

Epidemiological Patterns of Patellofemoral Injuries in Collegiate Athletes in the United States From 2009 to 2014

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Background: As many as 30% of patients with knee pain seen in sports medicine clinics have complaints related to the patellofemoral joint. There is a paucity of research available regarding patellofemoral injuries, mechanism of injury, and playing time lost in collegiate athletes.

Purpose: To describe the rates, mechanisms, severity, and potential sex-based differences of patellofemoral injuries in collegiate athletes across 25 National Collegiate Athletic Association (NCAA) sports.

Study Design: Descriptive epidemiology study.

Methods: Data from the 2009-2010 through the 2013-2014 academic years were obtained from the NCAA Injury Surveillance Program and were analyzed to calculate patellofemoral injury rates, mechanisms of injury, time lost, and need for surgery. Rate ratios and injury proportion ratios were used to quantify discernible differences between sex-comparable sports and timing of injury (ie, practice vs competition), respectively.

Results: The overall patellofemoral injury incidence rate was 16.10 per 100,000 athlete-exposures (AEs). Women's volleyball had the highest incidence of all sports (39.57 per 100,000 AEs). Injuries were 66% more likely to occur in competition than during practice. Female athletes experienced significantly more patellofemoral injuries than males in similar sports. Patellar tendinitis accounted for 49.2% of all patellofemoral injuries and was the most common injury in 20 of 25 studied sports. Patellar subluxation accounted for the most total days missed, and patellar dislocation had the highest mean days missed per injury (11.42 days). Patella fracture was the most likely injury to require surgery (80%).

Conclusion: Patellofemoral injuries were most common in sports that require jumping and quick changes of direction, specifically women's volleyball, men's and women's basketball, and women's soccer. The majority of patellofemoral injuries in this cohort were classified as patellar tendinitis caused by overuse. Most injuries resulted in no competition or practice time lost. This information may contribute to the development of prevention programs aimed at addressing the most prevalent types and mechanisms of injury in each sport to reduce the incidence of patellofemoral injury in these athletes.

Keywords: patellofemoral injuries; collegiate; athlete; epidemiology

Patellofemoral injuries are relatively common, comprising up to 30% of knee injuries seen in sports medicine clinics.^{3,8,18,21,23} These injuries are typically associated with jumping, cutting, and pivoting activities that eccentrically load the patella, resulting in conditions ranging from contusions, tendinopathy, and instability to avulsion injuries and tendon ruptures.^{14,15,18,23,25} The prevalence of patellar tendinopathy in nonelite athletes ranges from 11.8% to 14.4%.^{3,8,18,21} Furthermore, up to 53% of athletes cite chronic anterior knee pain as a contributing factor in the decision to quit their sport.^{3,12,20} Patellar or patellar tendon injuries have been reported to account for 29.5% of

all knee injuries in high school athletes, with a lower prevalence than medial collateral ligament (36.1%) and a higher prevalence than anterior cruciate ligament (25.4%) and meniscal (23.0%) injuries.²³ Patellofemoral injury accounts for 10.1% of all injuries in professional basketball players and 10.2% of all knee injuries in professional baseball players.^{1,4}

Despite some epidemiological research regarding patellofemoral injuries, much of the cited data refer to patellar tendinopathy in general and do not differentiate between specific types of patellofemoral injuries (eg, patellar subluxation, tendinitis, fracture). Furthermore, these studies have included relatively little comparison based on sport, sex, or mechanism of injury.^{3,5,14,21} A better understanding of the incidence of these injuries will allow physicians, coaches, and athletic trainers to be more aware of which

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athletes are at highest risk for specific injuries and to develop more effective prevention strategies. The purpose of this study was to report the incidence and mechanisms of specific patellofemoral injuries in National Collegiate Athletic Association (NCAA) athletes in 25 sports between the 2009-2010 and 2013-2014 academic years.

METHODS

The NCAA Research Review Board approved the study proposal, and an institutional review board determined that the use of the deidentified database did not constitute human participants research and was exempt. The data were subsequently obtained from the Datalys Center for Sports Injury Research and Prevention Inc, a nonprofit research organization that compiles and manages the NCAA Injury Surveillance Program (ISP). The collection methods are described briefly below; however, a more complete description has been published previously.¹⁰

Data Collection

Participating institutions encompassed all collegiate sporting levels (NCAA Divisions I-III), with voluntary representation from a variety of collegiate varsity sports teams. The proportion of reported data by each NCAA institution varied by sport, with some sports reporting as low as 0.66% participation (5 men's tennis teams out of 760 total). This is largely due to the method of reporting, which involved active participation on the part of the team's athletic trainer (ATC) to report injury data to the Datalys Center, by way of either a Datalys Center in-house injury surveillance tool or the school's own electronic health recording system. For each injury event, the ATC completed a standardized reporting document that was intended to fully describe the injury and exposure. Collected variables included event type (competition vs practice), body part, mechanism of injury, and number of athletes participating in the event. A preset list of options was available for selection regarding the mechanism of injury: player contact, surface contact, equipment contact, contact with out-of-bounds object (eg, wall or fence), no apparent contact (eg, rotation about a planted foot), overuse, and other/unknown. Further documentation by the ATC included logging time lost from competition and whether the athlete's injury required surgery. A physician was not required to confirm injury diagnoses.

After the reporting period, the data were deidentified and transferred to an aggregate database hosting all national data, ensuring that no personal information remained for any of the student-athletes. Multiple human and automated verification processes were used to ensure consistent data and exclusion of invalid values. For this particular study, all of the sport-specific data sets were sampled to determine the rates of patellofemoral injuries among all sports represented in the NCAA ISP database.

Definitions

A reportable injury was defined as any injury that both occurred as a result of participation in an organized intercollegiate practice or competition and required attention from a physician or ATC. A reportable athlete-exposure (AE) was defined as 1 student-athlete participating in 1 NCAA-sanctioned practice or competition in which he or she was exposed to the possibility of athletic injury, regardless of the time associated with that participation. This included only preseason, regular season, and postseason practices and competitions, excluding summer and individual workouts.

Statistical Analysis

All data were analyzed by use of Microsoft Excel 2016 software. The analysis included calculation of the overall incidence rate (IR) of patellofemoral injuries, the IR of patellofemoral injury in each sport in both practice and competition, and the types of injuries sustained in each sport. Rates were calculated as a ratio of injuries per 100,000 AEs. Rate ratios (RRs) were used to evaluate potential sex-related differences in the incidence of patellofemoral injuries overall and in comparable sports. All RRs are presented as the ratio of male IR to female IR. Injury proportion ratios (IPRs) were calculated to quantify the differences in patellofemoral injury rates between exposure type (ie, practice or competition). All IPRs are presented as the competition IR divided by the practice IR. Statistical significance was assessed by use of 95% CIs, with any CI not containing the value 1.00 deemed significant. Descriptive statistics were used to identify trends in the mechanisms of injury, time lost from competition, and need for surgery across sport and sex. The Fisher's exact test was used to compare injury severity and surgical intervention between the sexes (GraphPad Software).

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Ethical approval for this study was waived by the Tulane University Biomedical Institutional Review Board.

RESULTS

Between 2009 and 2014, a total of 602 patellofemoral injuries were reported during 3,739,004 AEs in 25 sports (Table 1). The overall patellofemoral IR was 16.10 per 100,000 AEs (95% CI, 14.81-17.39). Women's volleyball had the highest overall IR of all sports (39.57 per 100,000 AEs), followed by men's basketball (28.27) and women's soccer (25.96). Men's football was responsible for the most patellofemoral injuries of any sport, accounting for 141 of the 602 total injuries (23.4%). Practice injuries accounted for 72.6% of all injuries; however, the overall competition IR was significantly greater than the practice IR (IPR, 1.66; 95% CI, 1.39-1.98). This trend was seen exclusively in men's sports. Men were 2.38 times (95% CI, 1.88-3.00) more likely to sustain an injury during competition than during practice. Women experienced an essentially identical IR in competitions and practices (IPR, 1.00; 95% CI, 0.75-1.33). Of the 602 patellofemoral injuries, 525 (87.2%) were assessed by an ATC, 75 (12.5%) were assessed by a physician, 1 (0.2%) was assessed by a physician assistant, and data were not provided in this field for 1 (0.2%) injury.

Sex

Men's sports had an overall IR of 14.15 per 100,000 AEs, compared with 19.35 per 100,000 AEs in all women's sports (RR, 0.73; 95% CI, 0.62-0.86). Comparison of IR across similar sports yielded somewhat differing results (Table 2). Women's lacrosse and soccer players were significantly more likely to sustain a patellofemoral injury during practice than their male counterparts (lacrosse: RR, 0.32; 95% CI, 0.13-0.79; soccer: RR, 0.53; 95% CI, 0.29-0.96). Additionally, men's basketball players were significantly more likely to experience a patellofemoral injury during a competition than women's basketball players (RR, 2.41; 95% CI, 1.11-5.24). Women's soccer players were more likely overall to experience an injury compared with their male counterparts (RR, 0.51; 95% CI, 0.31-0.84). Furthermore, when all comparable sports were collated by sex, female athletes were significantly more likely to sustain patellofemoral injuries during practice as well as overall (practice: RR, 0.70; 95% CI, 0.55-0.89; overall: RR, 0.77; 95% CI, 0.63-0.95).

Injury Type

Among all sports, patellar tendinitis accounted for 296 of the 602 (49.2%) reported patellofemoral injuries (Table 3). Patellar subluxation ($n = 91$; 15.1%), patellofemoral pain syndrome (PFPS) ($n = 77$; 12.8%), and prepatellar bursitis ($n = 49$; 8.1%) were the next most common injury types. Patellar tendinitis was the most common injury in 20 of the 25 studied sports. Furthermore, tendinitis accounted for 100% of patellofemoral injuries in women's outdoor track, 85.7% of patellofemoral injuries in men's swimming, and 83.3% of patellofemoral injuries in men's outdoor track. PFPS was the most prevalent injury in women's field hockey, women's lacrosse, and women's softball, accounting for 50.0%, 29.4%, and 29.4% of injuries, respectively. Patellar subluxation was the most common injury in men's ice

hockey players, representing 33.3% of injuries. Finally, prepatellar bursitis was the most common injury reported among male wrestlers (30.8%).

Mechanism of Injury

Of the 602 documented patellofemoral injuries, the majority were classified as overuse/gradual (41.9%) or were caused by no apparent contact (30.6%) (Table 4). The remaining injuries were caused by contact (22.9%) or unknown (3.3%) or other (1.3%) mechanisms. Men's football accounted for the most injuries caused by no apparent contact ($n = 49$) and contact ($n = 54$). Women's volleyball accounted for the highest number of overuse/gradual injuries ($n = 41$), and women's indoor track had the most injuries caused by other mechanisms ($n = 3$). Women's outdoor track had the largest percentage of injuries caused by no apparent contact (5/9, 55.6%). Men's wrestling had the highest percentage of injuries caused by contact (10/13, 76.9%), and 100% (9/9) of the patellofemoral injuries in men's cross-country were classified as overuse/gradual.

When data were stratified by injury type, the mechanism of no apparent contact was the leading cause of patellar tendon strain (25/44, 62.5%), patellar subluxation (40/91, 44.0%), patellar dislocation (8/19, 42.1%), and patella fracture (2/5, 40.0%) (Table 4). An overuse/gradual mechanism was the main cause of PFPS (52/77, 67.5%), patellar tendinitis (188/296, 63.5%), and patellar osteoarthritis (3/6, 50.0%). Additionally, the majority of prepatellar bursitis (28/49, 57.1%) and infrapatellar bursitis (10/19, 52.6%) injuries were caused by contact with the playing surface.

Time Loss and Surgical Treatment

From 2009 to 2014, patellofemoral injuries resulted in 1719 days of practice or game-related time lost (TL) from sport among participating athletic programs. The majority ($n = 395$, 65.6%) of recorded patellofemoral injuries resulted in less than 24 hours of TL (Figure 1). The mean TL for all injuries was 3.06 days. Among injuries that resulted in more than 24 hours of TL, the mean TL was 10.32 days. Furthermore, 126 (20.9%) injuries resulted in 1 to 13 days of TL and were categorized as not severe. Severe injuries (≥ 14 days TL) accounted for 6.5% of all injuries, and 42 injuries (7.0%) resulted in an unknown amount of TL. Of note, 28 of the 42 (66.7%) unknown injuries resulted in the athlete's missing the remainder of the season, although it was not possible to determine how much time remained in the season at the time of injury.

Over the 5-year study period, patellar subluxation (648 days), tendinitis (482 days), and dislocation (217 days) were responsible for the most total TL for all athletes. Patellar dislocation resulted in the highest mean TL per injury (11.42 days/injury), followed by patellar subluxation (7.12 days/injury) (Figure 2). Twenty-five of 331 (7.6%) patellofemoral injuries in men's sports were severe, compared with 14 of 271 (5.2%) injuries in women's sports ($P = .25$). As a percentage of each sport's total number of injuries, women's outdoor track (22.2%), men's tennis (16.7%), and men's indoor track (15.0%) had the highest percentage

TABLE 1
Total Patellofemoral Injury Rates by Sport, 2009-2010 to 2013-2014^a

Sport	Patellofemoral Injuries, n			Injury Rate per 100,000 AEs (95% CI)			IPR (95% CI)
	Overall	Competition	Practice	Overall	Competition	Practice	
W volleyball	62	11	51	39.57 (29.72 to 49.41)	24.34 (9.96 to 38.73)	45.73 (33.18 to 58.29)	0.53 (0.28 to 1.02)
M basketball	61	22	39	28.27 (21.17 to 35.36)	47.37 (27.58 to 67.17)	23.03 (15.80 to 30.26)	2.06 (1.22 to 3.47) ^b
W soccer	56	19	37	25.96 (19.16 to 32.75)	36.44 (20.05 to 52.82)	22.62 (15.33 to 29.90)	1.61 (0.93 to 2.80)
W basketball	48	9	39	24.63 (17.66 to 31.60)	19.64 (6.81 to 32.48)	26.17 (17.95 to 34.38)	0.75 (0.36 to 1.55)
M tennis	6	0	6	23.38 (4.67 to 42.09)	0.00	29.75 (5.95 to 53.56)	0.00
W cross-country	10	0	10	22.47 (8.54 to 36.40)	0.00	24.62 (9.36 to 39.87)	0.00
W field hockey	8	1	7	21.46 (6.59 to 36.33)	11.09 (-10.65 to 32.83)	24.77 (6.42 to 43.12)	0.45 (0.06 to 3.64)
M cross-country	9	0	9	19.45 (6.74 to 32.17)	0.00	21.31 (7.39 to 35.23)	0.00
M indoor track	20	0	20	18.51 (10.40 to 26.62)	0.00	20.44 (11.48 to 29.39)	0.00
M wrestling	13	4	9	16.51 (7.54 to 25.49)	48.22 (0.96 to 95.48)	12.78 (4.43 to 21.13)	3.77 (1.16 to 12.25) ^b
W lacrosse	17	3	14	16.11 (8.45 to 23.76)	14.53 (-1.91 to 30.97)	16.49 (7.85 to 25.13)	0.88 (0.25 to 3.07)
M football	141	45	96	15.68 (13.09 to 18.27)	51.65 (36.56 to 66.75)	11.82 (9.46 to 14.19)	4.37 (3.07 to 6.23) ^b
W indoor track	14	2	12	13.79 (6.57 to 21.02)	21.61 (-8.34 to 51.56)	13.01 (5.65 to 20.37)	1.66 (0.37 to 7.42)
W gymnastics	6	0	6	13.24 (2.65 to 23.83)	0.00	14.57 (2.91 to 26.23)	0.00
M soccer	21	6	15	13.15 (7.53 to 18.78)	17.63 (3.52 to 31.73)	11.94 (5.90 to 17.98)	1.48 (0.57 to 3.81)
W outdoor track	9	3	6	12.66 (4.39 to 20.93)	24.46 (-3.22 to 52.14)	10.20 (2.04 to 18.35)	2.40 (0.60 to 9.59)
W ice hockey	12	5	7	10.60 (4.60 to 16.60)	16.77 (2.07 to 31.47)	8.40 (2.18 to 14.62)	2.00 (0.63 to 6.29)
W softball	17	7	10	10.53 (5.52 to 15.54)	10.90 (2.83 to 18.98)	10.29 (3.91 to 16.66)	1.06 (0.40 to 2.78)
W tennis	3	1	2	9.48 (-1.25 to 20.21)	12.78 (-12.27 to 37.83)	8.40 (-3.24 to 20.03)	1.52 (0.14 to 16.79)
M lacrosse	15	8	7	9.35 (4.62 to 14.08)	29.80 (9.15 to 50.46)	5.24 (1.36 to 9.12)	5.69 (2.06 to 15.69)
W swimming	9	0	9	7.39 (2.56 to 12.22)	0.00	8.14 (2.82 to 13.46)	0.00
M swimming	7	0	7	7.23 (1.87 to 12.59)	0.00	7.91 (2.05 to 13.76)	0.00
M ice hockey	20	12	8	7.06 (3.97 to 10.16)	17.56 (7.62 to 27.49)	3.72 (1.14 to 6.31)	4.71 (1.93 to 11.53) ^b
M outdoor track	6	0	6	6.93 (1.38 to 12.47)	0.00	8.08 (1.61 to 14.54)	0.00
M baseball	12	7	5	6.74 (2.93 to 10.56)	10.53 (2.73 to 18.33)	4.48 (0.55 to 8.42)	2.35 (0.75 to 7.4)
All W sports	271	61	210	19.35 (17.05 to 21.65)	19.34 (14.49 to 24.19)	19.35 (16.73 to 21.97)	1.00 (0.75 to 1.33)
All M sports	331	104	227	14.15 (12.63 to 15.68)	27.52 (22.23 to 32.81)	11.58 (10.07 to 13.08)	2.38 (1.88 to 3.00) ^b
Total	602	165	437	16.10 (14.81 to 17.39)	23.80 (20.17 to 27.43)	14.35 (13.00 to 15.69)	1.66 (1.39 to 1.98) ^b

^aSorted in descending order according to overall injury rate. AE, athlete-exposure; IPR, injury proportion ratio; M, men's; W, women's.

^bStatistically significant difference between competition and practice injury rates ($P < .05$).

TABLE 2
Patellofemoral Injury Rate Ratios for Comparable Men's and Women's Sports

Sport	Rate Ratio, Male to Female (95% CI)		
	Overall	Competition	Practice
Baseball/softball	0.64 (0.31-1.34)	0.97 (0.34-2.75)	0.44 (0.15-1.28)
Basketball	1.15 (0.79-1.68)	2.41 (1.11-5.24) ^a	0.88 (0.57-1.37)
Cross-country	0.87 (0.35-2.13)	—	0.87 (0.35-2.13)
Ice hockey	0.67 (0.33-1.36)	1.05 (0.37-2.97)	0.44 (0.16-1.22)
Lacrosse	0.58 (0.29-1.16)	2.05 (0.54-7.73)	0.32 (0.13-0.79) ^a
Soccer	0.51 (0.31-0.84) ^a	0.48 (0.19-1.21)	0.53 (0.29-0.96) ^a
Swimming	0.98 (0.36-2.63)	—	0.97 (0.36-2.61)
Tennis	2.47 (0.62-9.86)	0.00	3.54 (0.72-17.56)
Track and field: indoor	1.34 (0.68-2.66)	0.00	1.57 (0.77-3.21)
Track and field: outdoor	0.55 (0.20-1.54)	0.00	0.79 (0.26-2.46)
All comparable sports	0.77 (0.63-0.95) ^a	1.02 (0.70-1.50)	0.70 (0.55-0.89) ^a

^aStatistically significant difference between males and females ($P < .05$). —, the women's sport in these rows had 0 competition injuries and therefore a rate ratio could not be calculated.

of injuries that resulted in ≥ 14 days of TL. Men's football ($n = 16$), women's volleyball ($n = 5$), and women's soccer ($n = 4$) players sustained the highest absolute number of severe injuries. By injury type, patellar subluxation ($n = 18$), patellar tendinitis ($n = 10$), and patellar dislocation ($n = 6$) resulted in the highest absolute number of severe injuries. Furthermore, dislocations (31.6%) were the most likely injury to result in ≥ 14 days of TL, followed by patellar subluxation (19.8%) and patellar tendon strain (7.5%).

Of the 602 patellofemoral injuries reported across the 25 sports, 26 (4.3%) required surgery. Injuries were most likely to result in surgery in men's football (17/141, 12.1%) and women's basketball (3/48, 6.3%) players. Male athletes required surgery for 19 of 331 (5.7%) injuries, and female athletes underwent surgical intervention for 7 of 271 (2.6%) total injuries ($P = .070$). Among specific types of injuries, patella fracture (4/5, 80.0%), patellar dislocation (4/19, 12.1%), and patellar subluxation (10/91, 11.0%) were the most likely to require surgical intervention.

DISCUSSION

This epidemiological study of 25 NCAA sports found that the incidence of patellofemoral injuries was highest in women's volleyball. Overall patellofemoral injury rates were significantly higher during competition than during practice, which is consistent with previous epidemiological studies of other injuries (eg, hamstring, acromioclavicular joint, and glenohumeral instability injuries).^{2,9,11,13,17} The cause of injury may be associated with increased intensity during competition relative to practice. Interestingly, this particular trend was seen only in men's sports, with women sustaining equal IRs during both practice and competition. Men's football (51.65 per 100,000 AEs) and wrestling (48.22 per 100,000 AEs) had very high competition injury IRs. The extreme contact commonly seen in football and wrestling is likely limited during practice to protect the players. Because there are no women's equivalents of these sports, it is logical that the same association would not be seen

among women. Men's basketball also had a high competition IR (47.37 per 100,000 AEs) relative to both women's basketball players (19.64 per 100,000 AEs) and the general cohort (23.80 per 100,000 AEs). This discrepancy may be due to a more physical style of play in men's basketball compared with the women's game.

It is well established that female participants are at greater risk for certain injuries, such as anterior cruciate ligament tears.⁶ Our study also suggests that female athletes are at a higher risk of patellofemoral injuries than their male counterparts. Although conflicting reports are found regarding female sex as a risk factor for patellofemoral injuries, the overall consensus is consistent with our findings that women are at increased risk.^{5,6,8,14,18,19,21,22} Our results offer a potential explanation for disparities in the literature, as some of the observed sex-related differences in this study were dependent on sport and exposure type. For example, female soccer players had a higher likelihood of sustaining an injury during practice and overall than their male counterparts but had no increased risk during competitions. As such, there may be an interaction between an athlete's sex, sport, and exposure type that determines his or her risk for injury. Female athletes have been shown to have greater quadriceps angles (Q angles), femoral anteversion, and ligament laxity than their male counterparts, all of which are known risk factors for PFPS and patellar instability.^{6,18} Special consideration for female athletes may be needed to identify those most at risk for patellofemoral injuries and to develop strategies for injury prevention.

This study also found that patellar tendinitis was the most common injury type in 20 of the 25 included sports and was at least 3 times more common than the next most prevalent injury. Previous research has suggested that landing with a limited knee and hip range of motion and short landing time following a jump is associated with patellar tendinopathy.²⁴ As such, using a landing strategy with more ankle, knee, and hip flexion may decrease the incidence of chronic tendinopathy.²⁴ This is especially notable given that 3 of the 4 most commonly affected sports (women's volleyball, men's

TABLE 3
Injury Type by Sport, 2009-2010 to 2013-2014^a

Sport	Injury Type, n									Most Prevalent Injury Type
	Infrapatellar Bursitis	Prepatellar Bursitis	Patellar Tendinitis	Patellar Subluxation	PFPS	Patellar Tendon Strain	Patella Fracture	Patellar Dislocation	Patellar Osteoarthritis	
M baseball	0	1	8	1	1	0	0	1	0	Patellar tendinitis
M basketball	1	4	39	4	4	6	2	0	1	Patellar tendinitis
W basketball	1	1	22	10	7	3	0	2	2	Patellar tendinitis
M cross- country	0	0	5	0	4	0	0	0	0	Patellar tendinitis
W cross- country	0	1	5	1	2	1	0	0	0	Patellar tendinitis
M football	5	22	57	29	6	13	2	7	0	Patellar tendinitis
W field hockey	1	0	2	0	4	1	0	0	0	PFPS
W gymnastics	0	0	4	2	0	0	0	0	0	Patellar tendinitis
M ice hockey	2	3	7	4	4	0	0	0	0	Patellar tendinitis
W ice hockey	0	3	2	4	1	1	1	0	0	Patellar subluxation
M lacrosse	0	1	6	5	2	1	0	0	0	Patellar tendinitis
W lacrosse	0	4	4	4	5	0	0	0	0	PFPS
W softball	0	3	3	3	5	0	0	2	1	PFPS
M soccer	0	1	13	1	3	3	0	0	0	Patellar tendinitis
W soccer	3	1	20	11	15	3	0	1	2	Patellar tendinitis
M swimming	0	0	6	0	0	1	0	0	0	Patellar tendinitis
W swimming	0	0	5	2	2	0	0	0	0	Patellar tendinitis
M tennis	0	0	4	0	0	1	0	1	0	Patellar tendinitis
W tennis	0	0	2	1	0	0	0	0	0	Patellar tendinitis
M indoor track	1	0	14	0	2	3	0	0	0	Patellar tendinitis
W indoor track	1	0	7	1	3	1	0	1	0	Patellar tendinitis
M outdoor track	0	0	5	0	0	1	0	0	0	Patellar tendinitis
W outdoor track	0	0	9	0	0	0	0	0	0	Patellar tendinitis
W volleyball	2	0	46	5	7	0	0	2	0	Patellar tendinitis
M wrestling	2	4	1	3	0	1	0	2	0	Prepatellar bursitis
All M sports	11	36	165	47	26	30	4	11	1	Patellar tendinitis
All W sports	8	13	131	44	51	10	1	8	5	Patellar tendinitis
Total	19	49	296	91	77	40	5	19	6	Patellar tendinitis

^aM, men's; PFPS, patellofemoral pain syndrome; W, women's.

TABLE 4
Mechanism of Patellofemoral Injury by Injury Type 2009-2010 to 2013-2014^a

Injury Type	Overall Injuries, n	Injuries by Mechanism, n							
		No Apparent Contact	Contact: Apparatus	Contact: Surface	Contact: Person	Contact: Bounds	Contact: Object	Overuse/ Gradual	Other
Patellar tendinitis	296	86	3	5	4	0	188	3	7
Patellar subluxation	91	40	5	13	28	0	0	2	3
PFPS	77	17	0	1	2	1	52	1	3
Prepatellar bursitis	49	2	4	28	10	0	3	0	2
Patellar tendon strain	40	25	0	2	6	0	4	1	2
Infrapatellar bursitis	19	2	0	10	3	0	2	0	2
Patellar dislocation	19	8	0	3	7	0	0	1	0
Patellar osteoarthritis	6	2	0	1	0	0	3	0	0
Patella fracture	5	2	0	1	1	0	0	0	1
Total	602	184	12	64	61	1	252	8	20

^aSorted in descending order according to overall injuries. PFPS, patellofemoral pain syndrome.

basketball, and women's basketball) require frequent jumping. Encouraging athletes to increase knee and hip flexion to absorb landing force and increase landing time may reduce stress on the patellar tendon and thereby decrease injury risk. Gual et al⁷ found that implementation of eccentric squat training in addition to a standard exercise routine in basketball and volleyball was shown to improve lower limb strength when compared with controls. However, neither group reported any patellofemoral injuries, and the authors were unable to comment on the training regimen's utility as a prevention program.⁷

PFPS was the most commonly reported injury in women's field hockey, women's lacrosse, and women's softball. Patellar subluxation was the most prevalent injury in men's hockey, and prepatellar bursitis was the most common injury in men's wrestling. It is difficult to compare these results with those in the existing literature, as no previous studies have reported patellofemoral injury incidence stratified by injury type. As such, these results may be quite useful in improving prevention efforts. Wrestlers, for example, may benefit from the use of knee pads, as prepatellar bursitis is most likely to result from contact with the playing surface. Future research is warranted to determine whether these sports have unique factors that predispose athletes to these particular types of patellofemoral injuries.

The majority of PFPS and patellar tendinitis cases resulted from overuse. Previous studies concur with this finding, defining both PFPS and patellar tendinitis as overuse injuries.^{8,26} Patellar tendon strain, subluxation, and dislocation were most likely to be caused by the mechanism of no apparent contact (eg, rotation about a planted foot). Similar results have been demonstrated in an epidemiological study of high school athletes participating in various sports, with the most common cause of patellar subluxation and dislocation being categorized as noncontact.¹⁶ Most infrapatellar and prepatellar bursitis injuries were caused by contact with the playing surface, and a large proportion of patellar instability injuries were caused by contact with the

surface or contact with another player. This is also in accordance with findings by Mitchell et al,¹⁶ who reported that player-to-player contact was the second most common cause of patellar instability injuries and that contact mechanisms caused the greatest number of instability injuries. Specific measures may be warranted to address the most common causes of each injury. With the high IRs of patellar tendinitis and PFPS, improved training protocols to strengthen the muscles around the patella and augment recovery to decrease wear on the patella and patellar tendon may be especially useful in those athletes at highest risk of sustaining such injuries.

Although patellar instability was substantially less common than the other injury types, patellar subluxation and dislocation were among those most likely to be classified as severe injuries. Patellar subluxation resulted in the most total TL (648 days), whereas dislocation yielded the highest average TL per injury (11.42 days per injury). Patellar dislocation (38.6%) and subluxation (19.8%) represented the highest proportion of injuries that resulted in 14 days or more of TL and were also 2 of the most likely injuries to require surgical repair. These findings are similar to those of Mitchell et al,¹⁶ in which 20% of high school athletes with patellar dislocation and 14% with a patellar subluxation required more than 3 weeks to return to play. Additionally, 37% of dislocation patients and 11% of subluxation patients missed the rest of the season.¹⁶

The current study has several limitations. The diagnosis made by the health care provider was not standardized or validated. Further, the data were submitted via selection from a predefined set of injuries and mechanism of injury, which may have caused data submitters to choose the "best" option rather than the athlete's actual diagnosis. The sample sizes were inconsistent between sports, such that some calculations potentially have limited power in determining statistical significance. This was especially apparent in the comparison of sex-comparable sports, as groups became relatively small. Furthermore, these data consist of high-level

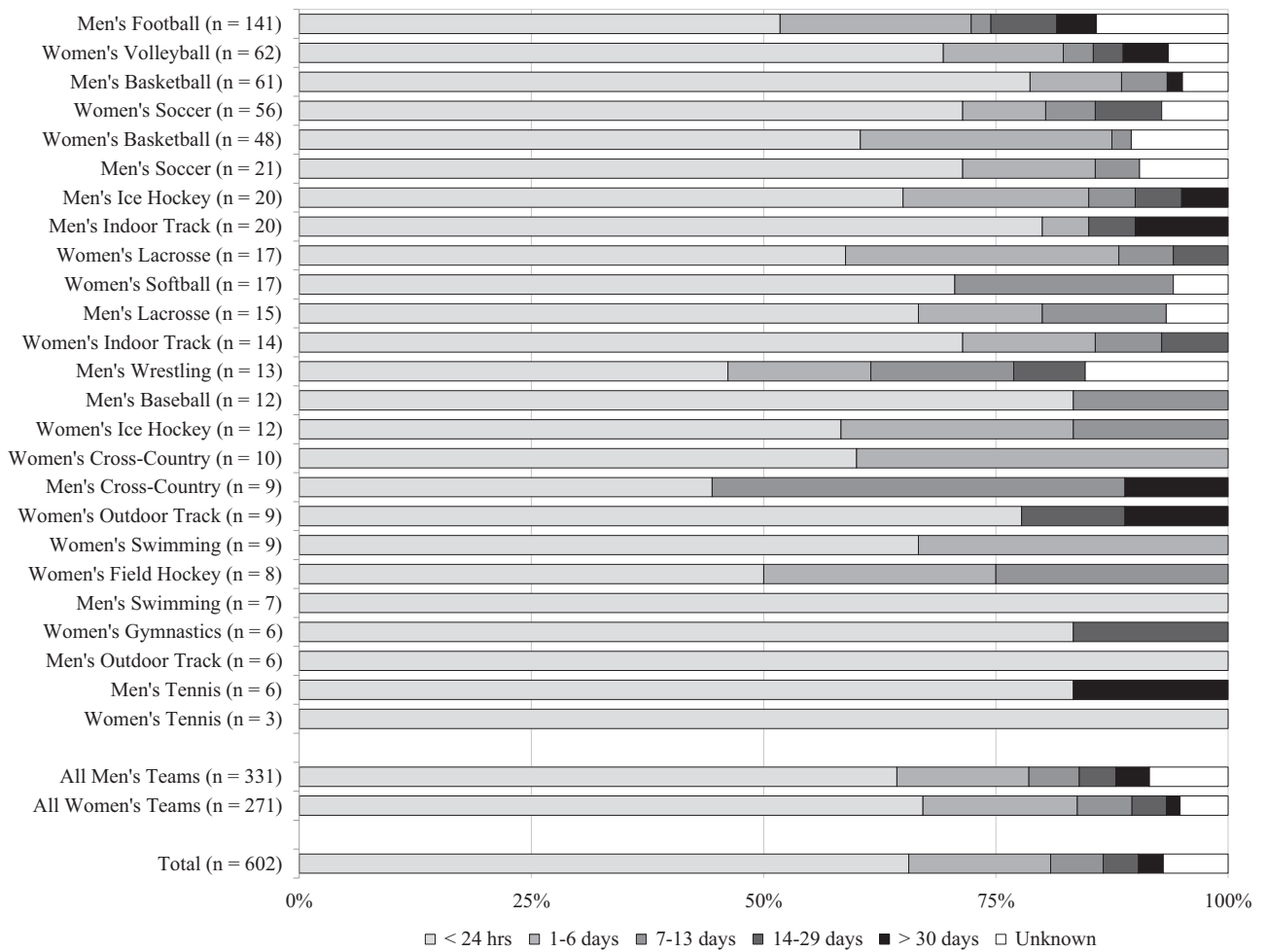


Figure 1. Time lost by sport.

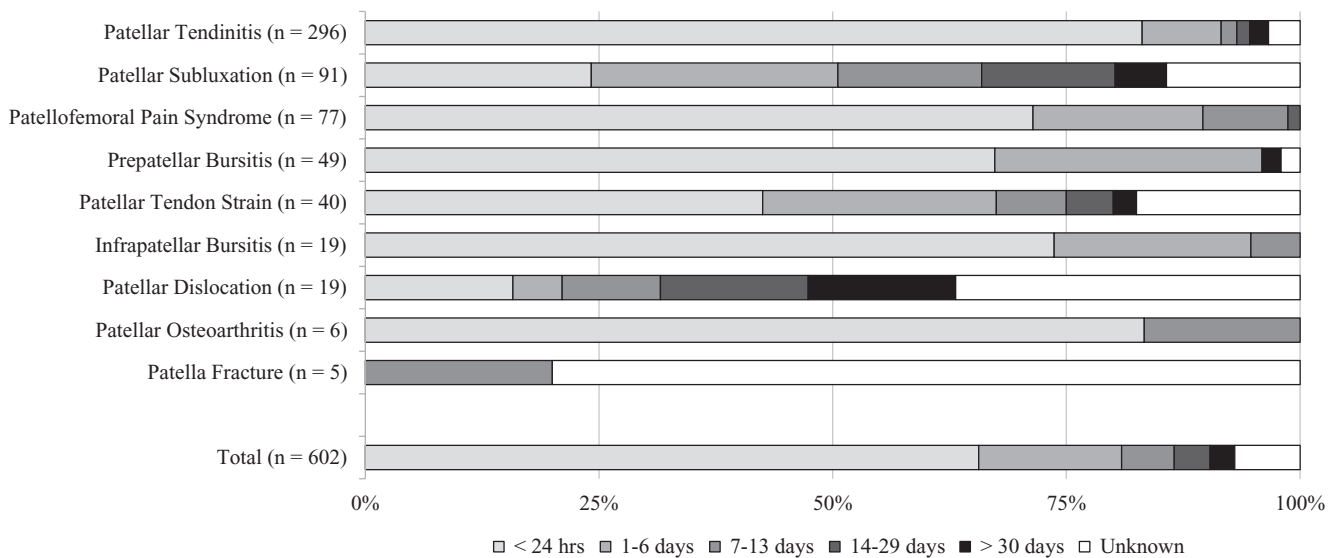


Figure 2. Time lost by injury type.

collegiate athletes and the results may not be generalizable to less competitive athletes or the overall public. Additionally, this was a retrospective study and, as such, has no mechanism to control for variables and is subject to selection bias of those programs that chose to participate in the ISP. Similarly, no mechanism was available for ensuring completion of injury reports by participating athletic programs, which may have led to the underreporting of some injuries.

CONCLUSION

Patellofemoral injuries are relatively common and can result in substantial time lost from sport. Women's volleyball, men's basketball, and women's soccer sustained the highest incidences of injury among the 25 collegiate sports included in this study. Injuries were significantly more likely to occur during competition than during practice in the male cohort. Female athletes sustained significantly more patellofemoral injuries than their male counterparts in sex-comparable sports. Although patellar tendinitis was the most common injury, cases of patellar instability resulted in the greatest amount of time lost from sport and were the most likely to require surgical treatment. Development of prevention programs aimed at the most prevalent types and mechanisms of injury in each sport may reduce the incidence of patellofemoral injury in these athletes.

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