

# Epidemiology of Pediatric Basketball Injuries Presenting to Emergency Departments

## Sex- and Age-Based Patterns

Aaron J. Zynda,<sup>\*†</sup> BS, K. John Wagner III,<sup>‡</sup> BS, Jie Liu,<sup>‡</sup> PhD, Jane S. Chung,<sup>‡§</sup> MD, Shane M. Miller,<sup>‡§</sup> MD, Philip L. Wilson,<sup>‡§</sup> MD, and Henry B. Ellis,<sup>‡§</sup> MD

*Investigation performed at the Scottish Rite for Children, Dallas, Texas, USA*

**Background:** There is limited epidemiologic data on pediatric basketball injuries and the comparison of these injuries before and after adolescence and between male and female athletes.

**Purpose:** To assess common sex- and age-based injury patterns in pediatric basketball players.

**Study Design:** Descriptive epidemiology study.

**Methods:** Injury data from the National Electronic Injury Surveillance System (NEISS) and participation data from the National Sporting Goods Association were used to complete this study. Data on pediatric basketball injuries between January 2012 and December 2018 in patients aged 7 to 11 years (childhood) and 12 to 17 years (adolescence) were extracted and used to calculate national injury incidence rates with 95% CIs. Sex and age group patterns were examined utilizing Pearson chi-square tests. Z tests were conducted for the comparison of injury rates between female and male athletes in each age group and overall injury rate across age groups.

**Results:** An average of 9582 basketball injuries were reported annually in the NEISS, which calculated to an annual national estimate of 294,920 injuries. The most common diagnoses were ankle strain/sprain (17.7%), finger strain/sprain/fracture (12.1%), concussion/head injury (9.4%), knee strain/sprain (4.5%), and facial laceration (3.3%). There was a significant increase in injury prevalence in adolescents (12- to 17-year-old category: 238,678 injuries per year) when compared with childhood (7- to 11-year-old category: 56,242 injuries per year) ( $P < .0001$ ). Concussions/head injuries occurred at a high rate in childhood, second only to finger strain/sprain/fracture, and at a similar rate in females and males (injuries per 100,000 athlete-days: 4.9 [95% CI, 3.1-6.7] vs. 5.9 [4.3-7.5], respectively;  $P = .41$ ). From childhood to adolescence, injury prevalence increased for all areas and across both sexes, except for female finger strain/sprain/fracture; however, the rate of increase for concussion/head injuries and knee injuries was significantly higher in female compared with male athletes ( $P < .0001$  for both). In adolescents, ankle injuries were the most common injury overall.

**Conclusion:** Ankle injuries continue to be the most predominant pediatric basketball injury. However, disproportionate rates of both knee and concussion/head injuries in female athletes during adolescent basketball are of concern and have implications for injury prevention.

**Keywords:** adolescent; basketball; child; descriptive epidemiology; injury; recreation/sports

In the United States, an estimated 60 million children aged 6 to 18 years participate in organized sports.<sup>16</sup> This number has been increasing steadily over recent decades, and with increased participation in competitive sports, there has also been an increase in sports-related injury.<sup>9</sup> Recent research has estimated that approximately 1.4 million injuries occurred across just 9 sports in the 2005 to 2006 school year.<sup>12</sup> As this estimate did not account for >9 sports or

younger populations, the actual number of pediatric injuries was likely much larger. Football, soccer, and basketball are among the most commonly studied sports, with injury rates and risk factors for ankles, knees, and concussions among the most commonly studied pathologies.<sup>25</sup> However, while data assessing the epidemiology of sports-related injury data in pediatric athletes exist, little has been done to evaluate risk factors between groups of pediatric athletes such as by sex pre- and postadolescence.

Since 1972 and the passage of Title IX, the number of high school female athletes has increased 9-fold.<sup>39</sup> In addition, 29 of 57 sports and activities tracked by the National

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Sporting Goods Association (NSGA) demonstrated increased female participation across all ages in 2019.<sup>38</sup> Evidence has suggested that injury incidence, mechanism, and outcomes may differ significantly among male and female participants.<sup>11</sup> For example, Hosea et al<sup>20</sup> reported that female collegiate level basketball players had a 25% increased risk of sustaining a Grade I ankle sprain compared with male basketball players. As basketball is among the most popular sports in the United States among children aged 12 to 17 years, with among the highest injury rates in persons aged >5 years,<sup>36</sup> contemporary epidemiologic data regarding basketball-related injuries is valuable for assessment and improvement of sport safety and injury prevention policies.<sup>38</sup>

While multiple studies have examined basketball injuries at the collegiate and professional levels, relatively few studies have assessed basketball injuries in pediatric populations.<sup>1,15,20,21,41,43</sup> Of the data that do exist for this younger population, emphasis is placed on athletes at the high school level. Pappas et al<sup>29</sup> found that age and sex patterns exist for the most common pediatric basketball injuries treated in US emergency departments (EDs) between 2000 and 2006, with higher rates of knee sprains occurring in adolescent girls than in adolescent boys. In addition, recent studies using the High School Reporting Information Online system (HS-RIO) to assess high school basketball injuries further affirmed that injury patterns varied by sex and type of exposure.<sup>8,13,14</sup> However, limited data exist assessing injuries sustained during childhood and puberty where periods of peak growth occur and injury risk may be heightened.

While studies in other sports have suggested that sports-related injury patterns differ significantly by age,<sup>42</sup> there is limited evidence of injury patterns in basketball. The purpose of this study was to use updated information from an ED injury reporting database to assess common sex- and age-based injury patterns in pediatric basketball players. It was hypothesized that there would be sex- and age-based patterns in pediatric basketball-related injuries, which are otherwise overlooked in an unstratified population.

## METHODS.

### National Electronic Injury Surveillance System

Injury data were obtained from the National Electronic Injury Surveillance System (NEISS), which is a publicly available database operated by the US Consumer Product Safety Commission (CPSC).<sup>30</sup> The NEISS provides a

nationwide probability sample of injuries based on ED visits from a network of approximately 100 hospitals in the US. Participating hospitals are grouped into strata, 4 of which are based on hospital size (at least 6 beds) and availability of services (24-hour ED) and 1 of which consists of children's hospitals. Each case (entry into the NEISS database) is assigned a statistical weight that is determined by the inverse of the probability of selection for the hospitals in each stratum, which allows for the calculation of nationwide injury estimates. Studies have demonstrated NEISS data to be reliable for the description of nonfatal injuries in the US.<sup>37</sup>

### National Sporting Goods Association Data

Participation data were obtained from the NSGA 2019 Sports Participation Report.<sup>38</sup> The NSGA survey results are based on approximately 34,000 individuals aged >7 years and older. The NSGA survey results estimate the number of participants and frequency of participation (number of days) in each sport by sex and age. This allows for the calculation of the total number of athlete-days. The NSGA 2019 Sports Participation Report was used to identify basketball participants in these age groups between January 1, 2012, and December 31, 2018.

### Participants

This was a descriptive epidemiology design utilizing de-identified data from public sources; therefore, patients were not involved in the conceptualization of the study. The NEISS was used to identify participants who sustained basketball-related injuries between January 1, 2012, and December 31, 2018. The database was queried for participants aged 7 to 17 years to coincide with available exposure data from the NSGA 2019 Sports Participation Report. The dataset included sex (male, female), age (7-17 years), basketball (organized, recreational), body part (eg, head, finger, knee, ankle), diagnosis (eg, dislocation, strain/sprain, fracture, concussion), disposition (eg, not admitted to hospital, admitted to hospital, fatalities), and narrative (free text description of injury from treating provider entered by CPSC coder). Exposure data from the NSGA 2019 Sports Participation Report categorizes participants by age into groups of 7 to 11 and 12 to 17 years, which we referred to as childhood and adolescent groups, respectively.

### Statistical Analysis

Sample weights were assigned to each NEISS case based on the inverse probability of being selected, which allows for

\*Address correspondence to Aaron J. Zynda, BS, Michigan State University, 308 W Circle Drive, East Lansing, MI 48824, USA (email: zyndaar@msu.edu).

<sup>†</sup>Michigan State University, East Lansing, Michigan, USA.

<sup>‡</sup>Scottish Rite for Children, Dallas, Texas, USA.

<sup>§</sup>University of Texas Southwestern Medical Center, Dallas, Texas, USA.

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Ethical approval was not sought for the present study.

TABLE 1  
Athlete-Days of Participation in Basketball Between  
2012 and 2018<sup>a</sup>

	7- to 11-Year-Old Athletes	12- to 17-Year-Old Athletes
Male	875.04	1522.4
Female	266.41	427.75

<sup>a</sup>Exposure data are from the NSGA 2019 Sports Participation Report.

The childhood group accounted for 19.1% of injuries (56,242 estimated injuries per year), and the adolescent group accounted for 80.9% (238,678 estimated injuries per year). The overall injury rates were higher in the adolescent group compared with the childhood group ( $P < .0001$ ). Male players accounted for 72.6% of all injuries (40,824 estimated injuries per year) in the childhood group and for 74.4% of all injuries (177,572 estimated injuries per year) in the adolescent group; female players accounted for the remaining 27.4% (15,418 estimated injuries per year) and 25.6% (61,106 estimated injuries per year), respectively. Overall, there was no significant difference in injury rate between male and female players (injuries per 100,000 athlete-days for males, 91 [95% CI = 73-109]; for females, 110 [95% CI = 92-128];  $P = .140$ ).

calculation of national injury estimates. Frequency distributions were calculated for sex and age groups for the 7 most common basketball-related injuries (body part and diagnosis). Sex and age group (childhood vs adolescent) patterns were examined utilizing Pearson chi-square tests and 95% CIs. Injury rates were reported as annual number of injuries per 100,000 exposures (athlete-days), calculated with the use of provided statistical weights. Exposure (denominator) data from the NSGA 2019 Sports Participation Report were used. The statistical weights for each NEISS case were then divided by the exposure data and annualized by dividing by the numbers of years of data capture ( $n = 7$ ).  $Z$  tests were conducted for the comparison of injury rates between female and male athletes in each age group and overall injury rate across age groups. Data were analyzed using SAS (version 9.4; SAS Institute). Statistical significance was defined a priori as  $P < .05$  for all statistical analyses.

## RESULTS

Over a 7-year period between 2012 and 2018, the average annual number of 7- to 17-year-old patients who presented in NEISS-participating US EDs for basketball-related injuries was 9582. Using the associated statistical weights, we calculated an annual national estimate of 294,920 visits for basketball-related injuries. Most estimated injuries (98.1%; 289,227 injuries per year) were categorized as ambulatory treatment, while only 1.2% (3656 injuries per year) were categorized as injuries requiring observation/admission or transfer to another facility. The remaining estimated injuries (0.7%) were categorized as deceased in the ED, left without being treated, or disposition unreported. Participation data over this period are presented in Table 1. Participation was higher in the adolescent group compared with the childhood group in both male and female basketball players.

TABLE 2  
Most Common Diagnoses and Calculated Injury Estimates

Diagnosis	Injury Estimate, n (% of Total Injuries)
Ankle strain/sprain	52,066 (17.7)
Finger strain/sprain	18,477 (6.3)
Finger fracture	17,229 (5.8)
Head internal injury <sup>a</sup>	15,328 (5.2)
Knee strain/sprain	13,377 (4.5)
Head concussion <sup>b</sup>	12,257 (4.2)
Facial lacerations	9689 (3.3)

<sup>a</sup>Includes injury to the brain not diagnosed as concussion, such as closed head injury, contusion, hematoma, etc.

<sup>b</sup>Includes only diagnosed concussion.

The 7 most common diagnoses, accounting for an estimated 138,423 injuries per year and 46.9% of the total visits, and calculated injury estimates across both age groups are presented in Table 2. None of the remaining 231 diagnoses accounted for >3% of the total visits.

Finger strain/sprain and finger fracture were combined into a single category (finger strain/sprain/fracture), and head internal injury and head concussion were combined into another category (concussion) for injury rate comparisons, resulting in 5 common diagnosis categories (Table 3). The rate of each of the 5 most common injuries was higher in the adolescent group compared with the childhood group ( $P < .05$ ), with the exception of finger strain/sprain/fracture for female players ( $P = .12$ ). Females had a higher rate of finger injury, and males had a higher rate of facial lacerations in both age groups. Female players had a higher rate of ankle strain/sprain among childhood basketball players, but there was no sex-based difference in the adolescent group. There was no sex-based difference in concussion or knee strain/sprain among the childhood group; however, the prevalence of each increased markedly from childhood to adolescence, and the rate of increase for head injuries and knee injuries was significantly higher in female compared with male athletes ( $P < .0001$  for both). Figure 1 shows the change in injury rate from childhood to adolescence for the 5 commonly diagnosed injuries.

## DISCUSSION

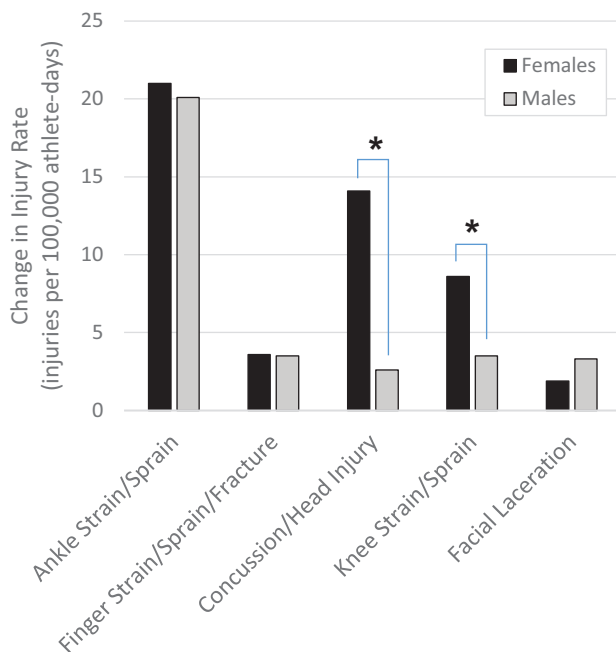
In the current study, we found that, between 2012 and 2018, approximately 300,000 ED visits annually were estimated to occur because of pediatric basketball-related injuries. This is a slight decrease from the number of visits due to pediatric basketball-related injuries ( $n = 325,465$ ) reported by Pappas et al<sup>29</sup> between 2000 and 2006. Whether this reflects a reduction or shift in presentation venue from ED to other care facilities is unclear.<sup>29</sup> The most common diagnosis in our study was ankle strain/sprain, followed by finger strain/sprain/fracture, and concussion/head injuries. The adolescent group accounted for most basketball injuries, and the injury rate increased substantially from childhood ( $P < .001$ ). Whereas male players accounted for >70% of the injury volume in both age groups, there was

TABLE 3  
Basketball Injuries Treated in US EDs Between 2012 and 2018 According to the NEISS Database<sup>a</sup>

	7- to 11-Year-Old Athletes			12- to 17-Year-Old Athletes		
	Male	Female	<i>P</i>	Male	Female	<i>P</i>
Ankle strain/sprain	3.4 (2.6-4.2)	6.1 (4.9-7.3)	<b>.0002</b>	23.5 (19.2-27.8)	27.1 (22.4-31.8)	.2688
Finger strain/sprain/fracture	8.0 (6.4-9.6)	13.8 (10.5-17.1)	<b>.0020</b>	11.5 (9.1-13.9)	17.4 (14.3-20.5)	<b>.0032</b>
Concussion	5.9 (4.3-7.5)	4.9 (3.1-6.7)	.4063	8.5 (6.7-10.3)	19 (15.1-22.9)	<b>&lt;.0001</b>
Knee strain/sprain	1.4 (1-1.8)	1.6 (1.2-2)	.4795	4.9 (3.7-6.1)	10.2 (8.2-12.2)	<b>&lt;.0001</b>
Facial laceration	1.5 (1.1-1.9)	0.5 (0.3-0.7)	<b>&lt;.0001</b>	4.8 (3.8-5.8)	2.4 (1.8-3.0)	<b>&lt;.0001</b>
Overall injuries by sex and age	46.7 (37.1-56.3)	57.9 (47.1-68.7)	.1284	116.6 (93.5-139.7)	142.9 (119.6-166.2)	.1166
Overall injuries by age <sup>b</sup>	49.3 (39.7-58.9)			122.4 (99.9-144.9)		

<sup>a</sup>Data are reported as number of injuries per 100,000 athlete-days (95% CI). Bolded *P* values indicate statistically significant differences between sexes ( $P < .05$ ). ED, emergency department; NEISS, National Electronic Injury Surveillance System.

<sup>b</sup>Statistically significant difference between age groups ( $P < .0001$ ).



**Figure 1.** The change in injury rate of the 5 most common basketball injury diagnoses from childhood (7- to 11-year-old athletes) to adolescence (12- to 17-year-old athletes). \*Statistically significant difference between sexes ( $P < .0001$ ).

no difference in overall injury rate between male and female players. Notably, the rate of concussion/head injuries and knee injuries in female athletes increased significantly from childhood to adolescence compared with that in male athletes ( $P < .0001$  for both). To our knowledge, this study is the most current epidemiological account of pediatric basketball injuries in the US.

### Common Diagnoses

The most common diagnoses reported in this study are consistent with those reported in previous epidemiologic studies.<sup>13,14,29</sup> Ankle and finger sprain were also the 2 most

common diagnoses for basketball players reported in the NEISS between 2000 and 2006.<sup>29</sup> Contemporary epidemiology studies utilizing other databases, such as the HS-RIO and National Athletic Treatment, Injury and Outcomes Network surveillance program, confirm these findings that ankle injuries present most commonly after youth basketball.<sup>4,8,13,14,29</sup> The main difference noted in our study was the frequency (9.4%) of concussions and head injuries, which was the third most common diagnosis. In the NEISS between 2000 and 2006, after ankle sprain (21.7%) and finger sprain (8.0%), the next most common diagnoses were finger fracture (7.8%), knee sprain (3.9%), and facial laceration (3.9%), with concussion and head injury being significantly lower (about 3%) than in our findings.<sup>29</sup>

The difference in concussion frequency between 2000 to 2006 and 2012 to 2018 data may be related to the increase in knowledge and awareness of concussion that has occurred over the past 2 decades. In July 2009, the first law pertaining to concussion management was passed in Washington. By 2014, every state had established similar legislation.<sup>6</sup> Subsequently, studies have shown a significant increase in the percentage of concussions reported since the legislation was enacted.<sup>7,17,22,33</sup> It is likely that this increase in concussion reporting after legislation was also reflected in the increase in the number of concussions diagnosed at EDs. Furthermore, a study by Zamarripa et al<sup>44</sup> demonstrated that >40% of parents seek care for their child's concussion at an ED, which was most likely also a contributing factor.

### Age-Based Patterns

Our results also revealed sex- and age-based differences in pediatric basketball injuries. From childhood to adolescence, the overall injury rate increased in both male and female players, which is consistent with that in previous literature.<sup>2,29</sup> A more notable change in injury rate was observed for ankle strains/sprains, knee strains/sprains, and facial lacerations, all of which demonstrated a sharp increase from childhood to adolescence. These changes are in accordance with those in previous studies and correlate increased injury rates with puberty and the adolescent

growth spurt.<sup>10</sup> The increased injury risk during this period of growth may be attributable to disproportionate muscle strength relative to osseous length, increased muscle tendon tightness,<sup>27</sup> bone mineralization changes,<sup>5</sup> and decreased physeal strength.<sup>28</sup> Factors such as increased strength, speed, and intensity of play at higher levels of competition that are associated with maturation may lead to greater force generation and, subsequently, an increase in injury risk as well.<sup>10</sup> Of note, concussions were a frequent cause of presentation in the childhood group, second only to finger injuries. This may be due to the increase in concussion knowledge and awareness but also suggests that the 7- to 11-year-old basketball player may be more susceptible to a head injury than to musculoskeletal injuries.

### Sex-Based Patterns

Unique sex-related patterns emerged in both age groups. Contrary to the NEISS data between 2000 and 2006, there was a higher rate of ankle strain/sprain among girls in the childhood group, but no difference between sexes in the adolescent group.<sup>29</sup> While the difference in the adolescent group was not statistically significant, the rate of female ankle strain/sprain in adolescence was higher than that of male ankle strain/sprain, which is the opposite of what was reported in the 2000 to 2006 data.<sup>29</sup> Previous data showed a higher rate of ankle strain/sprain among male players in the adolescent group and no sex difference in the childhood group.<sup>29</sup> This change could potentially be attributed to the increase in female basketball participation.<sup>39</sup> Furthermore, in our data, higher rates of finger strain/sprain/fracture were seen in female compared with male players in the childhood group, while data between 2000 and 2006 revealed no differences.<sup>29</sup> However, we combined finger fracture with finger strain/sprain; therefore, these differences should be interpreted cautiously. For concussions, there was no sex difference in the childhood group, but female players had a significantly higher injury rate compared with male players in adolescence. This pattern is consistent with existing evidence demonstrating that female athletes are at increased risk of sustaining a concussion and exhibit a higher rate of concussions than male athletes in comparable sports.<sup>23,24,32</sup>

As with the 2000 to 2006 data, female players had a higher rate of knee strain/sprain and finger strain/sprain/fracture in adolescence, while male players had a higher rate of facial lacerations in both age groups. This sex difference in knee and facial injuries has been described extensively in the literature.<sup>1,8,31</sup> The difference in knee injuries is attributed to sex-linked neuromuscular adaptations during maturation; boys exhibit concurrent neuromuscular gains with skeletal growth, while adolescent girls may have characteristic delays in neuromuscular adaptation, leading to a quadriceps-to-hamstrings strength ratio that exerts greater stress on the knee.<sup>3</sup> The difference in facial injuries is speculated to be due to more contact, faster gameplay, and greater intensity in male basketball play.

The most concerning pattern that emerged in our results was the disproportionate increase in both knee and concussion basketball-related injuries in female players from childhood to adolescence. The increase in male player injuries was similar for the ankle, finger, and face but much lower for knee and concussion/head injuries. We believe these findings demonstrating increased rates of injury in pediatric and adolescent girls indicate a need for education and injury prevention in female basketball programs. Ankle injury prevention programs have been employed in the secondary school setting<sup>26</sup> and have demonstrated a reduction in the percentage of ankle injuries compared with that reported in a previous study,<sup>4</sup> but this does not include injuries that occur outside of organized high school sport. Research has also shown the importance of injury prevention programs for reducing knee injuries.<sup>19,34</sup> There is an extreme sex differential in the rate of adolescent anterior cruciate ligament injuries, with the relative injury risk in female basketball 3.8 times that in male basketball.<sup>18</sup> Knee injury prevention programs have been found to be an effective method of reducing the occurrence and health care—related cost of these injuries.<sup>40</sup> Lower extremity injury prevention programs may convey multiple benefits for participants, including basketball-specific skills, neuromuscular control, and balance training components.<sup>40</sup> In relation to concussion/head injuries, previous studies have shown that female athletes are more likely to report concussion symptoms and be more honest in their reporting compared with male athletes,<sup>7</sup> which could be an explanation for the higher injury rate we found in adolescent female athletes. However, emerging evidence has demonstrated that female athletes are more likely to continue play immediately after a concussion,<sup>45</sup> illustrating the need for improved concussion education and perhaps style of play modifications. Future research efforts should focus on improving existing training and education protocols and implementing them into youth basketball programs, especially for the female athlete population.

### Limitations

The data reported in this study were subject to sampling error, as only a sample of EDs were available as a source for injury data rather than a census of all ED data or data from other medical settings. According to a report on the NEISS sample from the CPSC, an estimated 300,000 injuries result in a generalized sampling error of 7.0%.<sup>35</sup> Injuries presenting to EDs may be more severe compared with those injuries (eg, finger sprain) that may be managed on-site by an athletic trainer or at home by the athlete. Therefore, the most common diagnoses could change if other community-based injury repositories were available. In addition, athletes with minor or lesser injuries may have presented to 24-hour clinics (eg, Urgent Med or MedNow) for postinjury care, which could have affected injury rates and frequencies further. Overall, ED data may underestimate the burden of injury from basketball-related activity in the pediatric population.<sup>36</sup> Second, the broad diagnosis categories for basketball-related injuries in the NEISS make comparison with findings from other studies difficult. For

example, knee diagnoses reported in the NEISS do not specify if an anterior cruciate ligament or posterior cruciate ligament injury was present as opposed to a mild general sprain. In addition, although efforts were made to obtain nationally representative injury and participation data, both reporting systems employed weighted samples and may have been subject to further sampling bias. Finally, regarding the NSGA 2019 Sports Participation Report, 2010 was the first year that the NSGA utilized an online survey for data collection. Thus, comparisons with NSGA data collected before 2010 may have been subject to a degree of error because of differing sampling methodology.

## CONCLUSION

The number of pediatric basketball injuries presenting to EDs between 2012 and 2018 have decreased slightly in comparison with that reported in earlier studies, while ankle strain/sprain continues to be the most common diagnosis. However, disproportionate rates of female knee and concussion/head injuries during adolescent basketball suggest that knee injury prevention programs and concussion-based education should target female youth basketball. In addition, concussion/head injuries were a frequent cause of presentation in the childhood group, second only to finger injuries, which highlights the need to focus on this injury in the younger basketball population. Further investigation of these sex- and age-based patterns and the causes of these injuries is warranted to identify appropriate and focused injury risk reduction programs for youth basketball players.

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