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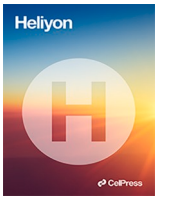

Changes in pediatric fracture patterns presenting to US emergency departments before, during, and after the COVID-19 pandemic

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A B S T R A C T

The purpose of this study was to analyze the demographics of pediatric fracture patients before, during, and after the COVID pandemic using US national emergency department (ED) data. The National Electronic Injury Surveillance System (NEISS) data for the years 2018 through 2021 was extracted for those <16 years of age, and organized into 24 consecutive bimonthly groups. There was a decrease in the number of ED visits for fractures in 2020 and returned to pre-COVID levels by March/April of 2021, except for small hospitals which demonstrated an earlier rebound beginning in late 2020. During the pandemic the incident locale was more frequently the home and less at schools/sporting venues, which returned to pre-COVID levels by March/April 2021. The proportion of those not discharged from the ED increases from March/April 2020 to March/April 2021. The median age was 8.8, 9.0, 8.2, and 8.7 years respectively for the years 2018, 2019, 2020, and 2021. Early in the pandemic there were more radius/ulna and fewer finger fractures and more tibia/fibula and fewer toe fractures; these changes did not return to pre-COVID percentages until the end of 2021. Fractures associated with bicycles and trampolines remained stable throughout the pandemic, those due to skateboards increased, and those due to playground and sporting activities decreased, with varying times of return to pre-COVID levels. In conclusion pediatric fracture patterns during the COVID-19 pandemic demonstrated many changes; most returned to baseline patterns by early/mid 2021 except for small hospital EDs which saw a much quicker rebound by late 2020. This national data gives health care providers/administrators information about what can happen during a modern day pandemic. If another pandemic occurs in the future mandating lockdowns, this data may be useful to guide resource and manpower allocations.

1. Introduction

The COVID-19 pandemic markedly disrupted the entire world. Lockdowns occurred early and rapidly, impacting human behavior and activities [1]. Changes were seen in health care, including orthopaedics. The initial effect of the pandemic on pediatric fractures was noted early on by Bram et al. [2] and later by others [3–6]. Bram et al. [2] noted a 2.5-fold decrease in the volume of fractures presenting to the Children's Hospital of Philadelphia during the pandemic. They also noted a decrease in the age of the children with fractures, those needing surgical treatment and those due to sports or occurring on playgrounds. They also noted an increase in the number of fractures occurring at home. Markiewitz et al. [3] looked at epidemiologic changes in pediatric fractures presenting to emergency departments (EDs) before and during the COVID-pandemic using the National Electronic Injury Surveillance System (NEISS) database. They found a 27 % decline in monthly pediatric fractures during the pandemic that persisted into the second half of 2020. There was a large reduction in fractures discharged to home from the ED and upper extremity fractures among older children sustained at school and in sports. Shaw et al. [4] noted that with stay-at-home orders during the pandemic in Colorado there was an increase in the number of fractures in younger children and those occurring at home; there was in increase in those due to trampolines, bikes and scooters, and a decrease in those due to sports; there were no differences in those needing surgical care or by fracture

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location. Turgut et al. [5] from Turkey noted that the average age of children with fractures decreased during the pandemic; the average age for girls decreased from 7.1 to 5.8 years and for boys from 8.7 to 7.8 years. The incidence of femoral and tibial shaft fractures increased, going from 1.9 % to 4 % of all fractures for the femoral shaft and 3.4 %–6.6 % for the tibial shaft. Schultz et al. [6] from Tennessee found that the incidence of elbow fractures remained constant during the pandemic. However, patients were more likely to present to the clinic compared to the ED, were more likely to be self-transported compared to ambulance transportation, and traveled longer distances to obtain care. The pre-COVID era patients traveled an average of 32.4 miles while the COVID era patients traveled an average of 43.3 miles to obtain care. There was an increase in the number of surgeries performed for those elbow fractures, an increase in the total number of operative hours, and the number of patients admitted to the hospital. The total number of operative hours required at their institution for treating those elbow fractures was 451 per year during the COVID pandemic and 286–354 years pre COVID 2007–2017.

None of these studies have investigated the "rebound effect", that is, what happened after COVID lock downs began to be lifted in late 2020 and 2021. The endpoints for pre-pandemic, pandemic, and post-pandemic are blurry. But as a general guideline, pre-pandemic was up to March 1, 2020, pandemic from March 2020 through February 2021 (coinciding with introduction of the vaccine and significant lifting of lockdowns), and post-pandemic from March 2021 onwards. The post-pandemic period is the time of interest in this study, and is when the rebound effect would occur. Further details are given in the Materials and Methods section below. It was the purpose of this study to further analyze the demographics of pediatric fracture patients before, during, and especially after (rebound) the COVID pandemic using NEISS data. The questions we wished to ask were 1) are the NEISS data results similar to those from single centers, 2) what changes were seen after the lockdowns began to be lifted, and 3) what changes were seen by specific sports and activities. This information will be helpful to guide institutions and health care providers in the event of another pandemic regarding manpower issues (both physician as well as nursing and other ancillary medical personnel) and resource utilization (operating rooms, equipment).

2. Materials and methods

2.1. Data source

The NEISS database was used for this study. The NEISS is a stratified, weighted dataset managed by the US Consumer Product Safety Commission (USCPSC) which collects injury data from ~100 hospitals in the United States and its territories having an emergency department (ED). The database includes date of ED visit, sex and age of the patient, diagnosis, disposition from the ED, incident locale, body part injured, hospital size (strata), and activity involved (consumer product). The NEISS data for the years 2018 through 2021 was extracted. The NEISS was queried for all injuries due to consumer products for these four years for those <16 years old. The 16-year-old age limit was used as most patients ≥ 16 years of age demonstrate adult fracture patterns and 16 is when transition into adult activities such as driving begins. This database excludes injuries due to motor vehicles and powder firearms. Disposition from the ED was classified as discharged or not discharged; those patients transferred from the initial NEISS hospital to another facility were defined as not discharged. The injury locale was grouped into 4 groups: 1) home, 2) street/highway, 3) schools and sports/recreation facilities, and 4) other public property.

The data was organized into 24 consecutive bimonthly groups beginning with January/February 2018 and ending with November/December 2021. This allows for comparisons between the different years within bimonthly groups, as there are well known seasonal variations in pediatric fractures [7,8]. Use of this publicly available de-identified data was determined to be exempt by our local Institutional Review Board.

2.2. Statistical analysis

Statistical analyses were performed with SUDAAN 11.0.01™ software (RTI International, Research Triangle Park, North Carolina, 2013) which accounts for the weighted, stratified nature of the data. The estimated number of injuries/ED visits is calculated, along with 95 % confidence intervals [CIs] of the estimate. When the actual number of patients (n) is < 20, the estimated number (N) becomes unstable and should be interpreted with caution; thus, we report both the n and N (Supplemental Files 1–3) which contain the raw data.

Detailed statistical analyses are difficult in a mostly descriptive study such as this due to two major variables: 1) seasonal variability [7,8] and 2) COVID pandemic factors. The COVID pandemic factors are: 1) when was the pandemic declared over, 2) when did lockdowns become lifted, and 3) if/when were all lockdowns lifted. These endpoints are blurry [9] and varied widely across the US due to varying local/statewide socio-political philosophies and subsequent actions [1,10,11]. As these definitions have no discrete endpoints, it is difficult to place a time where a time point analysis could be used (ie. joinpoint regression analysis (Joinpoint Regression Program, Version 4.8.0.1, April 2020; Statistical Research and Applications Branch, National Cancer Institute [https://surveillance.cancer.gov/joinpoint/])), although it has been used in other trauma demographic studies where specific time points could be reliably stated [12]. As the NEISS is a national database, it is not adequately granular to give detailed information regarding these definitions. We are thus showing an aggregate picture of what happened with pediatric fracture patterns in US EDs over the 4-year time span. Thus we concentrate on simple descriptions with an abundance of figures allowing the reader to visually see the data along with the p values for each analysis.

For some of the variables in the NEISS data set not every ED visit has data; this missing data is typically in the race/ethnicity of the patient, and incident locale. The ED date of visit is always given. In this series of patients, race was given in 60.2 % and incident locale

in 72.6 %; the patients sex was known in 99.999 %, anatomic location of the fracture in 99.999 %, and ED disposition in 99.92 %. The date of ED visit and specific fracture locations data was present in 100.0 % and 99.999 % respectively. No statistical imputations were performed for the missing incident locale data, as we wished to be totally accurate in our analyses.

Continuous data are expressed as both the mean as well as the median and interquartile range [IQR]. Categorical data are given as frequencies and percentages. Differences between continuous variables were determined using an ANOVA. Differences between categorical variables were determined with the χ^2 test. With such large data sets there may be many analyses with a $p < 0.05$ but may not be clinically important. Thus, we report the p value and will let the reader decide what is deemed significant/important. All the results from the detailed analyses are given in Supplemental Files 1–3 for the interested reader.

3. Results

There were a total number of 1,944,002 ED visits for fractures in this population over these four years. There was a decrease in the number of ED visits for fractures in 2020 (Fig. 1A) which returned to near pre-COVID levels by March/April of 2021. This was true for hospitals of all sizes except for small hospitals. The rebound began in early 2021 except for small hospitals when it began in the autumn of 2020 (Fig. 1B). The injuries during the pandemic occurred more commonly at home and less at schools and sporting venues and did not return to pre-COVID levels until March/April 2021 (Fig. 1C). Although the number of fractures decreased during the pandemic, the

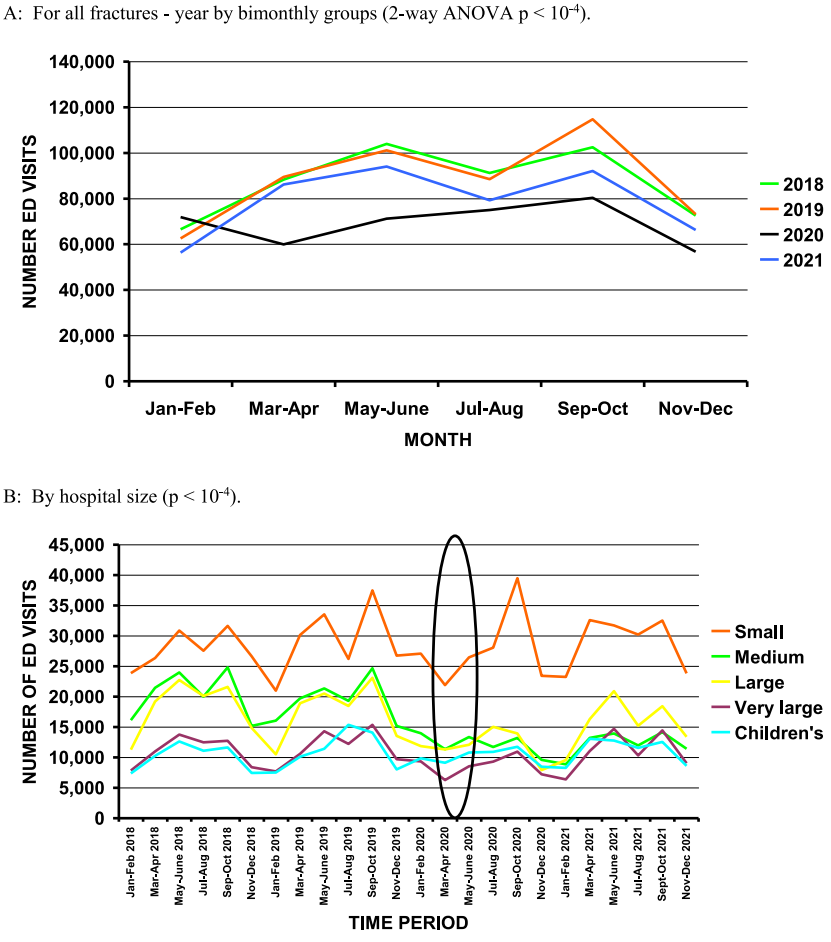
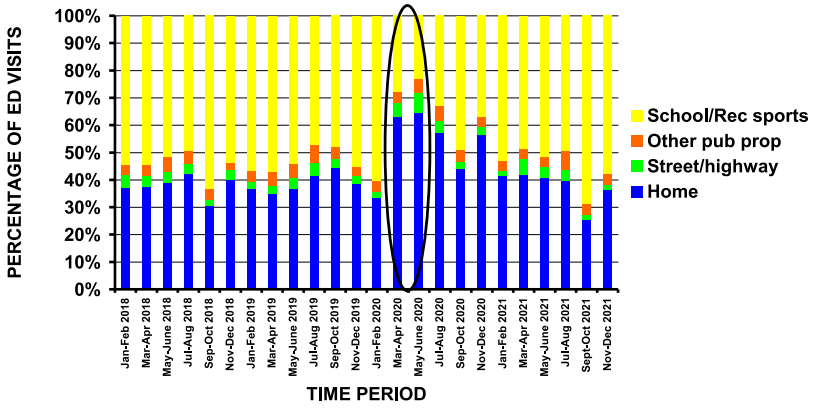


Fig. 1. The estimated yearly number of ED visits for all fractures in those <16 years of age. For figures B–E the initial months of the pandemic are demonstrated by the long black oval.
A: For all fractures - year by bimonthly groups (2-way ANOVA $p < 10^{-4}$).
B: By hospital size ($p < 10^{-4}$).
C. By incident locale ($p < 10^{-4}$).
D. By child's sex ($p < 10^{-4}$).
E. By ED disposition ($p = 0.0003$).
E–1: By percentage of patients not discharged from the ED ($p = 0.0003$).
E–2: By percentage of patients discharged from the ED ($p = 0.0003$).

C. By incident locale ($p < 10^{-4}$).



D. By child's sex ($p < 10^{-4}$).

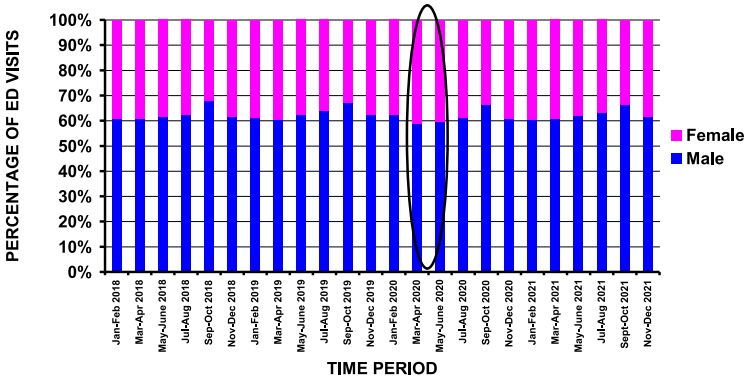


Fig. 1. (*continued*).

proportion of boys and girls remained equal (Fig. 1D) (although the p value was <10-4 for sex by the bimonthly group, visual inspection of Fig. 1D would indicate that it was not clinically important). The proportion of those discharged from the ED compared to those not discharged changed during the pandemic changed; there were fewer discharges for nearly a full year from March/April 2020 to March/April 2021 (Fig. 1E).

The average age was 8.7 years: 8.8 for 2018, 8.9 for 2019, 8.4 for 2020, and 8.8 for 2021 ($p < 10^{-4}$). The median age and IQR for these years were 8.8 [4.9, 11.9], 9.0 [5.0, 12.0], 8.2 [4.1, 11.6], and 8.7 [4.9, 11.9]. During the pandemic the average age decreased (Fig. 2A) due to a decrease in the number of children 5–14 years with those <5 years old showing minimal change (Fig. 2B). The average age did not return to pre-pandemic patterns until May–June of 2021 (Fig. 2C).

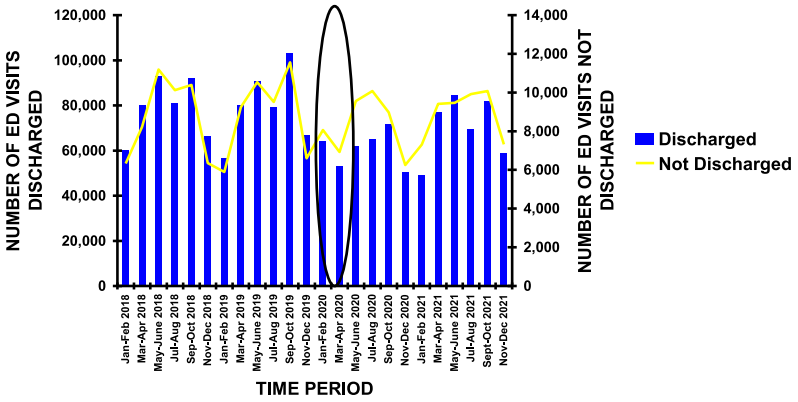
3.1. Fracture location

Over the entire 4 years there was minimal variability in the aggregate anatomic fracture location (Fig. 3A) considering seasonal variations. In the early phase of the pandemic (March–June 2020) there were more radius/ulna and fewer finger fractures (Fig. 3B) within the upper extremity and more tibia/fibula and fewer toe fractures (Fig. 3C) within the lower extremity. These differences did not return to pre-COVID patterns until the end of 2021.

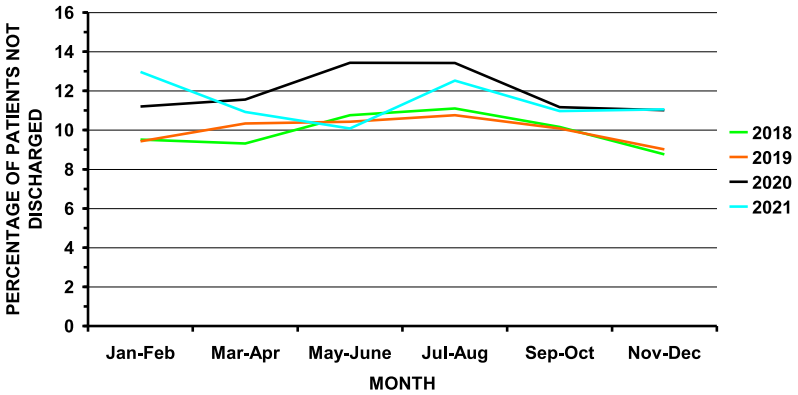
3.2. Specific activities

While there was an overall decrease in the number of fractures during the pandemic, certain activities remained stable or demonstrated an increase in the number of fractures. Those associated with trampolines remained stable throughout the pandemic (Fig. 4A). Those associated with bicycles showed numbers very similar to 2019, but during the 2021 recovery period the numbers for the summer and autumns were less (Fig. 4B). Those due to skateboards increased (Fig. 4C). All sporting activities which were analyzed (baseball/softball, football, soccer, basketball, gymnastics) showed a decrease with varying times of return to pre-COVID levels (Supplemental File 4). Baseball/softball returned to pre-COVID levels by July/August 2020 (Fig. 4D), football by January/February 2021, soccer by July/August 2021, basketball by May/June 2021, and gymnastics by September/October 2020. Playground

E. By ED disposition (p = 0.0003).



E-1: By percentage of patients not discharged from the ED (p = 0.0003).



E-2: By percentage of patients discharged from the ED (p = 0.0003).

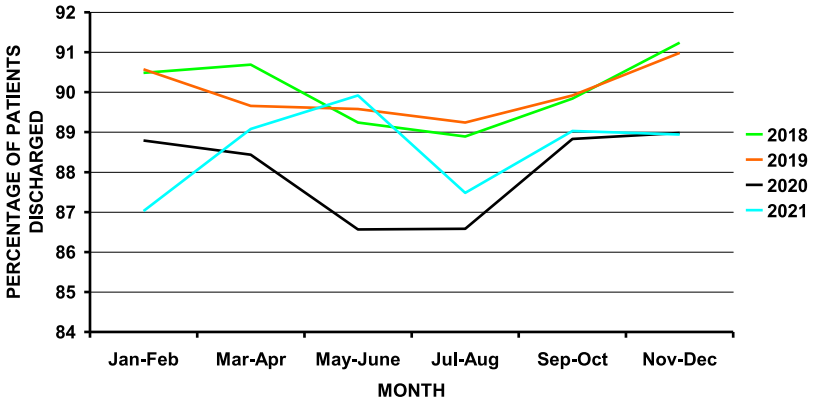
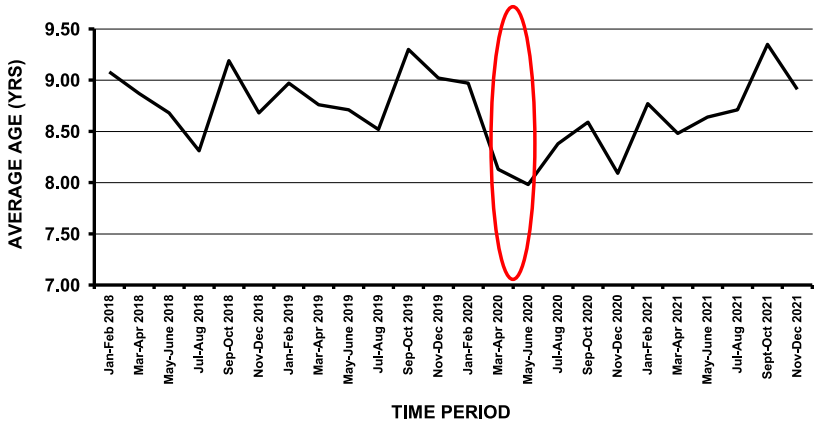
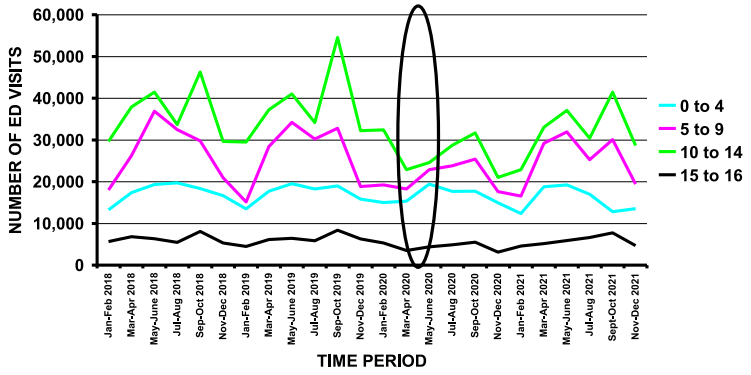


Fig. 1. (*continued*).

A: By average age ($p < 10^{-4}$).



B: By age group. Note the numbers for the 0 to 4 year and 15-to-16-year age groups were stable, but decreased for the 10 to 14 year and 5 to 9 year old age groups ($p < 10^{-4}$).



C: Age by year and bimonthly group (2-way ANOVA $p < 10^{-4}$).

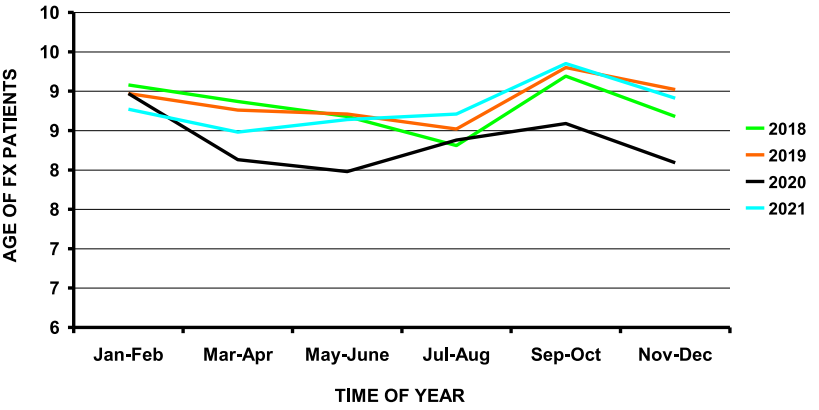
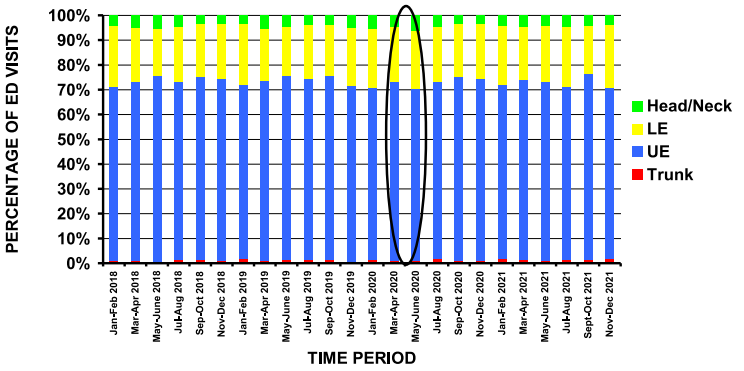
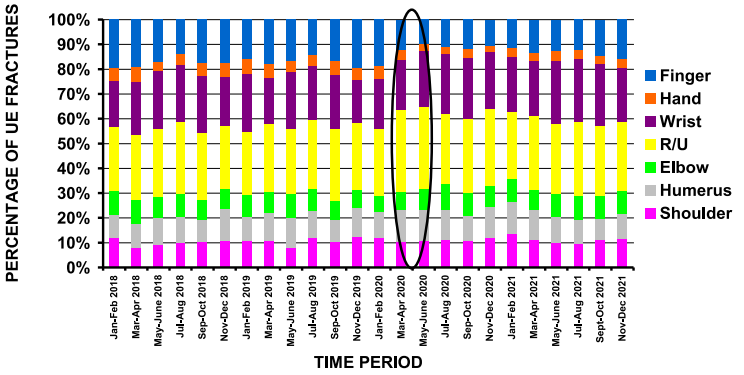


Fig. 2. Variations by age over the 4-year time span. The initial months of the pandemic are demonstrated by the long ovals.
A: By average age ($p < 10^{-4}$).
B: By age group. Note the numbers for the 0–4 year and 15-to-16-year age groups were stable, but decreased for the 10–14 year and 5–9 year old age groups ($p < 10^{-4}$).
C: Age by year and bimonthly group (2-way ANOVA $p < 10^{-4}$).

A. By the head/neck, upper extremity, lower extremity, and trunk ($p < 10^{-4}$). The initial months of the pandemic are demonstrated by the long black ovals.



B. Within the upper extremity ($p < 10^{-4}$).



C. Within the lower extremity ($p < 10^{-4}$).

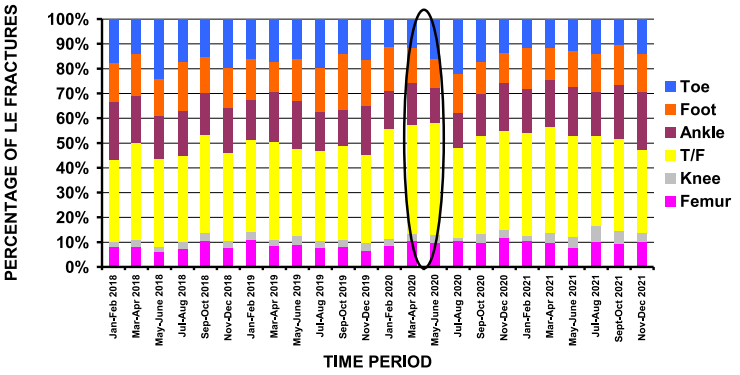


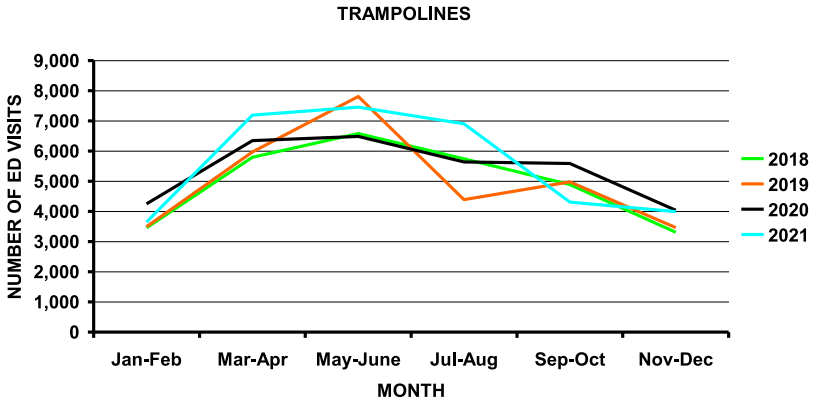
Fig. 3. Fracture location.
A. By the head/neck, upper extremity, lower extremity, and trunk ($p < 10^{-4}$). The initial months of the pandemic are demonstrated by the long black ovals.
B. Within the upper extremity ($p < 10^{-4}$).
C. Within the lower extremity ($p < 10^{-4}$).

equipment, a well-known cause of pediatric fractures, returned to pre-COVID levels by January/February 2021 (Fig. 4E). The results for the various types of playground activities (monkeybars, swings, slides) are shown in Supplemental File 5.

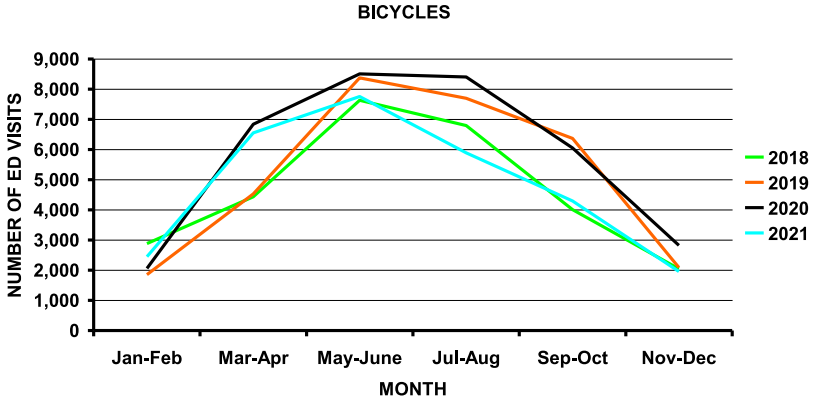
4. Discussion

The findings in this study are both similar and different compared to other pediatric fracture studies during the COVID-19

A: Trampolines (p = 0.013).



B. Bicycles (p =0.0001).



C. Skateboards (p = 0.008).

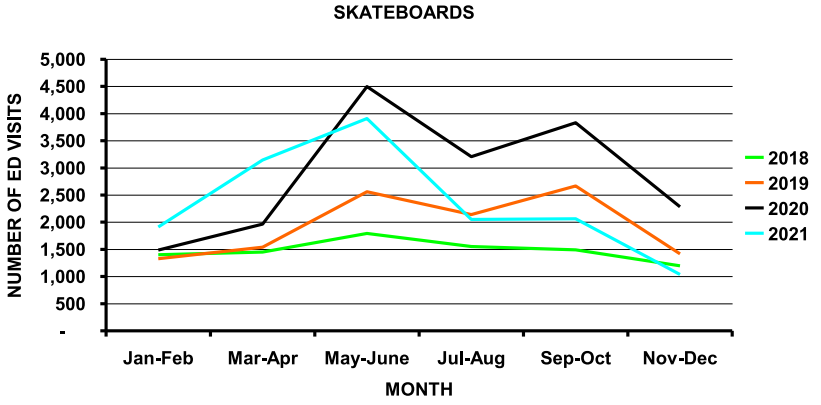
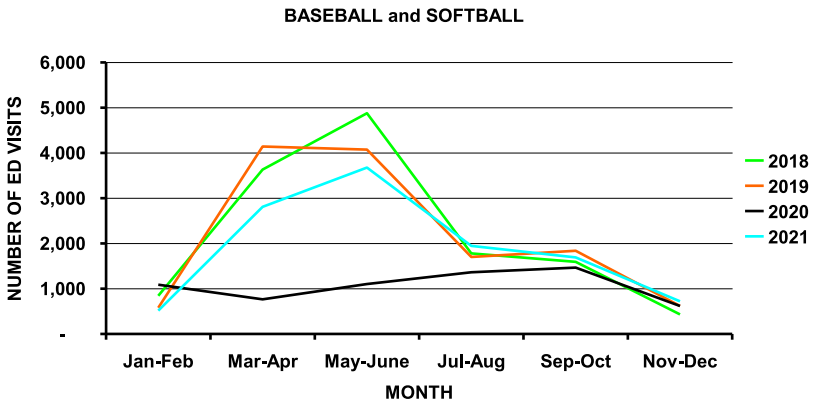


Fig. 4. The estimated yearly number of ED visits for fractures due to specific activities by year and bimonthly group.
A: Trampolines (p = 0.013).
B. Bicycles (p = 0.0001).
C. Skateboards (p = 0.008).
D. Baseball/softball ($p < 10^{-4}$).
E. Playground equipment ($p < 10^{-4}$).

D. Baseball/softball ($p < 10^{-4}$).



E. Playground equipment ($p < 10^{-4}$).

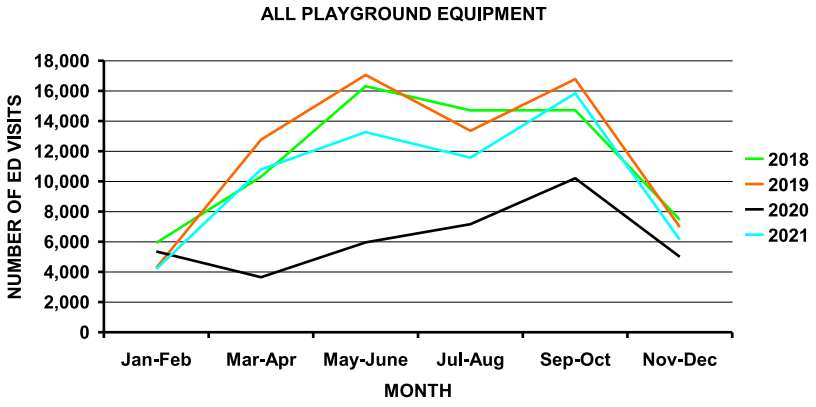


Fig. 4. (*continued*).

pandemic. Not surprisingly, there was an increase in the number of fractures occurring at home and fewer at schools and sporting/recreational locations (Fig. 1C) as noted by others [2–4,13]. These trends did not return to pre-pandemic values until the summer of 2021; by that time most sport/recreational and school/sporting activities had likely reopened (Fig. 4D). We noted no difference in the percentage of fractures in boys compared to girls throughout the entire study period (Fig. 1D), as observed by many others [2–6,13,14].

The average age of these pediatric fracture patients decreased during the pandemic due to fewer children 5 through 14 years of age with those <5 years old remaining stable. This is contrary to the finding by Shaw et al. [4], who noted that, while the average age decreased from 9.4-year pre-pandemic to 8.3 years during the pandemic, greater fracture numbers were seen among younger children. In our study the number of fractures in younger children remained stable through and after the pandemic. Turgut et al. [5] noted that the average age of those with fractures in their <16-year-old cohort was 8.2, 8.6, and 7.1 years for the years 2018, 2019, and 2020 respectively. Bram et al. [2] noted that the average in their series of pediatric fractures dropped from 9.4 to 7.5 years during the pandemic. In a series of lower limb pediatric fractures, Darling et al. [13] noted that the average age dropped from 11.1 to 6.9 years. Thus most studies demonstrate a decrease in the age of pediatric fracture patients during the pandemic, including ours. We surmise that our finding of no change in the number of those <5 years of age during the pandemic is likely due to the fact that most of these children were not in school or day care centers and thus would not be affected by the lockdowns.

Some studies noted an increase in the percentage of operative fractures during the pandemic [5,6], while others did not [2,13]. The ratio of ED discharged/not discharged was not available in two studies [2,13]. Bram et al. noted [2] no difference in the proportion of patients needing surgery between the pre-pandemic and pandemic time spans. One proxy for fracture severity is the number/percentage of patients discharged/not discharged from the ED. In this study we noted that the percentage of patients not discharged (Fig. 1-E1) increased in the early months of the pandemic (March/April through Sept/Oct 2021) with a concomitant decrease in the percentage of patients discharged from the ED (Fig. 1-E2) as noted by Markeiwitz et al. [3]. However hospital admission does not totally equate to the need for operative treatment, as certain fractures, especially tibia fractures, are often admitted for close neurovascular observation for the possible development of a compartment syndrome which requires immediate treatment. Other patients are admitted for pain control; finally, some are admitted for assistance with ambulation and crutch/walker training which are often not

available in an ED setting, especially at night.

In this study we noted minimal changes in the overall anatomic fracture location throughout the pandemic (Fig. 3A), similar to Bram et al. [2]. Within the upper extremity there were fewer finger/hand fractures and more radius/ulna fractures (Fig. 3B). Both Schultz et al. [6] and this study no significant differences in elbow fractures during the pandemic. We noted a decrease in the proportion of finger fractures, as did Turgut et al. [5]. We also noted a decrease in the proportion of toe but more tibia/fibula fractures during the early phases of the pandemic (Fig. 3C) as did others [4,5,13]. We did not notice an increase in femur fractures contrary to Turgut et al. [5]. The decreased proportion of toe and finger fractures is likely due to parent themselves feeling that the injury was not severe enough to risk a visit to the ED during the very concerning and infectious phases of the pandemic, and noting wanting to be exposed to the virus while in the ED.

When investigating specific activities, we noted a marked decrease in fractures due to playground equipment (Fig. 4E) as did others [2,14]. This is likely due to playground closures during the pandemic. The number of playground equipment associated fractures did not return to pre-pandemic levels until early 2021. (Detailed analyses of the various playground activities by swings, slides, monkey bars, etc. are shown in Supplemental File 5). As children were at home more during the lockdown phases of the pandemic, we noted an increase in the number of fractures due to bicycles and skateboards (Fig. 4B and C) which are easy activities that children can perform at home. This was similarly seen by others [2,4,14]. Even though most trampoline associated fractures occur at home [15,16] we surprisingly saw no real increase in the number of fractures from trampolines during the pandemic (Fig. 4A), dissimilar to the findings of Gornick et al. [14] where a decrease in the number of trampoline associated fractures was seen. Others noted an increase in fractures due to trampolines [2,4,13]. We have no formal explanation of these discrepancies in the number of trampoline associated fractures, but surmise that as the early months of the pandemic were March/April/May of 2020, the weather was relatively cold and children weren't going outside to play on the trampolines, and that the number of injuries during the summer would remain unchanged as schools are typically closed during the summer anyways and thus not be affected by lockdowns. Regarding the various sporting activities, we noted marked differences during the pandemic (Fig. 4D) with pre-pandemic numbers being reached at different times, ranging from mid 2020 to mid 2021 depending upon the sport (Supplemental File 4).

When looking at these different sports in detail, many of the patterns can be explained by the season during which they are most commonly played. Baseball/softball is typically a spring and summer sport, and in 2020 it was absolutely flat with no change in the number of fractures throughout the whole year. This would be expected as the first several months of the pandemic were marked by nearly total lockdown of schools and group sporting events. For American football, there was an increase in the autumn of 2020, and with football being an autumn sport, this would be expected. However, it was not as large as the pre- and post-pandemic years. The partial increase is likely due to the fact that some schools were beginning to open up in late 2020. A similar pattern was seen by Markiewitz et al. [3] who noted that the decrease in fractures persisted into the 2nd half of 2020. The same can be said for soccer, which is also typically an autumn sport in the US. Basketball is typically a winter sport in the US, and the large decrease in the number of fractures seen during the winter of 2020–2021 can be explained by that. Unlike football, basketball is played inside during the winter, while football is played outside during the autumn. It is known that early lifting of the lockdowns were more common in outdoor activities, while close, indoor gatherings were still maintained under lockdowns.

The small hospitals in the NEISS database demonstrated an earlier return to pre-pandemic patterns than the larger hospitals. It has been shown that rural US residents were less likely to participate in COVID-19 preventive health behaviors such as wearing masks, sanitizing their homes/workspaces and less likely to work from home [17]. These attitudes likely impacted the local philosophies on school closures and other activities of the children as well. If the lockdowns were of a lesser magnitude in the rural areas, then it would be expected to see an earlier return to pre-pandemic patterns of pediatric fractures.

This is the first study to use a national database looking at pediatric fracture patterns during the pandemic recovery beginning in 2021. This recovery was due to the roll out of COVID vaccines which followed with re-opening of facilities, especially schools and places of recreation/sport. Pre-pandemic numbers returned at different times for different variables. The overall number of fractures returned by early 2021 while the age distribution, incident locale, and proportion of patients discharged from the ED returned to pre-pandemic values later in the summer of 2021. Among the various activities studied (bicycles, skateboards, and playground equipment) most returned to pre-pandemic levels by early 2021. Those associated with sports demonstrated variable returns as discussed above.

There are certain limitations of this study. First, it studies only patients seen at EDs; thus, those seen at urgent care centers or other outpatient clinics are not counted. Second, it does not give an accurate value for those fractures needing surgical intervention, although not being discharged from the hospital is a reasonable proxy of such an event. We also do not know if there were any differences in time from injury to ED presentation, as some have noted an increase in that time interval [4] while others have not [2]. Third, it does not give figures for fractures due to motor vehicle crashes or firearms. Finally, regional specific analyses cannot be done due to the de-identified nature of each hospital in the NEISS sample. It would be very interesting to study any potential differences during rebound correlated with different times of re-opening, but unfortunately that is not possible due to the de-identified status of each NEISS hospital.

The strength of this study is that it is a national picture of pediatric fracture patterns and demographics before, during, and immediately after the COVID-19 pandemic. While these are national estimates and may not be locally applicable, they can give health care providers, especially ED providers, orthopedic surgeons, and health facility administrators important information about what can happen during a modern day pandemic. This data will be helpful in guiding the health care industry regarding resource and manpower allocation in the care of pediatric fractures if another pandemic would happen to occur in the near future. An increase in operative care for pediatric fractures [5,6]; the NEISS data does not give details regarding the care of those patients admitted to the hospital, but the proportion of patients admitted to the hospital increased during the pandemic in our study, indirectly supporting increased operative care. This has important implications regarding hospital staffing and resource utilization (operating rooms, equipment and supplies).

5. Conclusion

Pediatric fracture patterns before, during, and after the COVID-19 pandemic demonstrated many changes, but usually rebounded back to pre-pandemic patterns by early to mid-2021. However, EDs in small hospitals saw a much quicker rebound by late 2020 compared to larger size hospitals. The median age of the pediatric fracture cohort dropped by nearly 1 year during the pandemic. The overall general distribution in fracture location anatomically between upper extremity, lower extremity, trunk, and head/neck showed minimal changes over the peri-pandemic time span. There was a decrease in finger and toe fractures, with a concomitant increase in the number of radius/ulna and tibia/fibula fractures in the proportion of fractures during the early phases of the pandemic. Hopefully, another pandemic will not occur in the future, but if so, this is important information that can guide health care institutions and health care providers regarding manpower and resource utilization issues in such an event.

Data Availability statement

Has data associated with your study been deposited into a publicly available repository?
No.
Why?
The data is freely and publicly available on line to anyone at the NEISS website.

CRediT authorship contribution statement

Randall T. Loder: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Benjamin A. Johnson:** Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e20953.

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