ORIGINAL ARTICLE

The initial analysis of pediatric fractures according to the AO/OTA fracture classification and mechanisms of injuries

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ABSTRACT

BACKGROUND: The epidemiology of pediatric fractures has been changing timely, in a multifactorial fashion. The aim of this study was to put forward a recent 5-year epidemiological analysis of pediatric fractures, according to the current AO/OTA fracture classification, in the current decade of action for road safety.

METHODS: A total of 3261 pediatric patients who were diagnosed with at least one fracture related with orthopedics and traumatology in a level-one trauma center were included in this retrospective and epidemiological descriptive study. The patients were grouped according to their ages as follows; <2, 2–5.9, 6–9.9, and 10–17.9. The fractures were examined according to the AO/OTA classification.

RESULTS: A total of 3396 fractures were present in 3261 patients. The mean age of the patients was 9.8±4.6 (1–17). The number of patients according to the age groups was as follows; 28 (0.008%), 735 (22.53%), 863 (26.47%), and 1635 (50.99%), respectively. The most frequent three fractures according to the AO/OTA fracture classification were; 23 (radius/ulna distal 22.9%), 13 (humerus distal, 13.3%), and 7 (hand/carpal, 12%). About 68.8% and 31.2% of the patients were treated non-surgically and surgically, respectively. Overall mortality rate was 0.1%.

CONCLUSION: To the best of our knowledge, this study represents the first analysis of pediatric fractures according to the AO/OTA classification, over a 5-year period. As a future prospect, further multicentric epidemiological studies are warranted to constitute a sustainable action plan for the prevention of major traumas.

Keywords: AO/OTA classification; epidemiology; pediatric fractures.

INTRODUCTION

Traumatic injuries of the musculoskeletal system have been commonly and increasingly encountered and representing a major public health problem. Despite all public health measures, the incidence of pediatric fractures has increased over the years.[1] The life time probability of having a childhood fracture is approximately 42–64% in boys and 27–40% in girls, and there are considerable variations worldwide.[2,3] Studying the epidemiology of pediatric fractures is mandatory to develop preventive strategies. In general, it is a necessity to define fractures correctly to share a relevant common language. An appropriate classification system should be used for this purpose. Regarding the classification systems of fractures; being reliable, valid, accurate, relevant, and repeatable are the most importantly accepted prerequisites.[4–6] Although,

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some administrative classifications (e.g., International Disease Classification [ICD-10]) are commonly used in the hospital settings, the most consistent and commonly used classification of adult fractures is the AO/OTA classification.[7] This comprehensive classification system, which has been accepted worldwide, has been reported to be reliable, accurate, and valid.[7–10]

Due to its increasing incidence, it has become even more important to reveal the epidemiological characteristics and mechanisms of pediatric fractures. In fact, epidemiological studies are the first step in developing or improving prevention and treatment methods, avoiding preventable causes, and reducing fracture frequency. Considering these facts, it has become important to conduct descriptive epidemiological studies in a large number of patients using the most commonly used and the latest fracture classification system. Studies on fracture prevalence by specific age and gender groups in the developing countries are relatively scarce, mainly due to the lack of nationwide databases. On the other hand, epidemiological data change in a timely and multifactorial way; therefore, regular repetition of these studies is necessary to observe both the time trends of pediatric fractures and their socioeconomic effects.

In this context, the aim of the present study was to put forward a recent 5-year epidemiological analysis of pediatric fractures. To the best of our knowledge, this is the first epidemiological study that presents data on pediatric fractures, according to the current AO/OTA classification.

MATERIALS AND METHODS

Following the ethical approval of the Institutional Review Board, 3261 pediatric patients who were diagnosed with at least one fracture related with orthopedics and traumatology in a level-one trauma center, between the dates January 1, 2010, and December 31, 2014, were included in this retrospective and epidemiological descriptive study. This study was conducted as one part of a large epidemiological investigation, which also included an adult counterpart.

The demographic data related with all fractures related with orthopedics and traumatology that were encountered on an in-patient and outpatient basis, in patients younger than 18 years old were investigated. The patients included in this cohort were grouped into four age ranges; <2 years, 2–5.9 years, 6–9.9 years, and 10–17.9 years. The main demographic data which were investigated included age, gender, mechanism of injury, anatomical fracture sites, open fracture rate, pathological fracture rate, and overall mortality rate.

The AO/OTA classification was used to record and examine the data of the fractures.[8] Single experienced trauma surgeon evaluated each radiograph according to the valid and reproducible AO/OTA fracture classification system.

As this analysis was performed on the musculoskeletal fractures, which were only related with orthopedics and traumatology, fractures of the skull, maxillofacial, and chest wall were excluded from the study. The cervical vertebral fractures were also excluded due to the extensive management of these fractures by the department of neurosurgery in the present trauma center. In addition, non-union and malunion of previous fractures were excluded from the study.

The mechanism of injury related with the fractures was recorded under 11 titles; out-vehicle and in-vehicle accident, simple fall, fall height (>2 m), firearm, occupational and instrument related, sports related, self-harm, fractures after sprain, pounding injuries, and other traumas which cannot be classified. Second, the monthly and yearly admission times of all patients were given in detail. Third, the management of the fractures was also recorded as non-surgical and surgical. Finally, open and pathological features of each fracture type and the overall mortality rate of pediatric fractures were also presented.

The descriptive statistics of all variables were calculated and given as frequencies/percentages in categorical variables; as mean±SD or median (minimum, maximum) for numerical variables of normally distributed and skewed data, respectively. Statistical analyses were performed using the SPSS with version 20.0.

RESULTS

During the 5-year study period, 3396 fractures were present in 3261 patients, who were managed in the Department of Orthopaedics and Traumatology at Necmettin Erbakan University, Meram Faculty of Medicine Hospital. This number constituted 23% of a total number of 14,408 hospitalized patients (including elective surgeries) and 38% of a total number of 8585 patients who were diagnosed with and managed for at least one relevant fracture. Table 1 shows the 5-year demographic features of pediatric fractures, compared with adult fractures. The mean age of the patients was 9.8 (range 1–17 years). The male-to-female ratio was 2.6. Ninety-seven percent of the fractures were isolated and the rest was multiple fractures. Most of the patients admitted to the hospital during weekdays (68.9%) and were managed non-surgically (68.8%).

The comparative epidemiological characteristics of the fractures, according to each pediatric age group, are demonstrated in Table 2. The most common mechanism of injury was observed as simple fall at all age groups. In addition to the increase in the number of fractures with increasing age, it is remarkable that more fractures are seen in male than female in all age groups except Group 1 (<2 years).

Figure 1a and b demonstrates frequencies of all fractures, according to the AO/OTA classification. The overall and gender-specific frequency distribution curves according to

Table 1. Summary of five-year comparative demographic features in pediatric fractures with adult fractures

	Pediatric	Adult
Number of patients	3261	5324
Number of fractures	3396	5865
Mean age±Standard deviation (Range)	9.8±4.6 (1–17)	48.6±21.5 (18–100)
Male/female ratio	2.6	2.2
Fractures:		
Isolated (%)	97	92
Multiple (2) (%)	3	8
Time of admission:		
Weekday	68.9	68.7
Weekend	31.1	31.3
Anatomical Site:		
Upper limb (%)	73.7	48.8
Lower limb (%)	25	43.7
Axial skeleton (%)	1.3	7.5
The most common		
Fracture type (AO/OTA) (%)	23 (Radius/Ulna distal) (22.9)	7 (Hand/Carpal fractures) (19.6)
Mechanism of injury (%)	Simple fall (60.5)	Simple fall (38.6)
Season (%)	Summer (39)	Summer (32.5)
Management		
Non-surgical	68.8	54.4
Surgical	31.2	45.4
Other	–	0.2
Open fracture rate (%)	5.8	11.6
Pathological fracture rate (%)	1	1.8
Overall mortality rate (%)	0.1	0.4

the pre-defined age groups are depicted in Figure 2. Figure 3 demonstrates that frequency distribution of fractures was steady, on a yearly basis, over 5 years, in both genders. In addition, summer months were the time, when fractures were most frequently encountered and winter months, being the lowest (Fig. 4). The frequency distribution curves of fractures, which were encountered in the upper extremity, lower extremity, and axial skeleton, according to the pre-defined age groups, are demonstrated in Figure 5.

Overall, the most common AO/OTA fracture types were 23 (radius/ulna distal) (22.9%), 13 (humerus distal) (13.3%), and 7 (hand/carpal bones) (12%), as demonstrated in Figure 1a. All of the fractures were observed in males more than in females according to fracture type. While the most common fracture of the upper extremity was 23 (distal radius/ulna), the most common fracture in the lower extremity was 8 (foot). AO/OTA 32 (clavicle) fractures were the most common in the youngest age group (<2 years), and also, unlike other age groups, the male/female ratio was reversed in this group (Table 2). While the mean ratio of open fractures is 5.8%, it is observed that the rate of open fractures increased with age (Table 2). It was striking that 60.5% of all fractures occurred after simple fall (Table 2). In addition, although simple fall is in the first place in all age groups, the frequency of vehicle accidents and sports injuries increased significantly in the 10–17.9 age group (Fig. 6).

DISCUSSION

The most important result of the present study was that the epidemiological analysis of a large number of fractures in pediatrics, according to the AO/OTA classification, was reported firstly in the literature, over a 5-year of period in a level-one trauma center. The fracture and demographic characteristics were mostly different from that of the adult group, which was also investigated as a counterpart of the present study, simultaneously (Table 1).

The comprehensive AO/OTA classification, which was reported to be reliable, accurate, valid, and user-friendly, was used in this study.[7–10] According to this system, the most

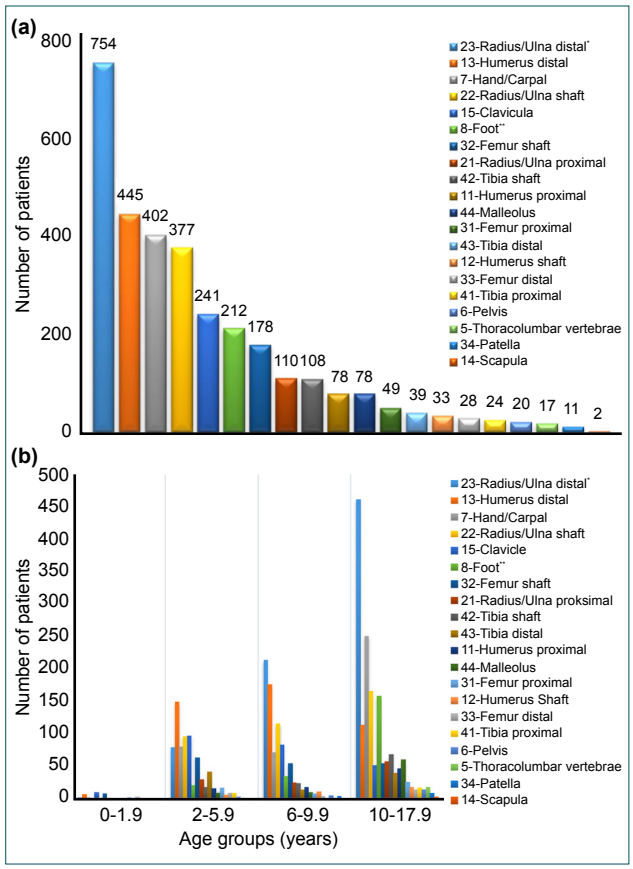

Figure 1. (a) Overall frequencies of fractures according to AO/OTA classification in decreasing order (*: The most frequent upper extremity fracture and **: The most frequent lower extremity fracture) **(b)** The fractures' frequencies according to the AO/OTA classification and age groups (*: The most frequent upper extremity fracture and **: The most frequent lower extremity fracture).

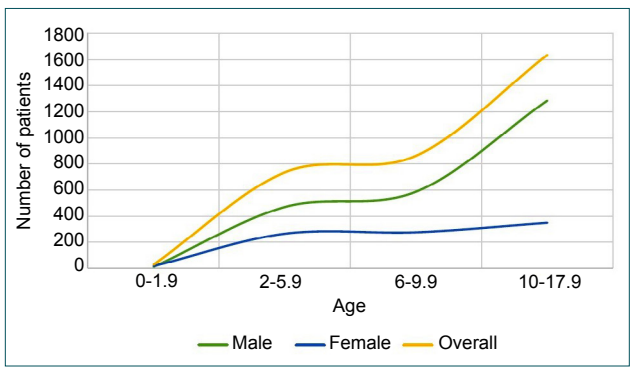

Figure 2. The frequency distribution curves of pediatric fractures (overall and gender specific).

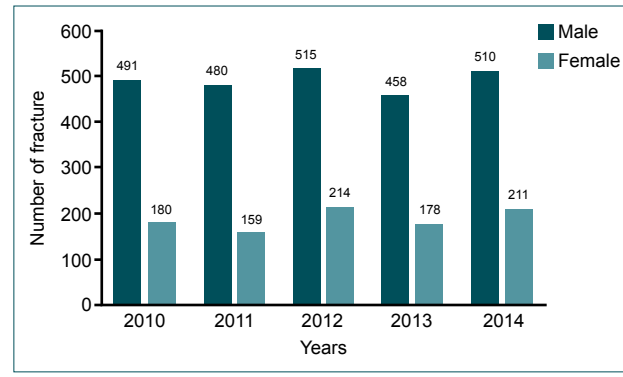

Figure 3. The yearly frequency distribution curves of fractures in males and females.

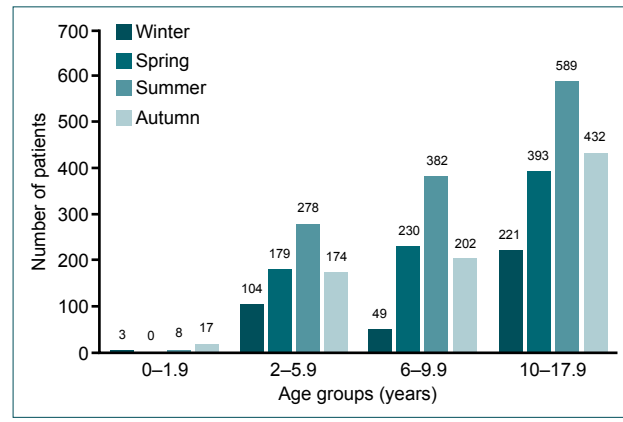

Figure 4. The seasonal frequency distribution curves of fractures in age groups.

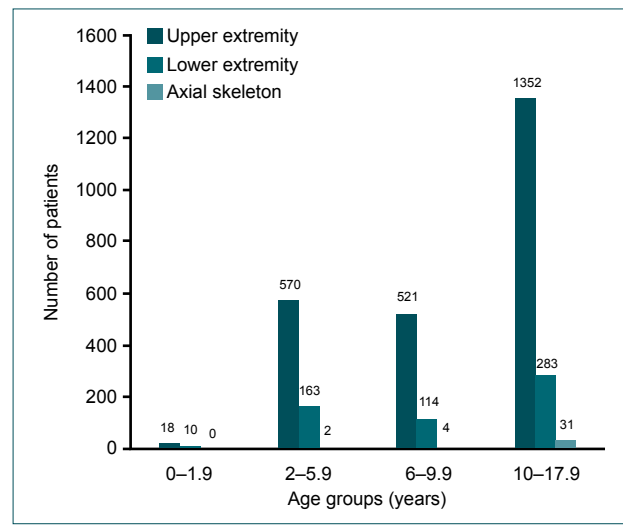

Figure 5. The frequency distribution curves of fractures, in upper extremity, lower extremity, and axial skeleton, according to the age groups.

frequently encountered pediatric fractures were 23 (radius/ulna distal), 13 (humerus distal), and 7 (hand/carpal bones).

The incidence of childhood fractures varies according to geographic region, age, and gender in the literature, but the annual incidence varies between 12 and 36/1000 children. [3,11,12] Socioeconomic, demographic, seasonal, and geopolitical factors may play a role in the difference of fractures' incidences. One of the reasons for the difference in fracture frequencies between countries is that the definition of the childhood age group is not clear, for example, while the World Health Organization (WHO) takes this range as 0–19, in some countries, the age of 0–16 is considered as childhood. Since the age of 0–18 is defined as childhood in

Table 2. The epidemiological characteristics of all fractures according to the age groups

Age groups (years)	n	Frequency (%)	Male/Female Ratio	Most common mechanism of injury	Open fracture (%)	Most common AO/OTA fracture type
0–1.9	28	0.008	0.64	Simple fall	0	32 (Clavicle)
2–5.9	735	22.53	1.77	Simple fall	5.4	13 (Humerus distal)
6–9.9	863	26.47	2.12	Simple fall	4.3	23 (Radius/Ulna Distal)
10–17.9	1635	50.99	3.68	Simple fall	6.9	23 (Radius/Ulna Distal)

our country's health system, we evaluated patients under the age of 18 in this study.

The epidemiology of fractures differs in different age groups due to the characteristics of the bone itself and the changing activities depending on the age groups. However, with increasing age from birth to the highest incidence between the ages of 12 and 15 years, the incidence of fractures somewhat increases linearly.[13,14] In our study, the incidence of fractures increases with age and is consistent with the literature. The peak in adolescence can be explained by rapid skeletal growth, increased secretion of growth-regulating hormones, and remodeling of the radial metaphysis.[15] Babies who are not-to-walk often suffer birth injuries and fractures from others, while children aged 2–5 begin new activities and have fractures due to running and falling, such as clavicle fractures, whose incidence decreases with age.[16] In addition, in our study, AO/OTA 32 (clavicula) fractures peak in the 2–5.9 age group and the frequency of this fracture decreases with advancing age. Older school-age children are more likely to experience fractures due to discovering new heights and speeds, especially supracondylar fractures that occur around the age of 6–10 while adolescents are more likely to have fractures from motor vehicle collisions, contact sports, and recreational activities.[13,16,17]

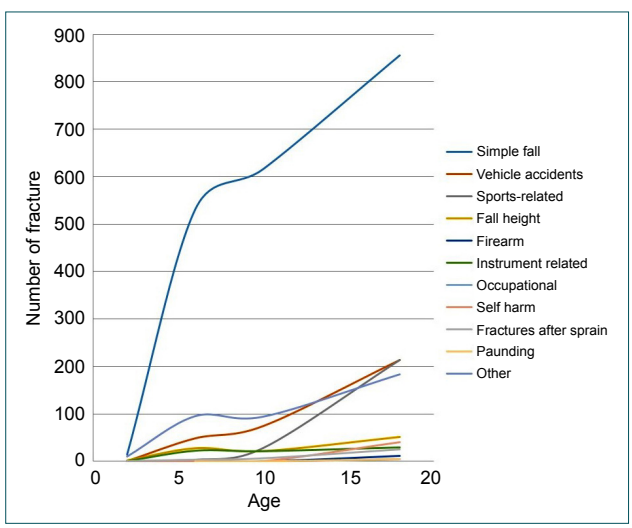

Figure 6. The frequency distribution curves of fracture mechanism, according to the age groups.

In the previous studies, the most common fractures in the pediatric age group are distal radius fractures followed by hand fractures.[3,11,13,17–22] In addition, approximately 1/3 of all pediatric fractures are seen in the lower extremity while 2/3 are in the upper extremity.[21–24] In the present study, upper extremity fractures were seen in 73.7%, and the three most common fractures in total were 23 (radius/ulna distal), 13 (humerus distal), and 7 (hand/carpal bones) according to AO/OTA classification. When evaluated according to the predefined age groups, distal humerus fractures take the first place in the 2–5.9 age group, while AO/OTA 23 (distal radius/ulna) fractures are the most common fractures in the 6–9.9 and 10–17.9 age groups, in accordance with the literature mentioned above. Furthermore, strikingly the frequency of AO/OTA 7 (hand/carpal bones) fractures increases significantly in the 10–17.9 age group and takes the second place after AO/OTA 23 (distal radius/ulna) fractures. Similarly, in the epidemiological study of Naranje et al.,[25] the total incidence of finger and hand injuries slightly exceeded distal forearm fractures, even in the 10–14 age group, and settled in the first place in the 15–19 age group. Unlike other age groups, the frequency of AO/OTA 15 (clavicle) fractures increased in the 0–1.9 age group in our study and ranked first. Similarly in a recent epidemiological study examining the early childhood period under the age of 5 in the USA, Wolfe et al.[26] reported very closely the incidence of forearm fractures and clavicle fractures, especially in the group under 1 year old. In our study, AO/OTA 13 (distal humerus) fractures were among the most common fractures in the overall total, while the highest rate was seen in the 6–9.9 age group, in accordance with the above literature. However, in our study, the rate of distal humerus fractures in the 2–5.9 age group exceeds forearm fractures, and this is not consistent with the literature. Although there is an increase in the incidence of humeral fractures, especially in this age group, forearm fractures remain the first in most of the studies.[12,24–26] Since the hospital where we conducted this epidemiological study is a university hospital trauma center, we accept many patients who were referred from the other district public hospitals and rural areas. While most forearm fractures in the pediatric age group can be treated conservatively even in rural areas, referral of distal humerus fractures requiring further surgery to our trauma center may explain the relative high number of distal humerus fractures compared to forearm fractures in this 2–5.9 age group.

It is clear in the literature that males have more fractures than females in pediatrics.[11,12,19,20,25,26] Male gender has been identified as an independent risk factor for fracture in the pediatric age, and Wolfe et al. showed an increased experience of fractures by 12%, Naranjie et al., 18%, and Lyons et al., 12%, compared to female gender. Although there is a general consensus that the risk of fracture increases in boys due to high sports participation and risk-taking behavior, there is actually a multifactorial situation. Even in a study controlling sports participation, Stracciolini et al.[27] found that male athletes were twice as likely to experience fractures than females. Although risk-taking behavior is difficult to identify, individual behavioral characteristics such as increased impulsivity, hyperactivity, and a bad perception of danger, especially during adolescence, may contribute to this tendency and thus increased fracture rates. In a Tasmanian study using interviews to detect behavioral characteristics, behaviors identified as having high risk-taking characteristics of adolescent individuals had a higher association with hand fractures.[28] In our study, similar to the literature, the mean male/female ratio was calculated as 2.6, and it is remarkable that this ratio increased up to 3.68 in the 10–17.9 age group. Especially in the 10–17.9 age group, as mentioned before, the excessive increase in the frequency of AO/OTA 7 (hand/carpal) fractures supports the Tasmanian study (Fig. 1). While these factors are actually difficult to identify in the trauma setting, this topic may open a new frontier to investigate children prone to fractures aid to specific measures and possibly help minimize their exposure to trauma through education.

The present study showed that summer months was the time, when fractures were most frequently encountered and winter months, being the lowest in all age groups except 0–1.9 age. It has been previously shown in studies conducted in Ireland and the United States that childhood fractures in the summer are approximately 2.5 times higher than in winter. In addition, the number of patients presenting with fractures increases 2 times more on days with more than average sunshine compared to days with less than average sunshine.[29,30] Although it has been suggested that rapid bone growth during the summer months may increase physeal fractures (slipped capital femoral epiphysis, Salter I fracture),[31] it has been shown by Landin et al.[17] that physical fractures do not show seasonal changes in the following years. The fact that the seasonal variation in our study was not significant in the 0–1.9 age group may be due to the time spent outside in this group was very limited and therefore was little affected by seasonal changes, and the number of patients in this group was too limited to make meaningful inferences. Furthermore, the city where this study was conducted is located in a geographical region in Turkey where the terrestrial climate is experienced and the winter conditions are cold, and therefore, the time spent in outside is reduced, especially in childhood, thus, a serious difference occurs in terms of fracture rates in summer and winter.

On the one hand, the rates of open and pathological fractures were also reported in this study, as 5.8% and 1%, respectively. On the other hand, the overall mortality rate related with pediatric fractures was also found as 0.1%. The epidemiological studies on fractures mainly focused on body regions or on separate special topics and a number of large population-based studies were also published till now. However, open and pathological fracture rates and fracture-related mortality were lacking. To the best of our knowledge, this information was first presented here in the relevant literature.

The present study showed that the frequency distribution of the factures was steady, on a yearly basis, over 5 years, in both genders. This finding indirectly reflects the consistency of the data and findings in this study. Simple fall was found to be the leading mechanisms of injuries for fractures in pediatrics in all age groups. The increasing rate of participation in sports activities at school age and adolescents increases the frequency of sports injuries in this age group. In addition, in this study, non-vehicle accidents with pedestrians or bicycles and in-vehicle traffic accident induced fractures increased in the 10–17.9 age group. This finding of our study is consistent with the previous studies.[17,19,32,33] Especially in this age group, we think that to reduce the incidence of fractures, it may be useful to provide traffic educations in schools and to make road arrangements (appropriate sidewalks, pedestrian under and overpasses, and bicycle paths) separating pedestrians and vehicles. Furthermore, the frequency of accidents and the severity of injuries can be reduced by legislative arrangements and educations on helmet use, especially in bicycle and motorcycle rides.

The most important feature of this study that distinguishes it from the other epidemiological studies is that the X-rays of all patients are examined and classified by us according to AO/OTA classification system, and with this feature, it is free from data entry errors that may occur in an epidemiological study made by processing diagnostic codes only from databases. Although the main strengths of this study include the relatively large sample size, and the reliable documentation of novel data over a long period of time, in a level-one trauma center, it possesses some limitations to discuss. First, the data belong to a single medical center. Although the results of this study can be applied to a specific population, our center is the oldest and the largest, major referral university trauma center in the investigated geographical region. Second, the data related with the associated injuries of other body parts such as skull, maxillofacial, and chest wall and cervical vertebral fractures were excluded and also the medical comorbidities of the patients, the time from admission to surgery, and the time of hospital stay were not reported in this study. These info and their effects will be reported in the subsequent epidemiological studies on the fractures of each anatomical region separately, as the next part of this main study, in the near future. Third, the subgroups of each fracture type of AO/OTA classification were not given in de-

tail. Because, these details are out of scope of this study and they will be presented in separate subsequent investigations of each anatomical regions' fracture. Fourth, we are not able to report neither incidence nor prevalence related with pediatric fractures for now, because of the presence of other smaller scale hospitals in the same geographical region. As this analysis was performed on the musculoskeletal fractures, which were only related with orthopedics and traumatology, fractures of cervical vertebrae were excluded due to the extensive management of these fractures by the department of neurosurgery in the present trauma center. Ultimately, this main study would serve as a kernel to expand the scope of our efforts to perform a larger, multicenter, and epidemiological study on pediatric fractures.

We believe that it is important to repeat the similar epidemiological studies at certain time intervals in terms of changes in fracture trends in childhood. Considering the burden on the healthcare system, treatment costs, disabilities, and even mortality due to the fractures, we think that knowing the fracture mechanisms and the physical or environmental effects that predispose to fractures provides convenience in terms of sustainable action plans.

Conclusion

To the best of our knowledge, this study represents the largest and the first epidemiological evaluation of pediatric fractures according to the AO/OTA classification, in a level-one trauma center, over 5 years. Further studies are still needed to determine risk factors and how to modify them to prevent morbidity in pediatric age. The present study warrants further multicentric, descriptive epidemiological studies, to constitute a sustainable action plan for the prevention strategies and allocations for major traumas and fractures in pediatrics.

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Ethics Committee Approval: This study was approved by the Necmettin Erbakan University Meram Faculty of Medicine Clinical Research Ethics Committee (Date: 21.08.2020, Decision No: 1179).

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Authorship Contributions: Concept: O.B., Z.D.D., N.A., A.F.K.; Design: O.B., Z.D.D., A.F.K.; Supervision: O.B., A.F.K., Z.D.D.; Resource: D.K., Z.D.D., N.A., H.Y.; Materials: Z.D.D., O.B., N.A., H.Y.; Data: N.A., H.Y., Z.D.D., A.F.K.; Analysis: D.K., A.F.K., O.B.; Literature search: A.F.K., O.B., M.N.D., H.Y., N.A.; Writing: O.B., A.F.K., M.N.D.; Critical revision: O.B., A.F.K., M.N.D..

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ORİJİNAL ÇALIŞMA - *ÖZ*

AO/OTA kırık sınıflamasına ve yaralanma mekanizmalarına göre çocuk kırıklarının analizi

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AMAÇ: Pediatik kırıkların epidemiyolojisi, çok faktörlü bir şekilde, zamanla değişim göstermektedir. Bu çalışmanın amacı, mevcut AO/OTA kırık sınıflamasına göre, yol güvenliği için mevcut on yıllık eylem planı kapsamında pediatrik kırıkların son beş yıllık epidemiyolojik analizini ortaya koymaktır.
GEREÇ VE YÖNTEM: Bu geriye dönük, epidemiyolojik tanımlayıcı çalışmaya birinci düzey bir travma merkezinde ortopedi ve travmatoloji ile ilişkili en az bir kırık tanısı almış 3261 pediatrik hasta alındı. Hastalar yaşlarına gore; <2, 2–5.9, 6–9.9 ve 10–17.9 olmak üzere dört yaş grubunda incelendi. Kırıklar AO/OTA kırık sınıflamasına göre değerlendirildi.
BULGULAR: Üç bin iki yüz altmış bir hastada 3396 kırık vardı. Hastaların ortalama yaşı 9.8±4.6 (1–17) idi. Yaş gruplarına göre kırık sayıları sırasıyla 28 (%0.008), 735 (%22.53), 863 (%26.47) ve 1635 (%50.99) idi. AO/OTA kırık sınıflamasına göre en sık görülen üç kırık; 23 (radius/ulna distal %22.9), 13 (humerus distal, %13.3) ve yedi (el/karpal, %12) idi. Hastaların %68.8'i ameliyatsız ve %31.2'si ameliyatla tedavi edildi. Toplam ölüm oranı %0.1 idi.
TARTIŞMA: Bildiğimiz kadarıyla bu çalışma, beş yıllık bir dönem boyunca AO/OTA sınıflandırmasına göre pediatrik kırıkları analiz eden ilk çalışmadır. Geleceğe yönelik olarak, majör travmaların önlenmesi için sürdürülebilir bir eylem planı oluşturmak amacıyla daha fazla çok merkezli epidemiyolojik çalışma yapılması gerekmektedir.
Anahtar sözcükler: AO/OTA sınıflaması; epidemiyoloji; pediatrik kırıklar.

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