.9%) was the most common fracture site. The most common etiologies and fracture sites were biking (19.6%) and humerus fractures (28.0%) in the ≤12 age range group, playing basketball (34.0%) and radius fractures (26.2%) in the 12–15 age range group, playing basketball (31.7%) and radius fractures (23.0%) in the 15–18 age range group. The most common etiologies were playing basketball (27.5%) in the male group and running (24.0%) in the female group. The male presented with significantly higher rate of radius fractures and nerve injury, significantly lower rate of femoral fractures than the female. The most common fracture sites were radius fractures in the basketball group (28.9%) and cricket group (37.5%), humerus fracture in the running group (20.0%), biking group (23.3%), and climbing group (45.0%), tibia fractures in the football group (28.9%) and playing SP bars group (50.0%), and ulna fractures (37.5%) in the ice skating group.

Sports-related fractures are common in children and adolescents, particularly in males. Basketball, running, and biking were the most common etiologies; radius, ulna, and humerus were the most common fracture sites.

Abbreviations: CFF = craniofacial fracture, CT = computed tomography, LEF = lower extremity fracture, MRI = magnetic resonance imaging, NI = nerve injury, SF = spine fracture, SP = single parallel, UEF = upper extremity fracture.

Keywords: adolescent, child, fracture, sports, traumatic

1. Introduction

Fractures are common among all types of pediatric injuries and comprise 10% to 25%.[1,2] The patterns of fractures vary between countries and even regions within a country, depending on the local climate, culture, and leisure-time activities.[3,4] We have previously analyzed the epidemiology of traumatic fractures in children and adolescents caused by falls[5] and motor vehicle collisions[6]; the incidence and pattern has its own characteristics with respect to different age groups, etiologies, and genders. Sporting activities are the third most common cause of fractures and they were the main causes of fracture-related hospitalizations and presentations to emergency departments among children.[7–17]
Although fractures due to sports account for a small proportion of injuries among children, many of them are preventable by modifying the environment and strengthening the education. Further research may help to identify preventive measures to reduce the number of fractures, in particular those involving sports in China. In the present study, we reviewed a multicenter (two tertiary hospitals in Chongqing, China) database of sports-related fractures in a population of children and teenagers <18 years of age that happened over a 10-year period between 2001 and 2010. The incidence and pattern were summarized with respect to different age groups, gender, and etiologies.

2. Materials and methods
2.1. Study population
Our study included 410 child and adolescent patients (<18 years old) with sports-related traumatic fractures between January 2001 and December 2010 and who were admitted to our university-affiliated hospitals. We made a definite diagnosis of traumatic fractures in child and adolescent patients (<18 years old) using X-rays, computed tomography (CT), and magnetic resonance imaging (MRI). The sports (etiologies) including playing basketball, running, biking, playing football, playing single parallel bars (SP bars), climbing, cricket, ice skating, rollerblading, long jumping, playing table tennis, and others. The fracture regions include upper extremity fracture (UEF), lower extremity fracture (LEF), craniofacial fracture (CFF) and spine fracture (SF). There were 6 children presented with multiple fractures from two fracture regions and 1 child presented with multiple fractures from three fracture regions. 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 frequency and independent samples t-tests to assess differences in the continuous variables.

3. Results
3.1. Demographic features and general characteristics
The study included 335 males and 75 female patients with a mean age of 13.5±3.1 years old and a sex ratio of 4.5. The most common etiologies and fracture sites were playing basketball (23.7%) and radius fractures (24.9%). The most common fracture regions were UEF (59.0%) and LEF (33.4%). A total of 35 (8.5%) patients suffered a nerve injury. A total of 30 (7.3%) patients sustained complications (Fig. 1).

Playing SP bars and rollerblading presented with the highest frequency of UEF. Long jumping and ice skating presented with highest frequency of LEF (Fig. 2) Biking and playing SP bars presented with highest frequency of CFF. Biking and Playing SP bars presented with highest frequency of nerve injury (NI) (Table 1). The incidences had a little seasonal variation and an obvious time and week variation, with peaks in summer (26.1%), 12:00–16:00 PM (33.8%), 16:00–20:00 PM (33.8%), and Friday (17.3%) (Fig. 3).

3.2. Characteristics respect to different age groups
The most common age group was <12 age range group (34.9% of all patients) and the patients in the age group had the smallest sex ratio of 2.4. The frequency of playing basketball in the <12 age range group presented with the lowest rate with 6.3%. Playing SP bars, climbing, and cricket in the <12 age range group presented with the highest rate of 10.5%, 9.8%, and 9.1%. Humerus fractures in the <12 age range group presented with the highest rate of 28.0%. Clavicle fracture in the 12–15 age range group presented with the highest rate of 10.6%.

The most common etiologies were biking (19.6%) and running (16.1%) in the <12 age range group, playing basketball (34.0%) and running (22.0%) in the 12–15 age range group, playing basketball (31.7%) and running (28.6%) in the 15–18 age range group. The most common fracture sites were humerus fractures (28.0%) in the <12 age range group, radius fractures (26.2%) and ulna fractures (19.9%) in the 12–15 age range group, and radius fracture (23.0%) and humerus fractures (17.5%) in the 15–18 age range group.

Figure 1. Complication distribution of all the fractures.
Figure 2. Frequencies of UEF (A), LEF (B), and NI (C) according to different etiologies.
3.3. Characteristics respect to different genders

The most common etiologies were playing basketball (27.5%) and running (21.5%) in the male group, and running (24.0%) and biking (20.0%) in the female group. The most common fracture sites were radius fractures (28.4%) in the male group and humerus fractures (28.0%) in the female group (Table 2). Fractures caused by playing basketball and football presented with significant higher rates in the male than the female. Fractures caused by ice skating presented with significant higher rate in the female than the male. Radius fractures and NI presented with significant higher rate in the male than the female. Femoral fractures presented with significant higher rate in the female than the male.

3.4. Characteristics respect to different etiologies

The most common fracture sites were radius fractures (28.9%) in the playing basketball group, humerus fracture (20.0%) in the running group, humerus fracture (23.3%) in the biking group, tibia fractures (28.9%) in the playing football group, radius fractures (50.0%) in the playing SP bars group, humerus fractures (45.0%) in the climbing group, radius fractures (37.5%) in the cricket group, and ulna fractures (37.5%) in the ice skating group (Table 3).

4. Discussion

Pediatric sports-related fractures are preventable occurrences, which may result in serious injury such as nerve injury (8.5%); we can prevent the happening of sports-related fractures through strengthening the protective measures and improving the sports equipment and environment. The most common etiologies were basketball (23.7%) and running (22.0%) in China, which were different from other studies, which showed football and rugby.[10,12,13] The most common fracture regions were upper limb fractures (59.0%) and lower limb fractures (33.4%); the most common fracture sites were hand/finger,[10] distal radius and metacar-

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Table 1

| Sport        | Number (%) | M/F (ratio) | Age  | UEF (%) | LEF (%) | CFF (%) | SF (%) | NI (%) | Commonest fracture |
|--------------|------------|-------------|------|---------|---------|---------|--------|--------|-------------------|
| Basketball   | 97 (23.7)  | 92/5 (18.4) | 14.9±2.0 | 63 (64.9) | 31 (32.0) | 0       | 7 (7.2) | Radius 28.9%     |
| Running      | 90 (22.0)  | 72/18 (40.0) | 14.2±3.0 | 48 (53.3) | 35 (38.9) | 7 (7.8) | 1 (1.1) | Humerus 20.0%    |
| Biking       | 60 (14.6)  | 45/15 (30.0) | 12.8±3.0 | 32 (53.3) | 17 (28.3) | 13 (21.7) | 2 (3.3) | Humerus 23.3%    |
| Football     | 45 (11.0)  | 44/1 (44.0)  | 14.7±2.4 | 23 (51.1) | 20 (44.4) | 2 (4.4) | 0       | Tibia 28.9%      |
| SP bars      | 22 (5.4)   | 17/5 (3.4)   | 11.3±2.5 | 20 (90.9) | 0         | 2 (9.1)  | 0       | Radius 50.0%     |
| Climbing     | 20 (4.9)   | 15/5 (3.0)   | 11.1±3.4 | 13 (65.0) | 4 (20.0)  | 3 (15.0) | 1 (5.0) | Humerus 45.0%    |
| Cricket      | 16 (3.3)   | 12/4 (3.3)   | 10.3±2.9 | 12 (75.0) | 2 (12.5)  | 1 (6.3)  | 0       | Humerus/Radius 37.5% |
| Ice skating  | 16 (3.3)   | 7/9 (0.8)    | 13.2±3.3 | 7 (43.8)  | 9 (56.3)  | 1 (6.3)  | 0       | Ulnar 37.5%      |
| Rollerblading| 10 (2.4)   | 9/1 (9.0)    | 10.8±3.3 | 8 (80.0)  | 2 (20.0)  | 0       | 0       | Radius/Ulnar 60.0% |
| Long jumping | 8 (2.0)    | 7/1 (7.0)    | 13.6±1.9 | 2 (25.0)  | 6 (75.0)  | 0       | 0       | Tibia 37.5%      |
| Table tennis | 4 (1.0)    | 4/0          | 13.0±0.8 | 3 (75.0)  | 1 (25.0)  | 0       | 0       | Radius/Ulnar 50.0% |
| Others       | 18 (4.4)   | 10/8 (0.8)   | 12.3±4.0 | 11 (61.1) | 10 (55.6) | 0       | 1 (5.5) | Ulnar 27.8%      |
| Total        | 410 (100)  | 335/75 (4.5) | 13.5±3.1 | 242 (60.0) | 137 (33.4) | 32 (7.8) | 6 (1.5) | Radius 24.9%     |

CFF = craniofacial fracture, LEF = lower extremity fracture, NI = nerve injury, SF = spine fracture, SP = single parallel, UEF = upper extremity fracture.

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Figure 3. Season, week, and time distribution.
pur,"\textsuperscript{112} finger phalanges, and distal radius.\textsuperscript{113} Although it is more difficult to change the intensity or conditions of a game, many strategies can be used during practice to limit player-to-player contact and other potentially injurious behaviors.\textsuperscript{8,9} Sports-related fractures are common in children and adolescents, particularly in males. They tend to be low energy injuries affecting the upper limb in particular. Preventive measures should be considered, including increasing public awareness and caregiver education especially the schools and public premises.

Fractures caused by rollerblading presented with highest frequencies of upper extremity fracture with 80.0\%, which was consistent with previous study (upper limb fracture: lower limb fracture = 68:11).\textsuperscript{111} Fractures caused by ice skating presented with highest frequencies of lower extremity fracture with 75.0\%, which was not consistent with previous study, which showed that upper limb fractures were the most common fracture sites in the ice skating injuries (upper limb fracture: lower limb fracture = 91:9).\textsuperscript{112} Fractures caused by biking presented with highest frequency of craniofacial fracture with 21.7\%. It may be because the patients caused by biking are easy to fall down and hurt their faces. The most common fracture sites were radius fractures in the playing basketball group (28.9\%) and cricket group (37.5\%), humerus fracture in the running group (20.0\%), biking group (23.3\%), and climbing group (45.0\%), tibia fractures in the playing football group (28.9\%) and playing SP bars group (50.0\%), and ulna fractures (37.5\%) in the ice skating group. So, we can prevent the happening of sports-related fractures through improving the sports equipment such as protective gear on upper limb when playing basketball and protective gear on lower limb when playing football.

The most common etiologies were biking (19.6\%) in the \( \leq 12 \) age range group, playing basketball in the 12–15 age range group (34.0\%), and the 15–18 age range group (31.7\%). The most common fracture sites were humerus fractures (28.0\%) in the \( \leq 12 \) age range group, radius fractures (23.0\%), and ulna fractures (15.9\%) in the 12–15 age range group. For children and adolescents 20 years of age and younger, pediatric bicycle-related hospitalizations are a significant public health problem; the morbidity and mortality among children and the economic costs to society are large.\textsuperscript{116} So, we should pay much attention to fractures caused by biking and humerus fractures in the \( \leq 12 \) age range group, fractures caused by playing basketball and radius fractures in the 12–18 age range group.

Fractures caused by playing basketball and football presented with significant higher rates in the male than the female. Fractures caused by ice skating presented with significant higher rate in the female than the male. Radius fractures and nerve injury presented with significant higher rate in the male than the female. Fractures caused by biking presented with significant higher rates in the male than the female. So, we can see that the pattern of fractures among the patients caused by sports has its own characteristics; targeted intervention strategies should be taken to decrease the incidence and burden of sports-related fractures. This study has several limitations. First, it was...
Table 3

The epidemiology of fractures caused by sport with a prevalence of ≥1%.

| Fracture      | Basketball (n=97) | Running (n=90) | Biking (n=60) | Football (n=45) | SP bars (n=22) | Climbing (n=20) | Cricket (n=16) | Ice skating (n=16) | Rollerblading (n=10) | Long jumping (n=8) | Tennis (n=4) |
|---------------|------------------|----------------|---------------|-----------------|----------------|-----------------|---------------|-------------------|----------------------|------------------|--------------|
| Radius        | 28 (28.9)        | 14 (15.6)      | 10 (16.7)     | 12 (26.7)       | 11 (50.0)      | 4 (20.0)        | 6 (37.5)      | 5 (31.3)          | 6 (60.0)             | 1 (12.5)        | 2 (50.0)     |
| Ulna          | 21 (21.6)        | 9 (10.0)       | 12 (20.0)     | 9 (20.0)        | 7 (31.8)       | 3 (15.0)        | 5 (31.3)      | 6 (37.5)          | 6 (60.0)             | 1 (12.5)        | 2 (50.0)     |
| Humerus       | 17 (17.5)        | 18 (20.0)      | 14 (23.3)     | 3 (6.7)         | 9 (40.9)       | 9 (45.0)        | 6 (37.5)      | 1 (6.3)           | 2 (20.0)             | 1 (12.5)        | 1 (25.0)     |
| Clavicle      | 7 (7.0)          | 12 (13.0)      | 2 (3.0)       | 4 (9.0)         | 0              | 0              | 0             | 0                 | 0                    | 0                | 0             |
| Metacarpal    | 4 (4.0)          | 1 (1.1)        | 1 (2.0)       | 2 (4.0)         | 0              | 0              | 0             | 0                 | 0                    | 0                | 0             |
| Finger        | 1 (1.0)          | 0              | 0             | 0               | 0              | 0              | 0             | 0                 | 0                    | 0                | 0             |
| Tibia         | 16 (16.5)        | 9 (10.0)       | 8 (13.3)      | 13 (28.9)       | 0              | 0              | 3 (18.8)      | 1 (10.0)          | 3 (37.5)             | 0                | 0             |
| Ankle         | 10 (10.3)        | 1 (1.1)        | 0             | 4 (4.4)         | 0              | 0              | 2 (12.5)      | 0                 | 0                    | 0                | 0             |
| Femoral       | 6 (6.2)          | 8 (8.9)        | 5 (8.3)       | 4 (8.9)         | 4 (20.0)       | 1 (6.3)         | 4 (25.0)      | 1 (10.0)          | 0                    | 1 (25.0)        | 0             |
| Fibula        | 5 (5.0)          | 5 (6.0)        | 1 (2.0)       | 5 (11.0)        | 0              | 0              | 4 (25.0)      | 1 (10.0)          | 0                    | 0                | 0             |
| Patellar      | 1 (1.0)          | 1 (1.1)        | 3 (5.0)       | 0               | 0              | 0              | 0             | 0                 | 0                    | 1 (12.5)        | 0             |

limited by the retrospective study design and the small number of patients. Second, there may be selection bias because this study includes patients referred to our hospitals.

5. Conclusions

Sports-related fractures are common in children and adolescents, particularly in males. Basketball and running were the most common etiologies; radius, ulna, and humerus were the most common fracture sites. The patient characteristics and fracture types identified by this study should be used to develop targeted prevention strategies.

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References

[1] Jones G, Cooley HM. Symptomatic fracture incidence in those under 50 years of age in southern Tasmania. J Paediatr Child Health 2002;38:278–83.

[2] Mamula V, Parkkari J, Kannus P, et al. Occurrence and risk factors of unintentional injuries among 12- to 18-year-old Finns—a survey of 8219 adolescents. Eur J Epidemiol 2004;19:437–44.

[3] 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.

[4] 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.

[5] 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.

[6] 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.

[7] Dompier TP, Kerr ZY, Marshall SW, et al. Incidence of concussion during practice and games in youth, high school, and collegiate American football players. JAMA Pediatr 2015;169:659–65.

[8] Houck Z, Asken B, Bauer R, et al. Epidemiology of sport-related concussion in an NCAA Division I Football Bowl Subdivision sample. Am J Sports Med 2016;44:2269–75.

[9] Robertson GA, Wood AM, Bakker-Dyos J, et al. The epidemiology and morbidity, and outcome of soccer-related fractures in a standard population. Am J Sports Med 2012;40:1851–7.

[10] Swenson DM, Henke NM, Collins CL, et al. Epidemiology of United States high school sports-related fractures, 2008-09 to 2010-11. Am J Sports Med 2012;40:2078–84.

[11] O’Farrell DA, Ridha HM, Keenan P, et al. An epidemic of roller-blade injuries in children. Injury 1997;28:377–9.

[12] Court-Brown CM, Wood AM, Atkin S. The epidemiology of acute sports-related fractures in adults. Injury 2008;39:1365–72.

[13] Wood AM, Robertson GA, Rennie L, et al. The epidemiology of sports-related fractures in adolescents. Injury 2010;41:834–41.

[14] Atken SA, Watson BS, Wood AM, et al. Sports-related fractures in South East Scotland: an analysis of 990 fractures. J Orthop Surg (Hong Kong) 2014;22:313–7.

[15] Fernandez WG, Yard EE, Comstock RD. Epidemiology of lower extremity injuries among U.S. high school athletes. Acad Emerg Med 2007;14:641–5.

[16] Shah S, Sinclair SA, Smith GA, et al. Pediatric hospitalizations for bicycle-related injuries. Inj Prev 2007;13:316–21.

[17] Lyons RA, Delahuntly AM, Kraus D, et al. Children’s fractures: a population based study. Inj Prev 1999;5:129–32.