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Extremity Fracture Rates in College-Aged Adults: Sex Differences and Contact-Classification Effects Across Eleven Sports, 2015–2024

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Abstract

Background

Extremity fractures are common, clinically significant injuries in collegiate sports, but prior epidemiologic studies have been limited to single institutions, single sexes, or single sports, leaving multi-sport, sex-stratified fracture risk poorly characterized nationally.

Hypothesis/Purpose

: To characterize upper and lower extremity fracture trends across 11 collegiate sports from 2015 to 2024, compare incidence by sex and contact classification, and identify high-risk sports.

Study Design

: Descriptive epidemiology study.

Methods

The National Electronic Injury Surveillance System (NEISS), a nationally representative sample of approximately 100 U.S. hospital EDs, was queried for sport-specific codes (field hockey, ice hockey, lacrosse, football, basketball, soccer, baseball, softball, wrestling, volleyball, gymnastics), fracture diagnosis (upper and lower extremity fractures were included), encounter date 2015–2024, and age 19–23 years. Sports were categorized using prior established categorization as contact/collision or limited contact/impact. Athlete-season denominators were derived from annual NCAA participation data by sport, sex, and year. National estimates used NEISS sampling weights. Multivariable negative binomial regression estimated incidence rate ratios (IRRs) adjusting for sex, sport, and contact classification. Sex-stratified rate ratios were calculated for co-ed sports, including baseball versus softball. Sensitivity analyses were restricted to organized-sport injuries.

Results

Crude fracture incidence ranged across the 11 sports, from 0.19 per 1,000 athlete-seasons in lacrosse to 4.79 in basketball (~ 1:25 ratio). After adjustment, every sport had significantly higher incidence than lacrosse (adjusted IRRs 1.83–22.25, all $p < 0.001$). Contact/Collision sports had 55% lower adjusted incidence than Limited-Contact/Impact sports (IRR 0.45, 95% CI 0.34–0.59, $p < 0.001$), driven largely by fracture rates in basketball and gymnastics. Males had approximately 5 times the adjusted incidence of females (IRR 5.03, 95% CI 3.77–6.70), significantly higher in every co-ed sport examined (rate ratios 2.09–11.45, all $p < 0.05$).

Conclusion

Sport-specific biomechanical demands, rather than broad contact classification, appear to drive acute extremity fracture risk in collegiate athletics. Male athletes face substantially higher acute fracture incidence than female athletes, despite females' well-documented higher risk of stress and overuse fractures, suggesting distinct mechanisms for sport-related injuries in these populations.

Clinical Relevance

: These findings support sport- and sex-specific, rather than contact-category-based, approaches to preparticipation risk counseling and injury-prevention resource allocation in collegiate athletics.

Introduction

Extremity fractures are some of the most clinically significant injuries sustained in sports, often resulting in extended recovery time, surgical intervention, and rehabilitation.[1,8] With more than half a million student-athletes competing annually across National Collegiate Athletic Association (NCAA) institutions, and more than 8 million student-athletes competing annually through National Federation of State High School Associations (NFHS) sports, understanding sport- and sex-specific fracture patterns is essential for informing both treatment and prevention strategies.[7,11]

While prior studies have investigated patterns and risk factors for injuries among collegiate-aged athletes, these have been limited largely by patient populations and scope. Hame et al. investigated fracture demographics at a single Division I institution over 14 years and found basketball carried the greatest risk for male athletes and gymnastics for female athletes.[4] Notably, there was no significant difference in overall fracture incidence between sexes, but there was a significantly higher rate of stress fracture in females.[4] A 2018 descriptive epidemiology study used the NCAA Injury Surveillance Program (NCAA-ISP) to characterize fracture rates in college football specifically, demonstrating that the rate of fractures occurring during competition were 10-fold higher than practice fracture rates. For these football athletes, hand/finger fractures were predominant and represented 35% of all injuries.[1] A 2025 study by Chandran et al. using the NCAA-ISP investigated fracture incidence across women's sports, identifying gymnastics as the highest-risk sport.[2] It also found fractures among all studied sports were most commonly classified as non-contact or overuse injuries (39.0%).[2] In field hockey and ice hockey, however, equipment/apparatus contact mechanisms accounted for > 60% of fractures.[2] Collectively, these studies are limited by single-institution samples, single-sex cohorts, or single-sport scope, leaving open the question of how fracture risk compares across sports and sexes nationally.

The purpose of this study was to (1) characterize upper and lower extremity fracture incidence across 11 collegiate sports over a contemporary 10-year period (2015–2024) using a nationally representative ED database, (2) compare fracture incidence by sex and contact classification, and (3) identify high-risk sports and athlete subgroups. We hypothesized that males would have higher acute extremity fracture incidence than females, that contact/collision sports would have higher rates than limited contact/impact sports, and that sport-specific variation would exist independent of contact classification.

Methods

Study design and databases

This was a retrospective cross-sectional study using the National Electronic Injury Surveillance System (NEISS) database. NEISS is a probability-based sample of approximately 100 U.S. hospital EDs, stratified by hospital size and geographic location, that captures consumer-product relating injuries presenting to the participating EDs.[13] Each case includes patient demographics (age, sex, race), date of encounter, diagnosis (or diagnoses), affected body part(s), disposition, a brief narrative describing the injury and circumstances, and sport code(s) associated with the injury. NEISS sampling weights allow calculation of nationally representative injury estimates. The NEISS database is publicly available and has been validated for injury surveillance research.[3]

This study was deemed non-human subjects research by the University of Virginia institutional review board (Project Number 783), as it involved analysis of existing, publicly available, deidentified data in which subjects cannot be identified.

Study population

The NEISS database was queried for cases meeting the following criteria: (1) sport-specific sport codes corresponding to 11 collegiate sports (field hockey, ice hockey, lacrosse, football, basketball, soccer, baseball, softball, wrestling, volleyball, and gymnastics); (2) fracture diagnosis code; (3) patient age 19 to 23 years (a proxy for collegiate-aged athletes); and (4) injury to the upper or lower extremity. The full code list, with cross-reference to the CPSC NEISS Coding Manual (January 2025, Rev. 1), is provided in Supplemental Table 1 and Supplemental Table 2.[13] Cases with product code "hockey - unspecified" were excluded due to limited case information (*n* = 50 raw cases; 1,938 weighted national estimate). Cases involving axial skeleton fractures (spine, pelvis, ribs) or facial fractures were excluded as the database categorizes these as "trunk", insufficiently nonspecific. Spine injuries were excluded because the granularity of NEISS coding is insufficient to confirm that a "trunk" fracture diagnosis corresponds specifically to the vertebral column rather than adjacent structures. The study period spanned January 1, 2015, through December 31, 2024. The case-narrowing sequence, with raw and NEISS-weighted case counts retained at each step for transparency, is shown in the CONSORT-style flow diagram (Fig. 1).

Contact classification

This study utilized the previously established definitions for sports as contact/collision, limited contact/impact, or noncontact per Ledoux et al. (2024).[9] This prior work included (ice) hockey, football, soccer, lacrosse, and wrestling among contact/collision sports; and basketball, volleyball, baseball/softball, field hockey, and gymnastics among limited-contact/impact sports.[9] This classification reflects the expected degree of intentional or incidental interpersonal contact inherent to each sport. Supplemental Table 1 stratifies these sports by contact classification. Classification systems are often used for preparticipation evaluation and risk counseling, but their relationship to acute fracture risk has not been systematically evaluated across collegiate-aged athletes. Understanding whether contact classification accurately predicts fracture incidence could impact injury prevention discussion and strategy.

Injury mechanism

Injury mechanism was classified from the free-text NEISS narrative field using a keyword scheme applied via word-boundary regular expressions, with categories assigned in the following priority order: player contact (e.g., tackle, collide, check, takedown), equipment contact (e.g., ball, puck, stick, bat, helmet), surface/fall (e.g., fell, slipped, turf, landed), non-contact (e.g., twisted, pivoted, jumped), and unspecified (narrative uninformative for mechanism). This classification is descriptive and hypothesis-generating only, as NEISS narratives are short (≤ 140 characters) and frequently do not state mechanism explicitly.

Denominator data

Athlete-season denominators were derived from annual NCAA Sports Sponsorship and Participation Rates Reports, which provide the total number of participating student-athletes by sport, sex, and academic year.[10] One athlete-season was defined as one student-athlete participating in one sport during one academic year. For the baseball versus softball comparison, male baseball and female softball athlete-seasons were used as sex-stratified denominators. These are the same denominators used for every incidence rate, rate ratio, and incidence rate ratio reported in this manuscript.

Statistical analyses

Incidence rate ratios (IRRs) compared fracture incident rates (per 1,000 athlete-seasons) between sports or exposure groups from regression models with an athlete-season offset, adjusting for sex. IRRs were used for the sport-level comparison (Table 1) and the pooled contact-classification comparison (Table 2). Crude rate ratios, calculated directly from observed counts and person-time without a regression model, were used for male:female comparisons within co-ed sports (Table 3). Odds ratios from multivariable logistic regression compared fracture diagnoses to all other ED

diagnoses among the same sports and age range (Table 4 and Table 5); this visit-level model did not include a person-time offset. Full modeling specifications for all analyses are provided in Supplementary Document 1.

Sport- and contact-level incidence models

Overall fracture incidence by sport (Table 1) is reported as a crude rate with exact Poisson confidence intervals. Lacrosse, the sport with the lowest observed rate, served as the reference category. Adjusted IRRs came from a single negative binomial regression that included sport and sex as predictors and log(athlete-seasons) as an offset. P-values were adjusted for the 10 pairwise comparisons using the Benjamini-Hochberg false discover rate (FDR) procedure. Sport and contact classification could not be included in the same model, because contact class is fully determined by sport; the contact-classification comparison (Table 2) therefore came from a separate model of the same type, with contact class in place of sport. See Supplemental Document 1 for full model details, including the omnibus sport-effect test.

Sex-stratified comparisons

We compared fracture incidence by sex within the seven co-ed sports in this dataset (those with both a men's and women's NCAA program). For each sport, the male:female ratio came from an exact Poisson rate-ratio test, with p-values FDR-adjusted across the seven comparisons. Football, wrestling, and field hockey have no sex comparator in this dataset and were excluded. Definitions and additional test detail are provided in Supplemental Document 1.

Logistic regression of fracture status

We used multivariate logistic regression to model the odds of a fracture diagnosis versus any other injury diagnosis, among all ED visits for the 11 sports and age range (not the fracture-only cohort). Predictors were sport, sex, age, calendar year, and body region; volleyball served as the sport reference, as the sport with the lowest fracture proportion among its own visits. All predictor p-values were FDR-adjusted jointly as one family. Model fit and discrimination were assessed with a Type II likelihood-ratio test and the area under the ROC curve (AUC), respectively. Full specification is provided in Supplemental Document 1.

Sensitivity analyses

NEISS captures any ED visit coded to a sport, including non-varsity play (intramural, club, recreational, pickup), while the NCAA athlete-season denominator counts only varsity participants. This mismatch may inflate rates in sports with large casual-play populations (e.g., soccer, basketball). We therefore constructed two sensitivity cohorts, restricting progressively to more clearly organized and explicitly varsity play, to test whether the direction of the sport, sex, and contact-class effects held. Cohort definitions are provided in Supplemental Document 1.

Software

All analyses were conducted in R version 2026.07.1 + 147, using MASS::glm.nb for negative binomial regression, base R poisson.test() for exact Poisson rate-ratio tests, glm(family = binomial) for logistic regression, car::Anova for Type II likelihood-ratio tests, broom::tidy for model output extraction, and stats::p.adjust(method = "BH") for false discovery rate correction.

Results

Study population

Of 364,676 raw NEISS records identified across the 11 sport product codes (all ages, all diagnoses; NEISS-weighted national estimate 11,725,389), 28,498 involved patients aged 19–23. Of these, 3,972 records had a fracture diagnosis (NEISS-weighted estimate 155,352); no records were subsequently excluded for missing sport code, sex, or other analytic variables, yielding a final analytic cohort of 3,972 fracture visits (weighted 155,352). Of these, 1,745 (weighted 66,740) occurred in Contact/Collision sports and 2,227 (weighted 88,612) in Limited Contact/Impact sports. Full case-narrowing counts are shown in Fig. 1.

Overall fracture incidence by sport and by contact classification

Crude combined-sex fracture incidence varied widely across the 11 sports, from 0.19 per 1,000 athlete-seasons in lacrosse to 4.79 per 1,000 in basketball, a rate approximately 25 times higher in basketball than in lacrosse. After adjustment for sex, every sport had significantly higher incidence than the lacrosse reference (all FDR-adjusted $p < 0.001$); adjusted IRRs ranged from 1.83 (baseball) to 22.25 (basketball). Notably, gymnastics' adjusted IRR (20.64) was proportionally much larger than its crude rate ratio vs. lacrosse (approximately 9 times higher) would suggest. See Table 1 for all sports' overall incidence and rates.

After adjusting for sex, athletes in Contact/Collision sports had 55% lower extremity fracture incidence than athletes in Limited-Contact/Impact sports (adjusted IRR 0.45, 95% CI 0.34–0.59, $p < 0.001$), driven largely by basketball and gymnastics' outsized incidence within the Limited-Contact group (Table 2) rather than a uniformly higher rate across all Limited-Contact sports.

Sex-stratified fracture incidence within co-ed sports

Among the seven paired sports, male athletes had significantly higher fracture rates than female athletes in every comparison (all FDR-adjusted $p < 0.05$). The male:female rate ratio was largest in basketball (RR 11.45, 95% CI 9.51–13.89) and smallest in ice hockey (RR 2.09, 95% CI 1.13–4.09), which was also the only comparison with an FDR-adjusted p-value above 0.01 ($p = 0.013$). See Table 3 and Fig. 2.

Predictors of fracture among all ED visits

Among 28,497 of the 28,498 ED visits identified for these 11 sports and age range (Fig. 1) 3,972 (13.9%) were fractures. One basketball-related visit was excluded from the model due to an unrecorded sex code. Crude fracture proportion among ED visits ranged from 10.4% (volleyball) to 19.0% (baseball); after adjustment, baseball (OR 1.89, $p < 0.001$), soccer (OR 1.86, $p < 0.001$), field hockey (OR 2.15, $p = 0.014$), and softball (OR 1.64, $p = 0.001$) had the highest odds of a fracture-associated visit relative to volleyball as the sport reference. Ice hockey, gymnastics, and basketball were not significantly different from volleyball after FDR adjustment. Upper-extremity injuries had substantially higher odds of being a fracture than "other" body regions (OR 3.39, 95% CI 3.10–3.72, $p < 0.001$), as did lower-extremity injuries (OR 1.22, 95% CI 1.11–1.34, $p < 0.001$); upper-extremity injuries also had significantly higher odds of fracture than lower-extremity injuries (OR 2.78, 95% CI 2.53–3.06, $p < 0.001$). This is a distinct analysis from Table 1 and Table 2 above (visit-level odds of a fracture diagnosis, not population incidence rate) and is presented here as Table 4 and Table 5. An omnibus Type II likelihood-ratio test confirmed that four of the five predictor blocks contributed significantly to model fit (sport: $\chi^2[10] = 135.13$, $p < 0.001$; sex: $\chi^2[1] = 5.66$, $p = 0.017$; calendar year: $\chi^2[1] = 28.21$, $p < 0.001$; body region: $\chi^2[2] = 930.43$, $p < 0.001$), while age did not ($\chi^2[1] = 0.00$, $p = 0.967$). The model showed modest discrimination between fracture and non-fracture visits (AUC = 0.657).

Body part-specific patterns

The site-specific heatmap (Fig. 3) shows that men's basketball carried the highest single-cell incidence for several distal sites: ankle (1.41/1,000), finger (1.31/1,000), hand (0.91/1,000), and wrist (0.64/1,000). Men's gymnastics showed a

notably elevated wrist-fracture rate (0.94/1,000, 95% CI 0.19–2.76) despite a small denominator (3,177 athlete-seasons; n = 3 fractures); and this estimate should be interpreted cautiously given the limited sample. Wrestling showed an unusual proximal-arm pattern, with upper-arm fractures (0.24/1,000) more common than shoulder fractures (0.08/1,000), a pattern consistent with the arm-bar/takedown mechanisms characteristic of the sport and distinguishable only because shoulder and upper-arm sites were classified separately in this analysis.

Injury mechanism

Mechanism classification from NEISS narratives (Fig. 4) showed field hockey fractures were predominantly attributed to equipment contact (55.6% of classified narratives; stick/ball mechanisms), and ice hockey showed the highest player-contact share of any sport (38.1%), consistent with legal body-checking. Across most sports, a substantial minority-to-majority of narratives were classified as mechanistically unspecified (range 22.2%–76.5% across sports, e.g., wrestling 76.5%, basketball 51.3%), reflecting the brevity of the NEISS narrative field (≤ 140 characters) and its frequent omission of mechanism detail. As such mechanism findings should be treated as descriptive and hypothesis-generating rather than definitive.

Sensitivity analysis

Sensitivity analysis restricting to the Organized-Play cohort (excluding narratives explicitly flagging recreational, intramural, high-school, or backyard play, or coded to home location) retained the large majority of records; sport, sex, and contact-classification effects were directionally consistent with the primary analysis (Supplemental Fig. 1).

Discussion

This study was a nationally representative analysis of extremity fracture incidence across multiple collegiate sports, stratified by sex and contact classification, over a contemporary 10-year period. Three principal findings emerged: (1) males demonstrated a 5:1 ratio of acute extremity fracture incidence to females, and a difference persisted within co-ed sports (between 2:1 in ice hockey to 11:1 in basketball); (2) although contact/collision sports had higher overall fracture rates, the two sports with the highest sport-specific incidence (basketball and gymnastics) are both classified as limited contact/impact; and (3) injury mechanisms varied substantially across sports, with surface/fall contact as the predominant mechanism in limited-contact sports and player contact as the predominant mechanism for collision sports.

Sex differences in acute versus overuse fractures

We found that males demonstrated approximately 5 times the adjusted incidence of acute extremity fractures compared to females across the cohort (adjusted IRR 5.03, 95% CI 3.77–6.70), a pattern that persisted across every co-ed sport examined, ranging from a roughly 2:1 difference in ice hockey to an 11:1 difference in basketball.

This magnitude of sex disparity in acute fracture risk is consistent with, and extends to, prior sport-specific and systematic-review evidence of elevated fracture risk among male athletes. A systematic review and meta-analysis by Hardaker et al. found that in sex-comparable sports, male athletes were 1.8 (1.37–2.7) to 2.8 (2.45–3.24) times more likely to sustain acute fractures than female athletes, and the risk was highest in competition.[5] Female athletes had a greater risk of foot/ankle injuries (relative risk (RR) 1.25; 95% CI 1.17–1.34), knee injury (RR 2.7; CI 1.4–5.5), and bone stress injury (RR 3.4; 95% CI 2.1–5.4) than male athletes.[5] Male athletes had a greater risk of hamstring injuries (RR 2.4; 95% CI 1.8–3.2) and hip/groin injuries (RR 2.26; 95% CI 1.31–3.88) than female athletes, especially in dynamic sports.[5] An epidemiological study of stress fractures by Rizzone et al. using the NCAA-ISP found the highest rates of stress fractures were women's cross-country, women's gymnastics, and women's outdoor track.[12] Among sex-comparable

sports, stress fracture rates were higher for women than in men (RR = 2.06; 95% CI = 1.71, 2.47), and the most common locations of injury were the metatarsals, tibia, and lower back/lumbar spine/pelvis.[12] Similarly, a 2026 study using the Pac-12 Health Analytics Program found bone stress injuries most commonly occurred in the lower extremity (81% of bone stress injuries), with women college athletes at greatest risk of bone stress injury.[14]

Taken together, our finding of markedly higher acute fracture incidence in males, set against a backdrop of established literature highlighting the predominance of stress and overuse injuries in women, suggests that distinct pathophysiological mechanisms underlie acutely traumatic versus overuse fractures. While prior studies have furthered understanding of fracture epidemiology in specific athlete populations, none have compared fracture incidence across multiple sports in both sexes using a nationally representative database, a gap this study addresses.

Contact classification and sport-specific risk

Interestingly, Contact/Collision classification did not predict higher aggregate fracture risk in this study cohort. After adjusting for sex, athletes in Contact/Collision sports had 55% lower fracture incidence than athletes in Limited-Contact/Impact sports (adjusted IRR 0.45, 95% CI 0.34–0.59, $p < 0.001$; Table 2). This pooled effect was driven disproportionately by two individual sports: basketball (adjusted IRR 22.25 vs. lacrosse) and gymnastics (adjusted IRR 20.64), both classified as limited-contact/impact, which together accounted for the highest sport-specific fracture incidence within the cohort (Table 1). Contact/Collision sports such as football and ice hockey, despite their reputation for high-impact play, had comparatively modest adjusted IRRs (2.74 and 4.41, respectively).

These findings challenge the assumption, implicit in widely used contact classification systems such as the one applied here, that broad contact category reliably predicts acute musculoskeletal injury risk.[9] Instead, our results suggest that sport-specific biomechanical demands (repetitive jumping and landing in basketball, and high-force dismounts and apparatus contact in gymnastics) may better predict acute fracture risk than a sport's contact classification alone. Gymnastics' disproportionately large adjusted IRR relative to its crude rate ratio is notable in this context; the sport's athlete population in this dataset is heavily female (approximately 5:1 female-to-male athlete-seasons), and sex-adjustment re-weights the sport-level comparison toward its smaller, higher-rate male subgroup, underscoring that sport-specific risk estimates in mixed-sex sports must be interpreted alongside their underlying roster composition.

Injury mechanism patterns

Injury mechanism varied substantially by sport. Field hockey fractures were disproportionately attributed to equipment contact (55.6% of classified narratives; primarily stick and ball mechanisms) despite the sport's limited-contact/impact classification, while ice hockey showed the highest player-contact share of any sport in this cohort (38.1%), consistent with legal body-checking under NCAA men's ice hockey rules. This player-contact-dominant pattern in our combined-sex ice hockey cohort contrasts with Chandran et al.'s finding that equipment/apparatus contact accounted for more than 60% of fractures in NCAA women's ice hockey specifically.[2] While this could be explained by the fact that body-checking is legal in men's but not women's collegiate ice hockey, our combined-sex cohort's mechanism profile likely reflects a disproportionately male-driven pattern. Across sports, a substantial share of narratives could not be mechanistically classified (range 22.2%–76.5%), reflecting the brevity of NEISS narrative fields (≤ 140 characters); as such these mechanism findings should be interpreted as hypothesis-generating rather than definitive. Even so, the equipment-contact pattern in field hockey and the player-contact pattern in ice hockey point toward mechanism-specific prevention targets that may be more actionable than guidance based on broad contact category alone.

Clinical implications

These findings support several concrete, sport- and sex-specific approaches to fracture prevention and clinical counseling in athletics in college-aged adults. First, the consistently higher acute fracture incidence in male athletes across every co-ed sport examined (from a 2:1 difference in ice hockey to an 11:1 difference in basketball) suggests that preparticipation counseling and injury-prevention resources should not assume comparable acute fracture risk between men's and women's programs of the same sport, even though overuse and stress-fracture risk runs in the opposite direction. Second, because basketball and gymnastics carried the highest sport-specific fracture incidence in this cohort despite their limited-contact/impact classification, athletic trainers and team physicians overseeing these programs should not deprioritize acute fracture surveillance or preventive strategies (such as landing-mechanics training or distal upper-extremity protective taping and bracing) on the basis of contact category alone; broad classification systems used for preparticipation risk stratification may need sport-specific refinement. Third, the mechanism patterns identified (equipment contact in field hockey, player contact in ice hockey) point toward actionable, sport-specific prevention targets: stick-handling technique and protective equipment standards in field hockey, and body-checking technique and neuromuscular training in ice hockey.[6] Taken together, these findings argue for injury-prevention strategies tailored to individual sports and sexes, rather than derived solely from broad contact-classification categories

Limitations

Of note, this study has limitations. First, there is a population mismatch in numerator versus denominator scope. NEISS captures any 19–23-year-old whose ED visit is coded to a sport's product code, including intramural, club, recreational, gym-class, and pickup play, while the NCAA athlete-season denominator counts only varsity participants. This has the potential to inflate rates in sports with large casual-play populations. A sensitivity analysis was performed to try to identify recreational or home play; however, given the brief length of NEISS narratives, home or recreational play were infrequently identified (Supplemental Fig. 1).

Second, inability to reliably include spine stress fractures was a limitation as coding of the pelvis/rib/spine area was one all under a "trunk" category. As such we could not determine the incidence of spine stress fractures in particularly high risk sports, such as gymnastics. Additionally, NEISS data is not granular enough to reliably cite whether each injury is an acute versus a stress fracture.As such spinal fractures, whether stress or acute, could not be reliably statistically analyzed or included.

Third, there are inherent limitations of the NEISS database. NEISS is a probability sample of roughly 100 US hospitals rather than a census of all EDs, and our analysis intentionally did not apply NEISS sample weights (see Methods). Raw case counts therefore systematically undercount the true national number of ED visits, so the rate-per-1,000-athlete-seasons figures reported here are best interpreted as internally comparable relative indices (for comparing sports, sexes, or contact classes against one another) rather than as literal estimates of national fracture incidence.

Of note, NEISS only captures injuries presenting to emergency departments and does not capture those treated in athletic training rooms, urgent care centers, or other settings; this likely underestimates total fracture incidence and may skew the captured cases toward more severe injuries. NEISS does not provide specific fracture location (for example, distal radius versus scaphoid), fracture classification, treatment details, or outcomes, limiting the clinical detail of the analysis. Injury mechanism was classifiable in only 22.2%–76.5% of cases, and mechanism categorization was based on brief narrative descriptions that may be incomplete or imprecise. The NEISS coding structure lacks the specificity of ICD-based systems, and some misclassification of diagnosis or sport is possible.18 Additionally, the use of athlete-seasons as the denominator, rather than athlete-exposures (standard in sports epidemiology), does not account for differences in the number of practices, competitions, or total hours of exposure across sports and between sexes.

Finally, as a retrospective database study, this analysis cannot establish causal relationships between risk factors and fracture incidence.

Conclusion

This nationally representative analysis of extremity fracture incidence across multiple collegiate sports showed higher rates of acute fractures in male athletes with highest sport-specific fracture incidence in basketball and gymnastics. Injury mechanisms also varied meaningfully by sport, suggesting that prevention strategies should be tailored to sport-specific injury mechanisms rather than derived solely from broad contact classification. These findings provide a foundation for targeted, sport- and sex-specific injury prevention strategies in collegiate-aged athletes.

Table 1
Overall Fracture Incidence by Sport

Contact Class	Sport	Fractures (n)	Athlete-Seasons	Rate /1,000 (95% CI)	Adj. IRR (95% CI)	p (FDR-adj.)
Contact/Collision	Soccer	822	541,701	1.52 (1.42–1.62)	8.80 (6.39–12.34)	< 0.001
	Wrestling	81	76,395	1.06 (0.84–1.32)	3.10 (2.09–4.63)	< 0.001
	Football	728	745,718	0.98 (0.91–1.05)	2.74 (1.97–3.87)	< 0.001
	Ice Hockey	63	68,362	0.92 (0.71–1.18)	4.41 (2.94–6.66)	< 0.001
	Lacrosse	51	273,276	0.19 (0.14–0.25)	1.00 (Reference)	Reference
Limited Contact/Impact	Basketball	1,696	354,106	4.79 (4.56–5.02)	22.25 (16.25–31.03)	< 0.001
	Gymnastics	33	19,091	1.73 (1.19–2.43)	20.64 (12.81–32.84)	< 0.001
	Softball	137	207,375	0.66 (0.55–0.78)	5.38 (3.43–8.45)	< 0.001
	Baseball	239	367,546	0.65 (0.57–0.74)	1.83 (1.30–2.63)	< 0.001
	Volleyball	104	202,453	0.51 (0.42–0.62)	6.41 (4.43–9.39)	< 0.001
	Field Hockey	18	61,934	0.29 (0.17–0.46)	7.85 (4.14–14.22)	< 0.001

CAPTION: Rate = fractures per 1,000 athlete-seasons, both sexes combined; 95% CI is the exact (Garwood) Poisson interval. Reference sport = lacrosse (empirically lowest crude combined-sex rate). Adjusted IRR and p-value from negative binomial regression (sport + sex + offset[log athlete-seasons]), Wald test, Benjamini-Hochberg FDR-adjusted across 10 comparisons.

Table 2
Pooled Contact/Collision vs. Limited-Contact/Impact — Adjusted IRR

Exposure	Adj. IRR (95% CI)	p-value
Limited Contact/Impact	1.00 (Reference)	Reference
Contact/Collision	0.45 (0.34–0.59)	< 0.001
Sex: Male vs. Female (covariate)	5.03 (3.77–6.70)	< 0.001

CAPTION: Separate negative binomial model (contact classification + sex + offset[log athlete-seasons]); sport is excluded from this model because it is collinear with contact classification (see Methods). Single a priori comparison; no multiplicity correction applied. Sex row shown for transparency as the model's adjustment covariate, not a primary endpoint of this panel.

Table 3
Sex-Stratified Fracture Incidence Within Co-Ed Sports

Sport (Pair)	Contact Class	Men n/Seasons (Rate)	Women n/Seasons (Rate)	Rate Ratio M:W (95% CI)	p (FDR-adj.)
Soccer	Contact/Collision	687 / 256,746 (2.68)	135 / 284,955 (0.47)	5.65 (4.69–6.84)	< 0.001
Lacrosse	Contact/Collision	42 / 148,370 (0.28)	9 / 124,906 (0.07)	3.93 (1.89–9.18)	< 0.001
Ice Hockey	Contact/Collision	49 / 42,824 (1.14)	14 / 25,538 (0.55)	2.09 (1.13–4.09)	0.013
Basketball	Limited Contact/Impact	1,575 / 188,375 (8.36)	121 / 165,731 (0.73)	11.45 (9.51–13.89)	< 0.001
Volleyball	Limited Contact/Impact	55 / 23,988 (2.29)	49 / 178,465 (0.27)	8.35 (5.58–12.53)	< 0.001
Gymnastics	Limited Contact/Impact	13 / 3,177 (4.09)	20 / 15,914 (1.26)	3.26 (1.49–6.88)	0.002
Baseball (M) / Softball (W)	Limited Contact/Impact	305 / 367,546 (0.83)	71 / 207,375 (0.34)	2.42 (1.87–3.18)	< 0.001

CAPTION: Rate = fractures per 1,000 athlete-seasons. Rate Ratio M:W = male:female rate ratio, exact two-sample Poisson rate-ratio test (poisson.test); Benjamini-Hochberg FDR-adjusted across 7 paired comparisons. Scope: all fracture sites (matches Table 1*), not restricted to extremity fractures. Football, wrestling, and field hockey are single-sex-sponsored in this dataset and have no sex comparator.*

Table 4
Adjusted Odds of Fracture (vs. Other Diagnosis) by Sport

Sport	Contact Class	ED Visits (n)	Fractures (n)	% Fracture	Adj. OR (95% CI)	p (FDR-adj.)
Football	Contact/Collision	4,268	728	17.1%	1.60 (1.28–2.02)	< 0.001
Soccer	Contact/Collision	5,001	822	16.4%	1.86 (1.49–2.33)	< 0.001
Wrestling	Contact/Collision	523	81	15.5%	1.45 (1.05–1.99)	0.037
Lacrosse	Contact/Collision	353	51	14.4%	1.48 (1.02–2.13)	0.051
Ice Hockey	Contact/Collision	511	63	12.3%	1.16 (0.82–1.63)	0.427
Baseball	Limited Contact/Impact	1,256	239	19.0%	1.89 (1.47–2.45)	< 0.001
Field Hockey	Limited Contact/Impact	107	18	16.8%	2.15 (1.20–3.70)	0.014
Softball	Limited Contact/Impact	923	137	14.8%	1.64 (1.24–2.16)	0.001
Gymnastics	Limited Contact/Impact	256	33	12.9%	1.42 (0.92–2.16)	0.130
Basketball	Limited Contact/Impact	14,299	1,696	11.9%	1.18 (0.96–1.48)	0.147
Volleyball	Limited Contact/Impact	1,000	104	10.4%	1.00 (Reference)	Reference

CAPTION: % Fracture = fractures / all ED visits for that sport, ages 19–23, any diagnosis. Reference sport = volleyball (empirically lowest fracture proportion among its own ED visits). Adjusted OR and p-value from multivariable logistic regression (sport + sex + age_c + year_c + body region); Wald test.

Table 5
Adjusted Odds of Fracture — Other Model Covariates

Covariate	Adj. OR (95% CI)	p (FDR-adj.)
Sex: Male vs. Female	1.14 (1.02–1.28)	0.031
Age (per year, centered at 19)	1.00 (0.97–1.02)	0.967
Calendar year (per year, centered at 2015)	1.03 (1.02–1.04)	< 0.001
Body region: Upper Extremity vs. Other	3.39 (3.10–3.72)	< 0.001
Body region: Lower Extremity vs. Other	1.22 (1.11–1.34)	< 0.001
Body region: Upper Extremity vs. Lower Extremity†	2.78 (2.53–3.06)	< 0.001†

CAPTION: p-values for Table 4 *and* Table 5 *were Benjamini-Hochberg FDR-adjusted jointly, as one family of 15 simultaneous tests from the single fitted model (10 sport comparisons + 5 covariate terms). †Post hoc pairwise contrast (Tukey-adjusted for the 3-way family of body-region comparisons via emmeans), not part of the FDR-adjusted family above.*

Declarations

Disclosure Statement

The following author(s) declared potential conflicts of interest:

M.E.K. is a consultant for ConMed, committee member for AOSSM, and committee member for AANA. T.M.B. is a paid consultant for J&J MedTech. The other authors (O.J.H., W.M.N., M.K.S.) report no potential conflicts of interest in the development and publication of this article.

Ethical approval

for this study was waived by the University of Virginia (Project number 783).

Competing Interests

M.E.K. is a consultant for ConMed, committee member for AOSSM, and committee member for AANA. T.M.B. is a paid consultant for J&J MedTech. The other authors (O.J.H., W.M.N., M.K.S.) report no potential conflicts of interest in the development and publication of this article.

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Author Contribution

OJH conceptualized and designed the study, performed the statistical analysis, interpreted the data, and drafted the manuscript. MKS supervised the study and substantively revised the manuscript. WMN supervised the statistical analysis and contributed to the study methodology by recommending methodological revisions. MEK critically revised the manuscript. TMB contributed to study conceptualization and critically revised the manuscript. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

Data Availability

The datasets analyzed in this study are publicly available. Injury data were obtained from the U.S. Consumer Product Safety Commission's National Electronic Injury Surveillance System (NEISS), accessible through the NEISS Query Builder at https://www.cpsc.gov/cgibin/NEISSQuery/home.aspx. Athlete participation data used to derive denominators were obtained from the National Collegiate Athletic Association (NCAA) Sports Sponsorship and Participation Rates Report, publicly available from the NCAA at https://www.ncaa.org/what-we-do/research/sport-sponsorship-and-participation-data/. The analytic code used in this study is available from the corresponding author upon reasonable request.

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Figures

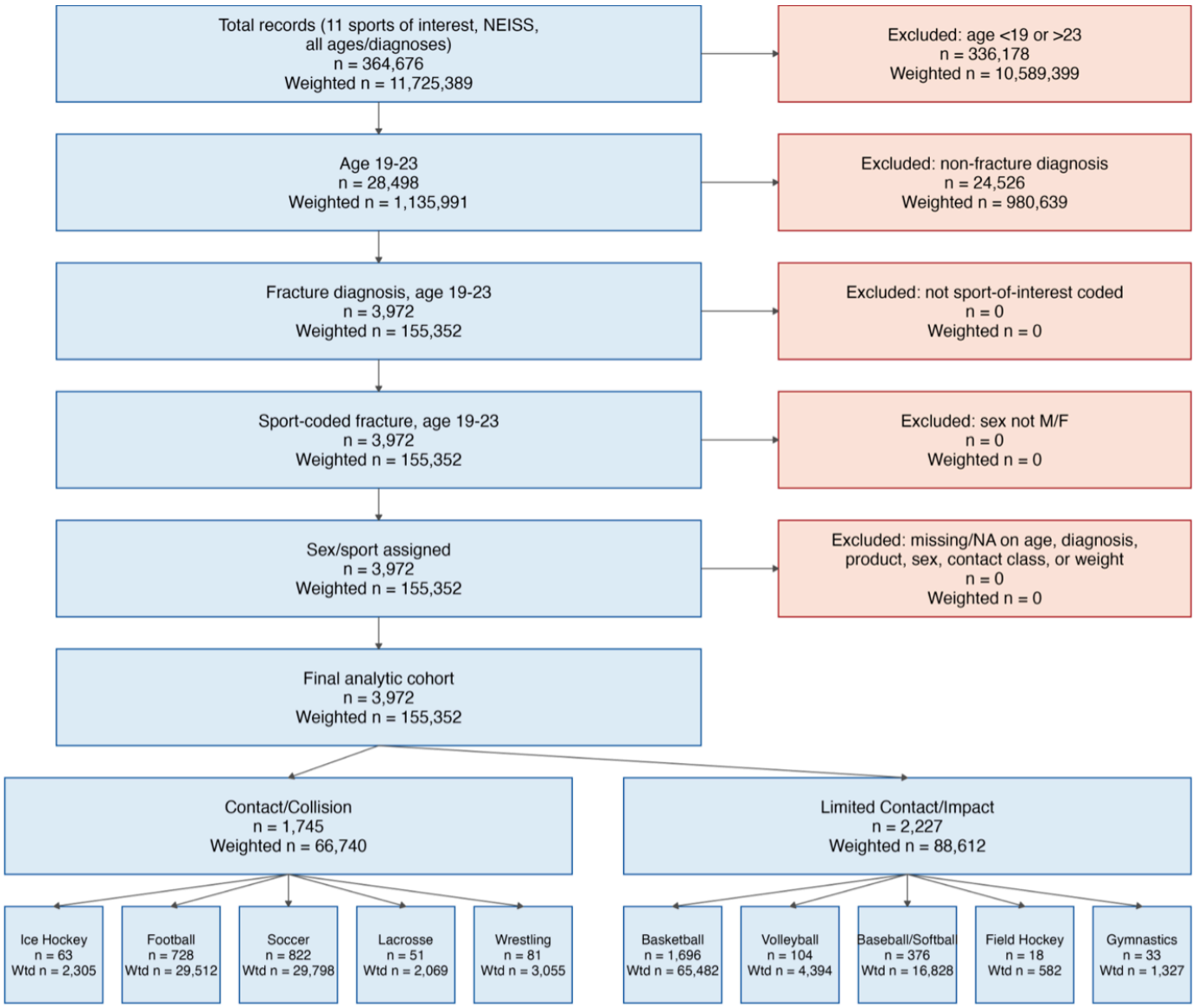

Figure 1

CONSORT-Style Flow Diagram of Case Selection

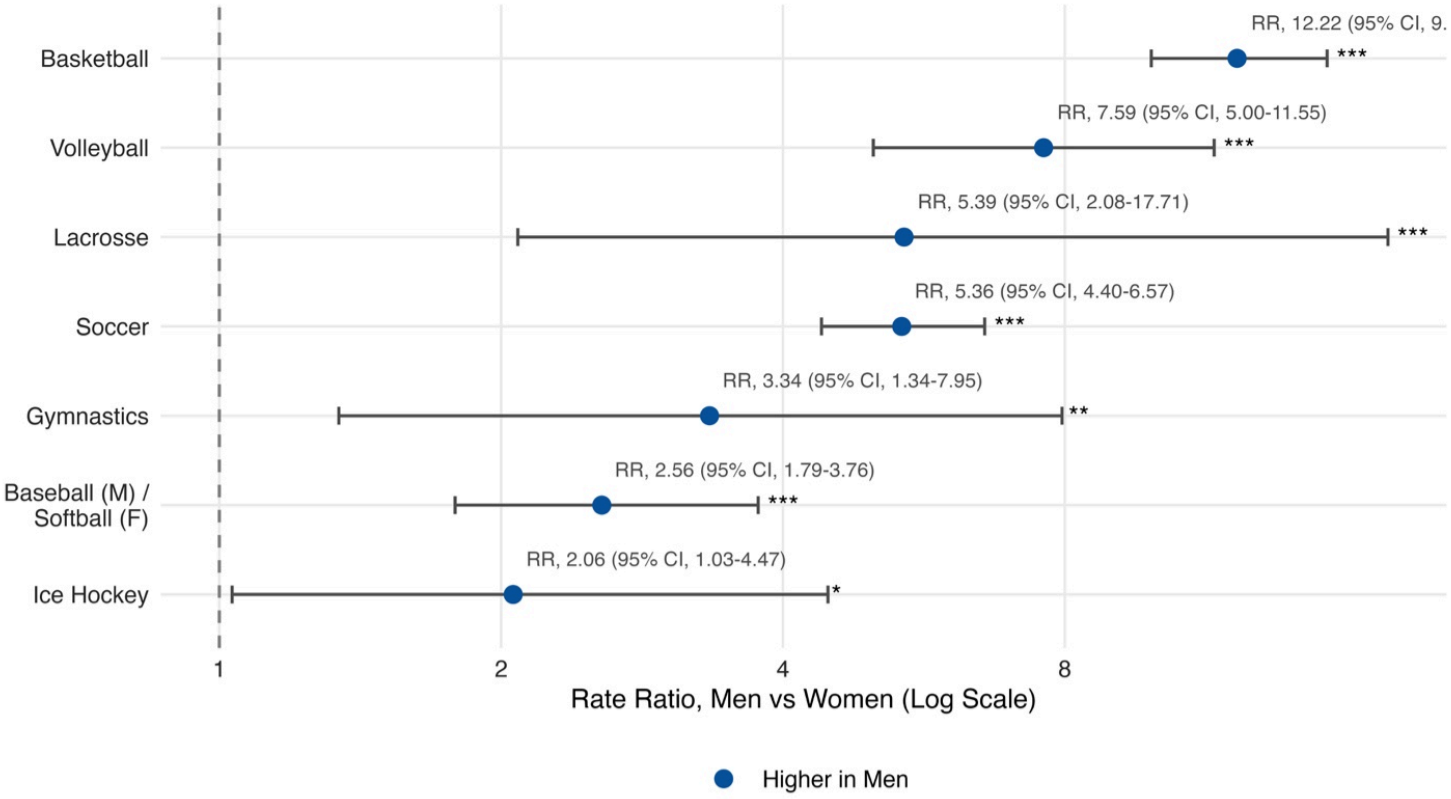

Figure 2

Extremity Fracture Rate Ratio: Men vs. Women by Sport

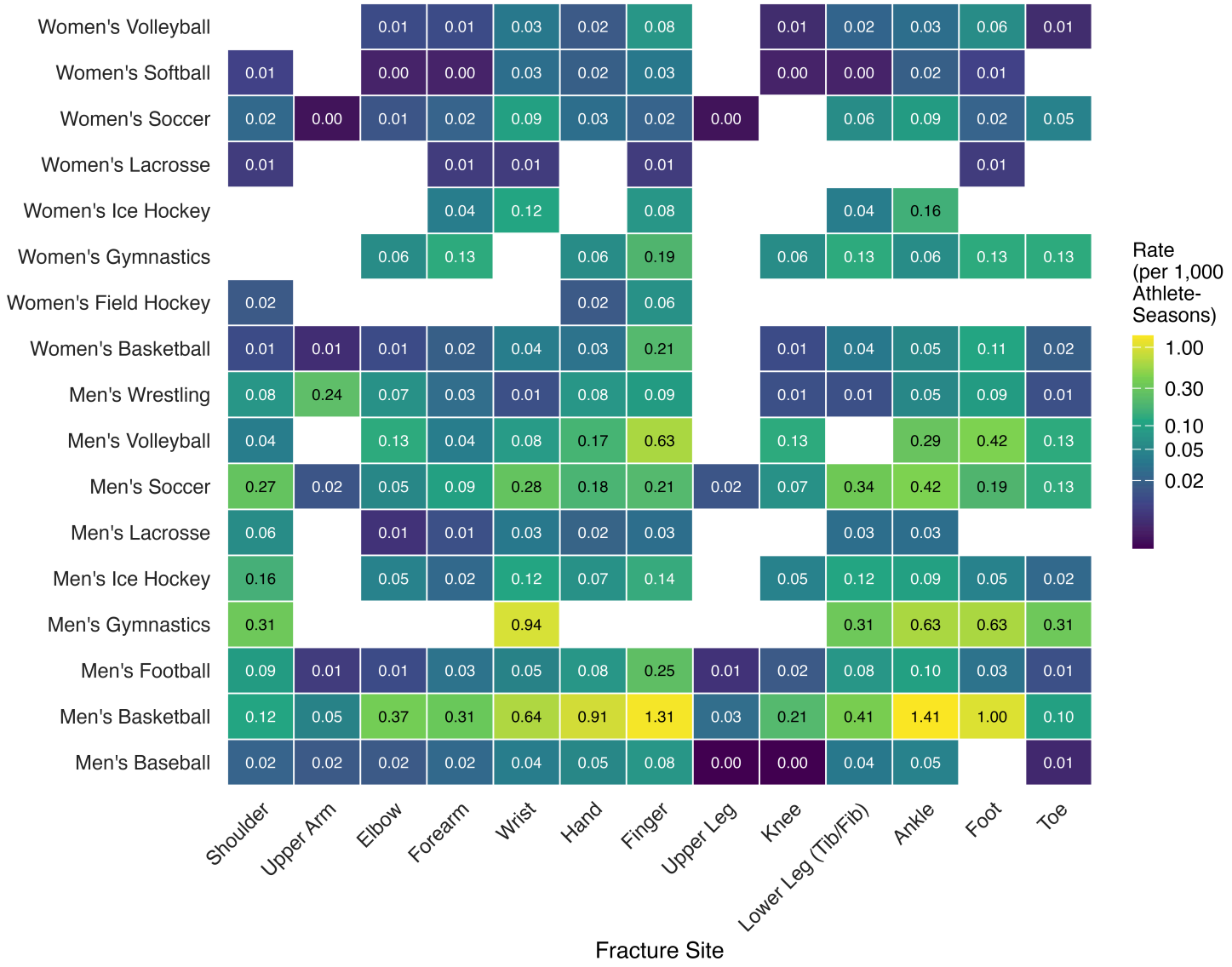

Figure 3

Site-Specific Fracture Incidence in College-Aged Athletes

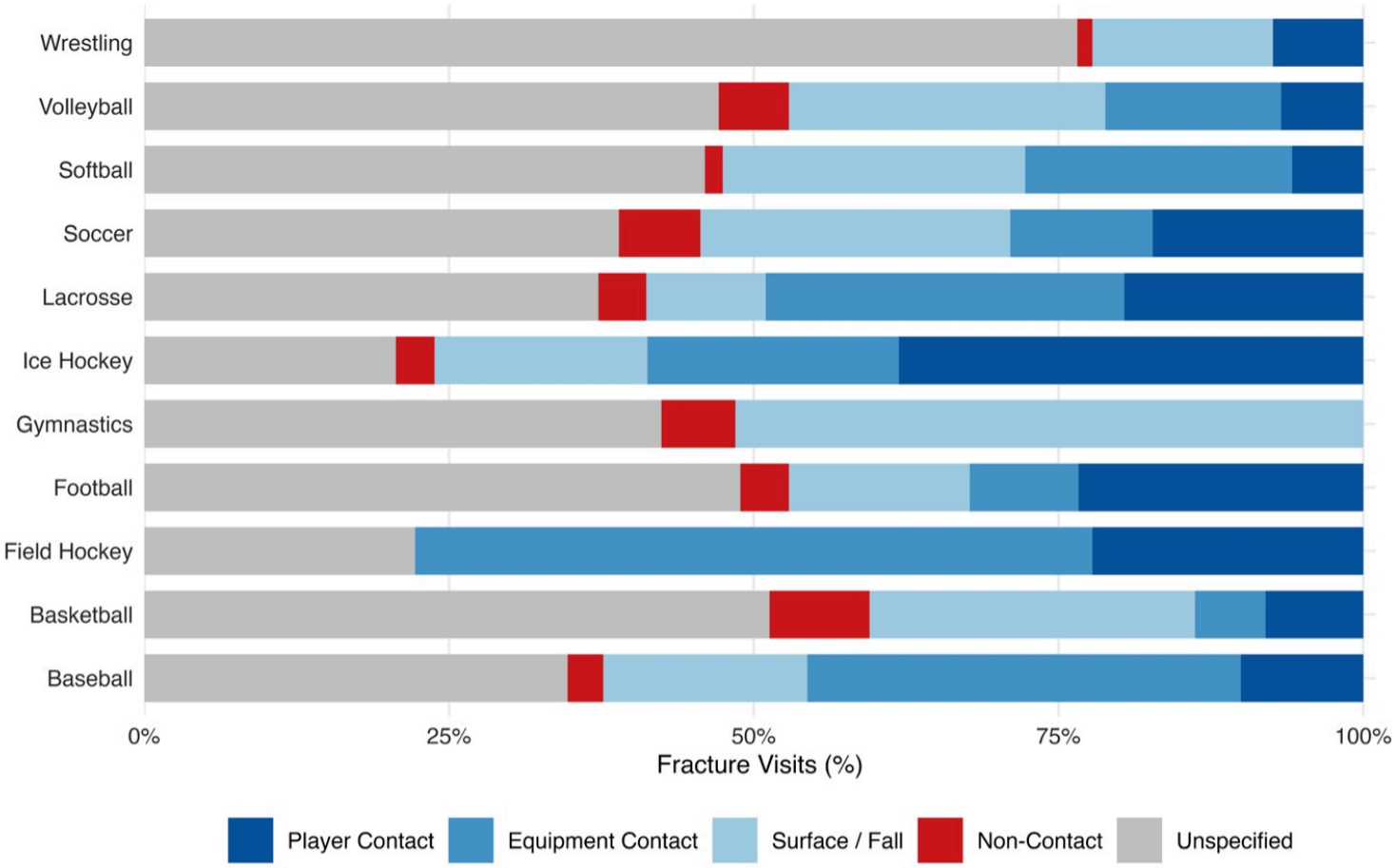

Figure 4

Mechanism Profile by Sport

Supplementary Files

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