Contents lists available at ScienceDirect

Journal of the Pediatric Orthopaedic Society of North America



Original Research

Patellar Instability Events Requiring Emergency Department Management — A 20-year Analysis



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ARTICLE INFO

Keywords: Patellofemoral instability Patellar dislocation Pediatric knee injury Emergency department

ABSTRACT

Background: Patellofemoral instability (PFI) is a common pediatric knee injury most prevalent among females in late adolescence. This study's purpose was to use a nationally representative database to examine epidemiologic trends in pediatric PFI events requiring management in emergency departments (ED).

Methods: The National Electronic Injury Surveillance System (NEISS) was queried from 2001 to 2020 for cases of knee "dislocation" or "fracture" in patients aged 0–18 years. Case narratives were used to confirm episodes of patellar instability. National estimates were calculated. Seasonal and temporal patterns of injury were assessed overall and within demographic subgroups using bivariate and multivariate analysis.

Results: Study criteria identified an estimated 208,673 cases of patellar instability presenting to United States EDs between 2001 and 2020. The mean annual frequency of injury was 10,434, with time series analysis estimating an increase of 256 dislocations per year (P < 0.001) over the study period. Seasonal injury peaks occurred during the Spring (April–May) and Fall (September–October) months. Males accounted for the majority (59%) of injured patients, and patients aged 15–18 were the most frequently injured age group (48%). A generalized linear model demonstrated that males had a higher rate of dislocations prompting ED management than females and patients aged 10–14 saw a slight increase in the rate of dislocations compared to patients aged 15–18 (P < 0.001). Seasonal variation in injuries was most evident among males and adolescents.

Conclusions: Findings from this study suggest a rising overall frequency of pediatric PFI injuries presenting to the ED. Statistically significant seasonal injury patterns were observed that appeared driven by male adolescent injury. This study highlights novel epidemiologic patterns and improves our understanding of patellar instability events requiring management in the ED.

Key Concepts:

- (1) Temporal trends found a significant rise in the annual number of patellar dislocations requiring an emergent evaluation driven by increases during the Spring and Fall.
- (2) Seasonal trends were likely driven by an increase in sports participation during the fall and Spring months.
- (3) Despite patellofemoral instability being more common in females, males were more likely to seek an evaluation at the emergency department after a patellar dislocation.
- (4) Although both males and females saw an increase in patellar dislocations over the course of this study, males and patients aged 10–18 demonstrated a higher rate and increase of dislocations.

Level of Evidence: Level IV - Retrospective Case Series

https://doi.org/10.1016/j.jposna.2024.100152

Received 13 August 2024; Received in revised form 13 December 2024; Accepted 15 December 2024

Available online 21 December 2024



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Introduction

Acute and recurrent patellofemoral instability (PFI) is a common condition impacting children and adolescents that can carry significant negative impact on patients' day-to-day lives [8]. Current literature estimates the rate of patellar dislocations ranges from 2.29 to 77.4 per 100, 000 people [3,4,6,7,9–14]. Recent work among patients requiring hospitalization and surgical treatment has indicated that presentations for instability and intervention among pediatric patients has increased, but it remains unclear if this is due to an increased rate of injury or earlier interventions [1,2]. Adolescents see the highest rate of patellar instability during a timeframe that coincides with higher rates of youth sports-related injuries [5,15–17]. Therefore, increasing sports participation over recent decades among this age cohort may be related to these epidemiologic changes.

While most epidemiologic literature has identified late adolescent females to have the highest reported risk for PFI with estimated incidence as high as 100 to 150 per 100,000, some studies report similar rates between sexes [4,9,13,14]. Sex-based anatomic differences, including greater ligamentous laxity and increased Q-angle due to pelvic width and limb alignment are thought to explain some of the differences in injury rates between sexes. However, sports participation is also frequently cited as a risk factor for instability, with many primary instability events occurring during sport participation [4,10,18,19]. A study by Mitchell et al. found that high school athletes had an injury rate of 1.95 per 100, 000 athletic exposures (AE) over a 6-year period [5]. Although the overall injury rate was lower within the female cohort, sex-comparable sports showed higher rates of injury among females.

Previous studies have used national databases to estimate the incidence of PFI, and recent surveys of a national administrative database have shown an increase in the admission and treatment rate of PFI [1,2, 20]. Most of the existing epidemiologic work on PFI is derived from data before the most recent decade and does not specifically explore child and adolescent instability or relies on smaller, single-center cohorts [1,4,5,9, 13,21]. Recently, Lyon's et al. published an epidemiological study on patellofemoral instability using the National Electronic Injury Surveillance System (NEISS) database that focused on PFI in all age groups [22]. This study aimed to use NEISS to examine patterns of pediatric PFI injury in greater detail, detailing the demographics, injury characteristics, annual patterns, and seasonal variation of pediatric patellar instability events requiring ED management over the last two decades. We hypothesized that PFI events requiring management in the emergency department (ED) have been increasing over recent decades, as well as that the Fall and Spring months will demonstrate a higher incidence coinciding with higher rates of sports participation among student athletes.

Materials and methods

Patient identification

NEISS is a database capturing injury data from a nationally representative sample of emergency rooms across the United States. It catalogs injuries presenting to a representative sample of US EDs NEISS that was queried from 2001 to 2020 for cases of knee dislocation or fracture in patients aged 0–18 years using dislocation (55) and fracture (57) diagnosis codes and knee (35) body part code. Case narratives were screened to identify episodes of patellar subluxation or dislocation with or without associated fracture. Cases with the fracture diagnosis code were excluded if their narrative did not mention concurrent patellar instability. Additionally, cases of tibiofemoral dislocations were excluded.

Data collection

Patient age at the time of injury and case disposition were identified using native NEISS database variables. "Case disposition" recorded

patient admission to the hospital for further treatment after their ED visit or release to return home. NEISS narratives, which include a "one liner" description (e.g. "11-year-old male jumping on a trampoline when another child's head hit his knee: patellar D/L") of the mechanism and type of injuries were then screened to assure cases met study criteria and to categorize the mechanism of injury. A random sampling of 100 cases was completed by two authors to ensure interrater reliability across case narrative categorization was measured at Cohen's Alpha of >0.9 prior to completion of screening the remainder of the cases. Injury characteristics included the descriptive mechanism of injury (direct blow, fall, running, walking, twisting/turning, jumping, other and not stated), contact status (contact or noncontact mechanism), and the patient's activity level at the time of injury (active or resting) were extracted and categorized. Seasonality was categorized based on the treatment date of the emergency visit. Spring was defined as March 1 to May 31, Summer from June 1 to August 31, Autumn from September 1 to November 30, and Winter from December 1 to February 28.

Data analysis

The cohort was summarized using descriptive statistics on patient demographics and injury characteristics and treatment. Patient age was categorized as preschool aged (<5 years), childhood (5–9), early

Table 1.

| Demographics and | injury | characteristics | of study | cohort. |
|------------------|--------|-----------------|----------|---------|
| | | | | |

| Patient and injury characteristics | Cases, | National | % | 95% CI | |
|---------------------------------------|--------|----------------------------------|------|--------|--------|
| | n | estimates <i>n</i> , (95% CI) | | Lower | Upper |
| Age | 6721 | 208674 | 100% | 165224 | 252122 |
| <5 | 172 | 5371 | 3% | 4080 | 6661 |
| 5 to 9 | 433 | 12479 | 6% | 9647 | 15310 |
| 10 to 14 | 3211 | 99610 | 48% | 78341 | 120879 |
| 15 to 18 | 2905 | 91214 | 44% | 71493 | 110935 |
| Sex | | | | | |
| Male | 4016 | 123266 | 59% | 97206 | 149326 |
| Female | 2705 | 85407 | 41% | 67550 | 103265 |
| Mechanism | | | | | |
| Fall | 1606 | 46527 | 22% | 35393 | 57660 |
| Twisting/turning | 831 | 28587 | 14% | 19139 | 38034 |
| Direct blow | 595 | 18190 | 9% | 14445 | 21935 |
| Jumping | 436 | 12737 | 6% | 8897 | 16577 |
| Running | 136 | 4151 | 2% | 2788 | 5513 |
| Walking | 60 | 2048 | 1% | 1181 | 2914 |
| Other | 887 | 27409 | 13% | 21176 | 33641 |
| Not stated | 2170 | 69025 | 33% | 54577 | 83474 |
| Contact status | | | | | |
| Noncontact injury | 4180 | 159970 | 62% | 98338 | 159970 |
| Contact injury | 776 | 23704 | 11% | 18538 | 28871 |
| Not stated | 1765 | 55814 | 27% | 43720 | 67909 |
| Activity status | | | | | |
| Active | 6050 | 189029 | 91% | 149580 | 228479 |
| Resting | 467 | 14009 | 7% | 10471 | 17546 |
| Not stated | 204 | 5635 | 3% | 4121 | 7149 |
| *Case disposition | | | | | |
| Released | 6420 | 199570 | 96% | 158216 | 240891 |
| Hospitalized/ observed | 301 | 9104 | 4% | 6565 | 11643 |

adolescence (10–14), and late adolescence (15–18) for statistical analyses. The NEISS database consists of survey data and includes sample weights and stratum, which enable us to estimate the cohort's demographics, injury characteristics, treatment, and prevalence on a national level using the R package "srvyr." [23] National trends in monthly and annual frequency were assessed based on patient age and sex. Bivariate analysis was performed to compare injury patterns based on patient demographics. Time series analysis was then conducted on the entire cohort and demographic subgroups, analyzing trend, and seasonality. A Mann-Kendall test was used to test the presence of monthly and yearly trends. Finally, a generalized linear model was used to estimate the effects of age group, sex, and season on the frequency of dislocations by month. All statistical analyses were done using R and SAS statistical software.

Results

NEISS coding identified 11,962 cases, which were screened to 6721 meeting study criteria and included in the study analyses. Of the 6721 cases that met inclusion criteria, 100 were reviewed by 2 raters (KH and NH) for mechanism of injury, contact status, and activity level, which found a Cohen's Alpha of >0.9 (P < 0.01) for interrater reliability. Using the weights and strata from the NEISS survey data, the included cases represented an estimated 208,674 PFI injuries (95% CI 165224-252122) seen nationally in EDs over the 20-year study periods. Overall, the majority of injuries occurred in males (59%) and within the early (48%) and late adolescent (44%) age groups. Of identified injury mechanisms, falls (22%) and twisting/turning (14%) were the most prevalent. Nearly twothirds of injuries were noncontact in nature, and the vast majority (91%) occurred while the patient was active. Most patients (94%) were released without observation or hospitalization (Table 1). Bivariate analysis demonstrated no differences in injury mechanism based on age group or sex (P > 0.05). The generalized linear model demonstrated that males had significantly more dislocations compared to females (P < 0.001) after controlling for age group and seasons. Additionally, patients aged 10-14 demonstrated a large increase in the rate of dislocations compared to patients aged <5 and 5-9, and a slight increase compared to patients aged 15–18 (*P* < 0.001, Fig. 1).

Times-series analysis revealed a significant rise in the annual number of injuries, estimating an increase of around 256 dislocations per year (95% CI 194–318, P < 0.001, Fig. 2). A Mann-Kendall test confirmed a significant increasing trend in dislocations over the period of this study (P < 0.001). The annual injury frequency increased among both male and female patients (Fig. 3). Seasonally, there were observable peaks in injury frequency during the Spring and Fall. A generalized linear model estimated that both Fall (P < 0.001), and Spring (P = 0.02) saw significantly more dislocations per month on an average compared to the Summer. There were no significant differences between the frequency of dislocations between the Summer and Winter. This seasonal variation was most prominent among males and among the adolescent age groups (Figs. 4 and 5).

Discussion

Recent research has found an increase in the incidence of patellar instability events requiring hospitalization and surgical treatment among pediatric patients; however, the question remains whether the increase is due to an increased rate of injury or earlier interventions [12,13]. The present study sought to evaluate if there has been an increase in the incidence of pediatric patellar instability requiring emergent evaluation and management using a nationally representative sample over the last two decades, and whether the Fall and Spring months, seasons when there are high levels of sports participation among students, coincided with a higher frequency of injuries. By utilizing the NEISS database, our study provides a unique perspective on the longitudinal incidence of patellar instability events requiring emergent treatment in the United States. We observed a rising frequency of patellar instability episodes presenting to EDs in the US over a 20-year period with the greatest concentration of injuries occurring during the Spring and Fall seasons. Additionally, sex-specific injury patterns in our study differed from those described in previous epidemiologic work with emergently evaluated injuries more commonly occurring among adolescent males [3-7]. This discordant finding may be the result of ED sampling capturing acute dislocations and those with associated osteochondral injury that warrant concerns for a more immediate evaluation and management. Together,



Figure 1. Monthly trend of estimated number of patellar dislocations presenting for management in United States Emergency Departments (2001-2020).



Figure 2. Estimated number of dislocations per year stratified by sex.



Figure 3. Estimated number of dislocations per month stratified by sex.

our findings support prior work indicating a rising incidence of pediatric PFI and highlight seasonal sport participation and specific demographic characteristics as potential drivers of these recent epidemiologic changes [12,13].

Our findings identified a statistically significant increase in the frequency of pediatric PFI over the two-decade study period with an estimated annual increase of 256 dislocations per year during this time, predominantly driven by an increase in injuries in patients aged 10–18. This observation is corroborated by Lyon's et al.'s finding of a statistically significant increase in dislocations annually in patients' aged 10–19 over a similar period [22] and coincides with rising rates of other ligamentous injuries often attributed to increased youth sports participation [24–27]. On a seasonal level, the changes observed in our study were driven by spikes in injury frequency during the Spring (April–May) and Fall (September and October), which is also consistent with prior literature reporting an increased risk for ligamentous injury during sports activity and the early stages of the sports season [5,28–30]. Notably, both sexes demonstrated increasing injury frequency over the study period annually, but seasonal changes appeared predominantly driven by the adolescent male cohort.

One of the unique aspects of the present study is the utilization of a national database of injuries treated in the ED stratified by pediatric age groups to account for varying childhood development factors. By focusing on only injuries requiring emergent treatment, we highlight trends specifically among instability events that are likely acute dislocations, higher-impact injuries, or those with associated osteochondral injury. Patients experiencing recurrent instability associated with common risk factors such as trochlear dysplasia, patella alta, or ligamentous



Figure 4. Estimated number of dislocations per year stratified by age group.



Figure 5. Estimated number of dislocations per month stratified by age group.

laxity may become accustomed to the dislocation events and comfortable managing independently or in an outpatient setting. This may explain the demographic patterns observed in our study that differ from the established epidemiology of patellar instability occurring more commonly adolescent females. Sex-based differences in overall participation in sports may also contribute, as suggested by Mitchell et al.'s work among high school athletes. The authors observed that while the prevalence of PFI in sex-comparable sports (i.e. sports that both sexes participate in such as soccer, baseball/softball, lacrosse, etc.) was higher in females, the overall prevalence of injury remained higher in males. Previous literature has demonstrated that higher-intensity sports and high impact activities are associated with ligamentous injury and increased risks of patellar instability [29–33]. The mechanisms of injury in this study indicated a close association with physical activity with twisting, direct collision, jumping, and running accounting for 31% of the injuries. These mechanisms strongly suggest sports participation or other forms of physical activity, which is supported by the fact that 91% of injuries occurred, while the patients were active. Falling was identified as the most common mechanism of injury, which may also be related to sports participation or high-impact collisions. When accounting for both age and sex, males and patients aged 10–18 demonstrated a higher rate of dislocations. Therefore, despite female sex being commonly cited as a risk factor for PFI, our results indicate that early- and late-adolescent male patients are most likely to require emergent treatment for PFI episodes [9,16,34,35]. Lyon et al. also found that patellar dislocations requiring ED treatment were majorly male [22]. Mitchell et al. noted that male-dominated sports are also more closely associated with higher-impact activities, such as football, that increase the risk of a dislocation [5]. Higher-impact activities correlate with contact injuries, which were responsible for nearly double the injuries compared to noncontact. Contact injuries were more common among male athletes. Conversely, noncontact injuries were more common among female athletes [5]. These discrepancies might be explained by higher male participation in high impact, contact sports but further research is necessary.

Findings from this study indicate that patients aged 10 years and older account for most of the PFI events presenting to the ED. Both the 10–14-year-old and 15–18-year-old age groups demonstrated similar temporal trends. The gradual rise in injuries over the study period appeared driven in part by frequency spikes during the Spring and Fall months. Current literature among pediatric cohorts generally reports that first-time dislocation is most common in patients aged 10–16, with the highest incidence occurring at 15-year-olds [4,10,15,16]. These age groups also have the highest rate of sports participation. Together, these findings appear to support the theory that sports-related, acute dislocations in adolescents may be the primary driver of recently observed epidemiologic frequency trends.

This study has several key limitations that are typical for a large, nationally representative database. NEISS only documents cases that present to the emergency room, which may lead to a bias toward acute and highenergy dislocators and away from those with chronic, recurrent instability resulting from low-energy events. As a result, our cohort demographics were different than those typically observed in PFI populations and may have been weighed more toward those with anatomically normal knees requiring greater force to sustain dislocation. However, we feel this more appropriately captures clinically significant single episodes with the greatest likelihood of ultimately requiring operative management. Additionally, NEISS only codes for knee dislocations without a differentiation between subluxations and dislocations, but we believe it is unlikely for subluxations to require ED management. It also avoids lumping subluxation-type episodes of instability with true dislocation as this distinction has clear implications on clinical decision-making. Diagnostic granularity within NEISS is limited, and distinction of associated injuries such as loose bodies is not always available. NEISS also does not capture treatment or follow-up patient data, preventing analysis of required interventions or time away from sports. Finally, inconsistent case data on injury mechanism and lack of granularity for activity data at the time of injury limit our evaluation of these factors on the PFI events in this study.

Our analysis of pediatric PFI using the NEISS database identifies distinct demographic and temporal patterns unique from prior studies. These findings help to contextualize the epidemiologic evolution of this injury pattern in recent decades. Early and late adolescent males appear to account for the increasing frequency of pediatric patellar instability with injury mechanism and seasonality suggesting sports participation as a key factor in these changes. Further research should seek to better understand the evolving patterns of pediatric sport-related PFI to identify avenues for potential preventative intervention.

Consent for publication

The author(s) declare that no patient consent was necessary as no images or identifying information are included in the article.

Author contributions

David Kell: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Nathan Houlihan:** Writing review & editing, Writing – original draft, Methodology, Investigation,
Formal analysis, Conceptualization. Kevin Huang: Writing – review &
editing, Writing – original draft, Methodology, Investigation, Formal
analysis, Data curation, Conceptualization. Sulagna Sarkar: Writing –
review & editing, Writing – original draft, Methodology. John
Schlechter: Writing – review & editing, Writing – original draft,
Conceptualization. Brendan A. Williams: Writing – review & editing,
Writing – original draft, Methodology, Investigation, Formal analysis,
Data curation, Conceptualization.

Funding

This research study received no direct funding.

Declaration of competing interests

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.

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