HHS Public Access
Author manuscript
Inj Prev. Author manuscript; available in PMC 2025 January 25.

Published in final edited form as:
Inj Prev. ; 30(1): 46–52. doi:10.1136/ip-2023-044971.

Are there seasonal patterns for emergency department visits for head injuries in the USA? Findings from the National Electronic Injury Surveillance System-All Injury Program

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Abstract

Introduction—Previous international research suggests that the incidence of head injuries may follow seasonal patterns. However, there is limited information about how the numbers and rates of head injuries, particularly sports- and recreation-related head injuries, among adults and children evaluated in the emergency department (ED) vary by month in the USA. This information would provide the opportunity for tailored prevention strategies.

Methods—We analysed data from the National Electronic Injury Surveillance System-All Injury Program from 2016 to 2019 to examine both monthly variation of ED visit numbers and rates for head injuries overall and those due to sports and recreation.

Results—The highest number of head injuries evaluated in the ED occurred in October while the lowest number occurred in February. Among males, children ages 0–4 years were responsible for the highest rates of head injury-related ED visits each year, while in females the highest rates were seen in both children ages 0–4 and adults ages 65 and older. The highest number of head

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Contributors JD and KS designed the project; JD, KS, and RL developed the theoretical framework; KY performed the statistical analysis; JD supervised the project; all authors discussed the results and contributed to the final manuscript. JD is the guarantor of the manuscript.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

injuries evaluated in the ED due to sports and recreation were seen in September and October. Head injury-related ED visits due to sports and recreation were much more common in individuals ages 5–17 than any other age group.

Conclusion—This study showed that head injury-related ED visits for all mechanisms of injury, as well as those due to sports- and recreation-related activities, followed predictable patterns —peaking in the fall months. Public health professionals may use study findings to improve prevention efforts and to optimise the diagnosis and management of traumatic brain injury and other head injuries.

INTRODUCTION

Head injuries result from trauma to the face, scalp, skull, brain or underlying tissue and blood vessels in the head. Traumatic brain injuries (TBIs) are a serious type of head injury and are associated with millions of cases of disability and deaths worldwide.[1] In the USA alone, more than 223 000 TBI-related hospitalisations occurred in 2019 and more than 64 000 TBI-related deaths occurred in 2020.[2] Suicide, unintentional falls and motor vehicle crashes are leading mechanisms of TBI-related hospitalisations and deaths in the USA.[3] Certain groups have a higher risk for sustaining a TBI or living with long-term problems that result from this injury.[4] For example, a meta-analysis showed that worldwide, men have twice the odds of having a history of TBI than women.[1]

In addition to variations in TBI and other head injury risk by group, there is evidence that the risk for these injuries might follow monthly or seasonal patterns. Zemek *et al* reported that during an 11-year period in Canada, healthcare visits for concussions, often referred to as mild TBIs, followed a cyclical pattern.[5] Concussion-related visits were highest in the fall and winter and lowest in the summer—driven in part by ice hockey-related injuries. A review of medical records in a South Korean medical system found that visits for patients with a mild TBI were highest in the summer, while visits for patients with a moderate or severe TBI were highest in the Winter.[6] The authors hypothesise that these patterns likely stem from dangers due to winter weather and geographical conditions of agricultural areas in South Korea.[6] In contrast, researchers in Norway found that most injury-related deaths in children (most commonly from head and neck-related injuries) occurred in the spring and summer, potentially due to extended daylight hours and more time for exposure to injuries (eg, motor vehicle crashes).[7]

In the USA, research on seasonal trends for head injuries is limited, but there is evidence to suggest that paediatric healthcare visits due to TBI and other head injuries increase in the early fall.[8] This coincides with the start of fall sports which is when American football, a sport which has been shown to be a leading cause of youth sports concussion, is typically played.[8,9] Leading mechanisms of TBI-related healthcare visits and deaths in the USA also show seasonal variation. Unintentional fall-related emergency department (ED) visits are higher during the winter compared with other seasons.[10] Conversely, deaths due to motor vehicle crashes tend to peak in the summer months and are lowest in January and February.[11] In 2020, the number of suicides was highest in July and lowest in April and December.[12] Taken together, it is likely that head injuries, including TBIs from all mechanisms, in the USA display some monthly or seasonal variation. However, to our knowledge, there are no published studies on seasonal and monthly variations among both adults and children seen in US EDs for head injuries.

Awareness of monthly or seasonal patterns of TBI and other head injuries in the USA may help inform the dissemination of clinical information about head injuries to healthcare centres. Further, it provides an opportunity to develop and target prevention efforts by cause to groups and areas at increased risk, as well as to inform resource allocation in medical settings (eg, access to specialists). While a previous study has examined seasonal patterns of paediatric head injuries that were treated outside of the ED,[8] no studies have looked at head injuries that were treated in the ED, which is an important site of care for suspected head injuries.[13] The purpose of this project is therefore to describe whether there are monthly variations in head injury-related ED visits overall, as well as by sex and age. To build on prior research among paediatric patients in the USA, this analysis also examined head injury-related ED visits in the USA that are due to sports- and recreation-related activities.

METHODS

This cross-sectional study used data from the National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP). [14] NEISS-AIP is operated by the US Consumer Product Safety Commission (CPSC) in collaboration with the US Centers for Disease Control and Prevention (CDC). NEISS-AIP collects data on all first-time visits for nonfatal injuries treated in 66 US hospital EDs through stratified probability sampling. All hospitals in the NEISS-AIP dataset have at least 6 beds and provide 24-hour ED services. The sample included five strata of which four represented different levels of hospital size, determined by the volume of ED visits. The fifth contained children's hospitals. Data are weighted by the inverse of the probability of selection to produce national estimates. Trained onsite hospital coders collect data for injury-related ED cases from medical records at NEISS-AIP sample hospitals. Key variables are coded and these data, as well as a brief narrative that summarises information about how the injury was sustained, are entered into a computer and electronically transmitted to CPSC. NEISS-AIP quality assurance coders at CPSC review all data elements and narratives, then classify the cause of injury for each case. This study used publicly available data with no patient or public involvement.

We included ED visits for head injury from 1 January 2016 to 31 December 2019. Cases were classified as a head injury if the primary body part injured was the head. Head injuries included the diagnoses of concussion or internal organ injury, laceration, contusion or abrasion of the head. Therefore, this analysis includes both TBIs and more superficial injuries. However, the head injuries that have been labelled as TBIs in previous studies using NEISS-AIP data (concussions and internal organ injury of the head)[15,16] comprised 74% of all head injuries in the sample (data not shown).

We applied descriptive methods to examine monthly variation of ED visits for head injury. Date of treatment was used to define the month of ED visits. Monthly counts were the average of the 4 years of combined data. Number and rates of head injury-related ED visits, alongside their 95% confidence intervals (CIs), were calculated. When comparing rates across different age groups, we employed statistical tests that focused on examining the CIs. Differences were considered statistically significant if their CIs were not overlapping (included in online supplemental tables). Graphical representations of monthly ED visits are presented. All visit numbers were expressed as weighted national estimates. We stratified analysis by sex and age groups to examine monthly ED visits rates. We also examined head injuries due to sports- and recreation-related activities. NEISS-AIP has a sports- and recreation-related variable, which has 39 mutually exclusive categories. Sports- and recreation-related categories are based on an algorithm that considers both the consumer products involved (eg, bicycles or accessories, or in-line skating) and the narrative description of the incident. An injury was considered to be sports- or recreation-related if it included a sport-related consumer product or the narrative description of the injury indicated it was caused by a sports- or recreation-related activity.

Bridged-race vintage census population estimates, which are annual updates to the US Census data to ensure accurate demographic representation, were used as the denominator to calculate age-specific rates per 100 000 population.[17] All analyses were conducted using SAS-callable SUDAAN, V.11.0.3 (RTI International), accounting for sample weights and the NEISS-AIP complex survey design.

RESULTS

Between January 2016 and December 2019, there were 288 037 (weighted national estimate: 15 712 359) ED visits for head injuries in the USA (online supplemental table 1). On average, the estimated number of head injury-related ED visits peaked in October (351 939, 95% CI 282 560 to 421 317), followed closely by September (347 491, 95% CI 279 491 to 415 490) (figure 1). A smaller peak occurred in May (344 933, 95% CI 277 667 to 412 200). The number of head injury-related ED visits was lowest on average in February (293 164, 95% CI 233 934 to 352 394). This pattern held true for each of the years studied (online supplemental figure 1). The most common cause of head injury-related ED visits was unintentional falls across all months; unintentional falls were responsible for about half of all visits for most months (data not shown). The average monthly rate of head injury-related ED visits was similar in males and females for most age groups (figure 2 and online supplemental table 2). Although several age groups had overlapping confidence intervals for both males and females, generally males and females ages 0–4 years and 65 and older had higher rates of head injury-related ED visits than other age groups across all months (figure 2 and online supplemental table 2). Among males, those ages 26–44 and 45–64 years generally had lower rates of head injury-related ED visits across all months.

The estimated number of head injuries evaluated in the ED due to sports and recreation mirrored the pattern of head injuries overall; peaks were found in September (52 606, 95% CI 39 333 to 65 879), October (50 414, 95% CI 37 364 to 63 465) and May (43 613, 95% CI 32 881 to 54 346) (online supplemental table 3). The lowest numbers of head injury-related ED visits due to sports and recreation occurred during winter months (figure 3). For both males and females, youth ages 5–17 years generally had the highest rates of head injury-related ED visits due to sports- and recreation-related activities compared with other age groups (figure 4 and online supplemental table 4). However, the monthly patterns for this age group differed by sex. While the rate of head injury-related ED visits due to sports- and recreation-related activities for males ages 5–17 years peaked in September and October, females ages 5–17 years had a bimodal distribution, with peaks seen in both May and September. For males ages 5–17, the valley in the rate of head injury-related ED visits due to sports- and recreation-related activities was seen in December while for females ages 5–17 years the valley was seen in July. Other age groups showed limited monthly variation in the rate of head injury-related ED visits due to sports- and recreation-related activities.

Figure 5 displays the average monthly number of sports- and recreation-related head injury ED visits for males and females ages 5–17 years by the top three activities for each sex. Football was responsible for the greatest number of ED visits overall for males, with steep peaks in September and October (online supplemental table 5). Basketball, soccer and playground activities were the most commonly documented causes of head injury-related ED visits for females ages 5–17 years, but there were few discernible monthly patterns.

DISCUSSION

This study, one of the first of its kind in the USA, described monthly patterns in head injury-related ED visits in the USA over a 4-year study period. Consistent monthly patterns were found when combined over years and in each individual year. This underscores the injury prevention framework promoted by experts worldwide that contends that injuries are not random events, but instead are influenced by predictable individual, social, structural and environmental factors within communities.[18–20] Patterns identified through this analysis show that a higher number of head injury-related ED visits occur in the fall and spring months—peaking in October, September and May—and are less common in the winter months. These patterns correspond with the seasonal patterns reported by some of the leading mechanisms of injury for TBI.[10–12] For example, the National Safety Council reported that the death rate per 100 million vehicle miles driven peaks in September in most years.[11] Findings from this study, as well as those on leading mechanisms of TBI, may be used by public health professionals to optimise the timing of when prevention messages and strategies are disseminated.

Several evidence-based strategies exist in the USA to prevent the leading mechanisms of TBIs and other head injuries, including addressing unintentional falls among older adults, self-harm (including suicide), high-risk sports- and recreation-related activities, and motor vehicles crashes.[21–24] However, implementation of evidence-based strategies is often challenging (due in part to resource, social and environmental-related factors) and may be inconsistent—limiting the ability to substantially mitigate TBI and other injury incidence on a widescale basis.[20 25] Several strategies, including better use of strategic partnerships to reach key audiences and decision-makers, as well as social marketing efforts, have shown to be beneficial strategies to improve implementation of injury prevention programmes.[26 27]

Overall and monthly patterns for head injury-related ED visits differed by sex and age in the USA. Among both males and females, children ages 0–4 years and older adults (65 and older) had higher rates of head injury-related ED visits each year. Most TBI-related ED visits, hospitalisations and deaths among young children and older adults are caused by unintentional falls.[3 28] A recent study found that while children's activities (eg, running, climbing, tripping) accounted for the greatest proportion of fall-related TBIs treated in EDs among those ages 5 years and under, actions by others (eg, being dropped) accounted for the greatest proportion of fall-related TBIs in the ED among those ages 1 year and younger.[29] Healthcare professionals can provide education to parents about fall risks among young children (especially as they are learning to walk), as well as how to create safe home environments to reduce the risk (eg, using stair gates). While there are currently no studies on seasonal patterns for unintentional falls among children, Kakara *et al* found a peak in unintentional fall-related ED visits among older adults, age 65 and older, in winter months.[10] Caregivers and healthcare providers may consider increasing fall prevention messaging during the winter to help older adults prevent injuries.[30]

Male youth ages 5–17 years had the highest rate of sports- and recreation-related TBI ED visits. While the number of head injury-related ED visits remained relatively steady across all months for most males, the number of head injury-related ED visits among males ages 5–17 years varied widely with the highest numbers occurring during the fall months of September and October. The overall pattern of head injury-related ED visits for males ages 5–17 years mirrored those for sports- and recreation-related ED visits for this group. Findings suggest that football injuries are the key driver for the fall peak in head injury-related ED visits among young males. American football is played by an estimated 3 million youth in the USA each year[31 32] and accounted for more than 25% of the more than a quarter of a million ED visits among children ages 17 and under for sports- or recreation-related TBIs between 2010 and 2016.[15] American football is not commonly played by females and may help explain why the rate of head injury-related ED visits in October for males ages 5–17 years was about two times higher than for females of the same age. It is unclear why the number of sports- and recreation-related ED visits for head injury among females ages 5–17 peaked in both the spring (May) and fall (September). One possible explanation may be the spring and fall youth soccer seasons. In addition to being one of the most played sports among females ages 5–17 years,[31 32] a paper by Sarmiento *et al* found that soccer contributes to more TBI-related ED visits among females than many other popular contact and non-contact sports-related activities.[15] Educating adults, including coaches and parents, on concussion safety can help mitigate the seasonal patterns of head injury that result from sports- related activity among children and youth. A randomised control study demonstrate that disseminating CDC HEADS UP concussion educational materials to coaches and parents may help improve communication with youth athletes about concussion safety.[33] Timing the dissemination of these materials by sports programmes prior to the start of the American football and soccer seasons, along with reminders and safety tips throughout the season, may be beneficial.

Prior studies note predictable patterns for TBI and other head injury-related healthcare visits in other countries. However, these patterns do not align with each other nor that of the USA. Due to the inherent limitations in surveillance data for ED visits, this analysis does not allow for an examination of why variations between countries exist. Previous research shows that some differences may be explained by factors such as weather. These studies highlight how differences in weather, among other factors, may lead to dangerous driving conditions and/or icy sidewalks,[10 34] length of daylight by season,[34] exposure to violence and access to firearms,[7 35] and participation in seasonal sports- related activities (eg, ice hockey and American football).[5 9] Building on this, future studies that explore possible factors that influence injury patterns and differences between communities is warranted. This approach is consistent with the injury prevention model, first developed by van Mechelen *et al* and later adapted by others to be more inclusive of external factors and evaluation of interventions, which places surveillance as foundational to the development of more targeted studies and the identification of effective prevention strategies.[36–39]

Strengths of this study include the examination of 4 years of data and the large population size. However, this study has limitations. The most recent data from 2020 was not included due to documented aberrations in care seeking due to the COVID-19 pandemic.[40] The NEISS-AIP only includes head injuries resulting in visits to hospital EDs. Most persons who sustain a head injury, including TBI, do not seek care in an ED[13 41]; therefore, the numbers presented here are likely an underestimate of the true prevalence of head injuries in the USA. Second, NEISS-AIP only includes the principal diagnosis and primary body part recorded during the initial injury visit; therefore, some cases for which a head injury was a secondary diagnosis (eg, multiple-trauma injuries) might have been missed. Finally, while NEISS-AIP collects data from a large sample of hospitals (n=66), there is a potential risk of selection bias of these hospitals and thus a resulting risk to the generalisability of our findings. It is possible, for example, that another sample of hospitals would find higher or lower numbers of head injuries.

CONCLUSION

This study demonstrated that head injury-related ED visits for all mechanisms of injury, as well as those due to sports- and recreation-related activities, followed predictable patterns —peaking in October and September in the fall and May in the spring. Findings from this study may be used by public health professionals to optimise dissemination of evidence-based interventions for the leading mechanisms of head injuries and other TBIs, such as promotion of older adult fall prevention strategies during the winter months. Moreover, widespread distribution of head injury and concussion safety and management information to sport programmes prior to youth American Football and soccer seasons may be beneficial to promote athlete safety. Future research may examine whether seasonal patterns exist for different causes of head injury-related ED visits and whether policies and practices, such as state concussion laws for student athletes, are effective in preventing these ED visits over time.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Funding

The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Disclaimer

The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Data availability statement

Data are available in a public, open access repository. Data are publicly available.

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WHAT IS ALREADY KNOWN ON THIS TOPIC

- Millions of head injuries, including traumatic brain injuries (TBIs), occur worldwide on an annual basis.

WHAT THIS STUDY ADDS

- Head injury-related emergency department (ED) visits follow a monthly and seasonal pattern, with the highest number of visits occurring in October and the lowest occurring in February. More head injury-related ED visits due to sports and recreation occur in the fall.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- Public health professionals may choose to time the dissemination of TBI prevention messages based on the time of the year when there is the highest risk, particularly for those caused by sports and recreation.

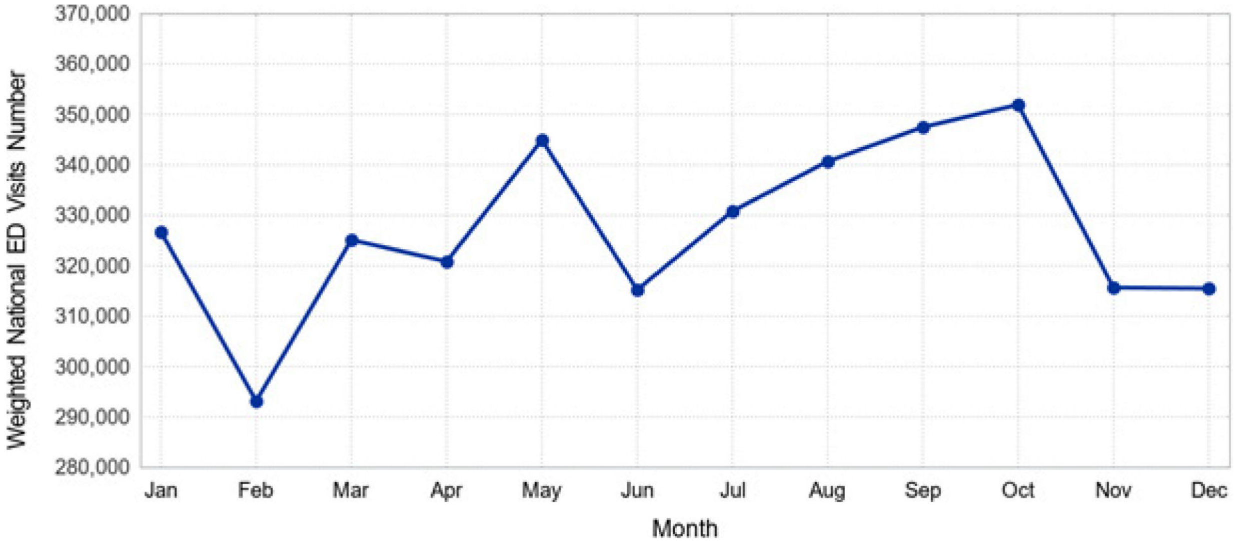

Figure 1.

Average monthly number of head injury emergency department (ED) visits, National Electronic Injury Surveillance System-All Injury Program, 2016–2019, USA.

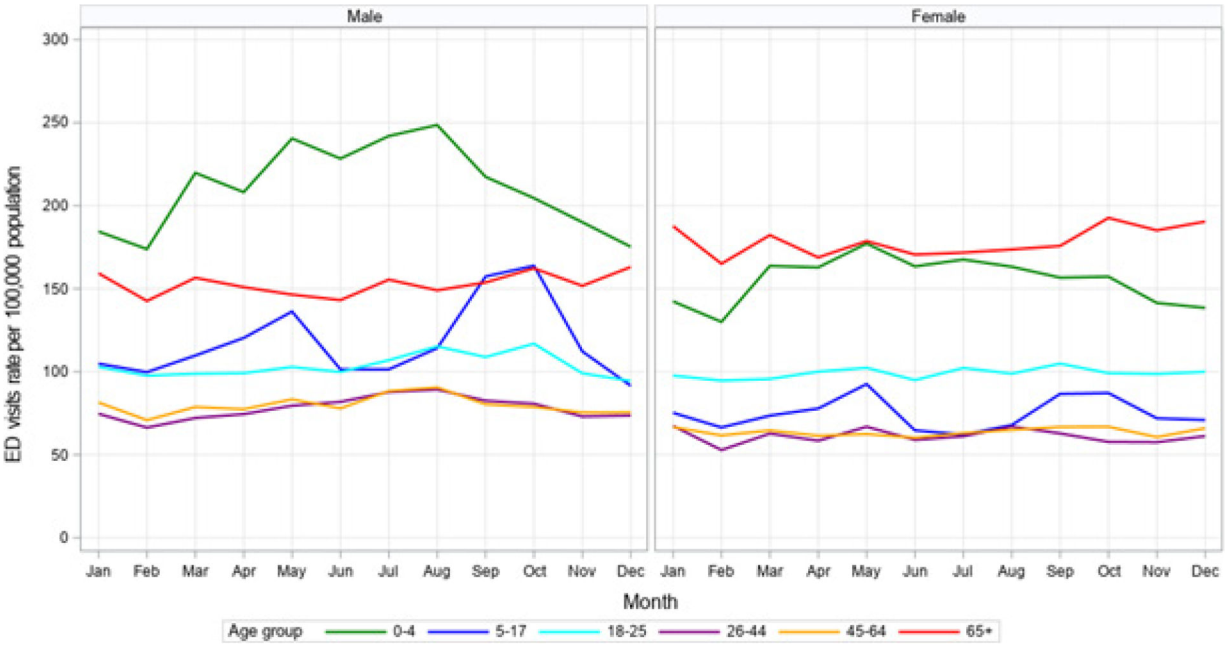

Figure 2.

Average monthly rate of head injury emergency department (ED) visits per 100 000 population, by sex and age, National Electronic Injury Surveillance System-All Injury Program, 2016–2019, USA.

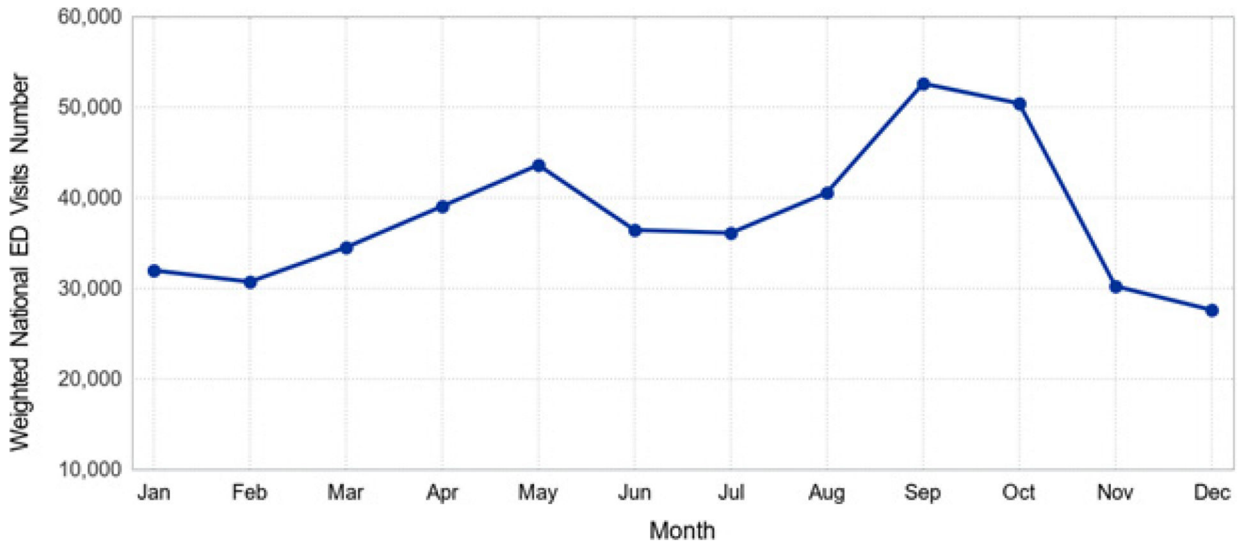

Figure 3.

Average monthly number of sports- and recreation-related head injury emergency department (ED) visits, National Electronic Injury Surveillance System-All Injury Program, 2016–2019, USA.

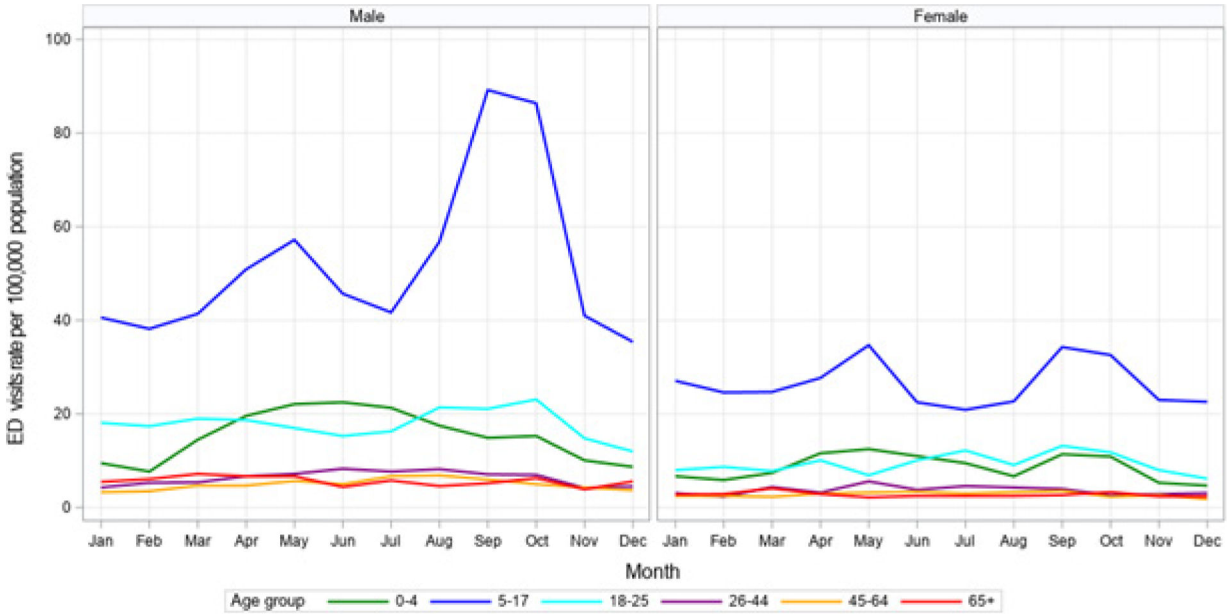

Figure 4.
Average monthly rate of sports- and recreation-related head injury emergency department (ED) visits per 100 000 population, by sex and age, National Electronic Injury Surveillance system-All Injury Program, 2016–2019, USA.

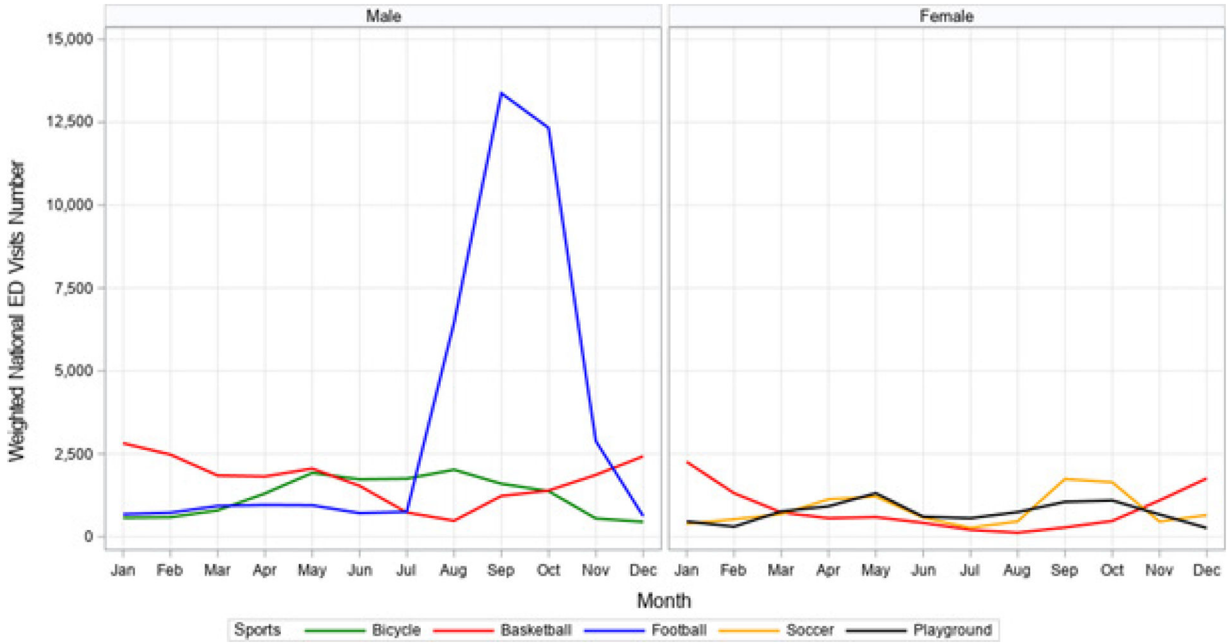

Figure 5.

Average monthly number of top three causes of sports- and recreation-related head injury emergency department (ED) visits in age 5–17 years by sex, National Electronic Injury Surveillance System-All Injury Program, 2016–2019, USA.