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Original Research

Longitudinal Analysis of Subsequent Musculoskeletal Injuries and Predictive Value of Index Injuries in Collegiate Women's Field Hockey

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Abstract

International Journal of Exercise Science 18(5): 182-192, 2025. https://doi.org/10.70252/ODDM9341 This study investigates the longitudinal patterns of musculoskeletal injuries in an NCAA field hockey team, emphasizing the predictive value of index injuries on subsequent injury rates. Analyzing a dataset from a women's collegiate field hockey team, this research monitored 810 injuries across 124 athletes from 2008 to 2024. The study categorized injuries as local, nonlocal, and recurrent, employing a negative binomial regression to assess the impact of index injuries on the total number of career injuries. Results indicated that ankle sprains, hamstring strains, and back strains significantly predicted the total number of career injuries. Furthermore, the analysis revealed that the majority of subsequent injuries occurred within 69 days of the index injury, suggesting a critical window for targeted interventions. The findings underscore the need for robust longitudinal data and standardized reporting to enhance injury prevention strategies in field hockey.

Keywords: Subsequent injuries, NCAA, predictive analysis, injury surveillance, longitudinal study, return-to-play protocols, index injuries, athlete health management

Introduction

Sport participation comes with an inherent risk for injury.[1] Becoming an athlete at any level requires consistent exposure to physical training through practice and competitions. Treatment of injuries could negatively impact the athlete and organization through time away from competition, time away from training, health care costs, and can affect the success of a team or individual.[2,3] It is for this reason that athletic organizations allocate resources towards keeping athletes injury free. Of particular interest in sports epidemiology are *musculoskeletal injuries* (MSI), which are defined as damage to tissues of the muscular or skeletal system including bone, ligaments, tendons, and other soft tissues.[4] Given the large amount of MSI seen in active populations (e.g., MSI are the leading cause of ER visits for athletes in the US[5] and account for most sports injuries[1]), many studies focus on them in pursuit of prevention methods.[6]

The first step in preventing injuries is to identify and describe them[7], a process that requires clear classification and accurate reporting. Across sports organizations, and levels of competition, various injury surveillance protocols attempt to record and classify MSI. For example, in a consensus statement issued by the International Olympic Committee (IOC), they categorize injuries by relationship to sports activity, mode of onset, and mechanism of injury to name a few.[8] The validity and reliability of the reported data is dependent upon multiple factors including *who* is reporting, *what* defines an injury, and *if* the athlete is giving medical professionals accurate information.[9] It is for this reason that clearly defined reporting protocols are required to attain consistent data.

In addition to ensuring accurate reporting of an initial injury to a previously healthy tissue, also known as the *index injury*, it is important to recognize that *subsequent injuries* (i.e., any injury that occurs after an index injury) can result from previous injuries,[10] increasing the likelihood for an athlete to suffer more total injuries in their career[11,12] whether due to incomplete healing of previously injured tissues (exacerbation), or reinjury of a fully recovered tissue defined by the ability of the athlete to return to play and competition (recurrence).[8] *Subsequent injury categorization* (SIC) models consider this cyclic nature and have reporting strategies that accommodate them.[8,13] Traditional injury models do not delineate between recurrent or new injuries, nor do they specify if a subsequent injury was of the same type.[14–16] In the IOC consensus statement,[8] they propose a SIC framework adapted from Hamilton et al which categorizes subsequent injuries based on if the injury occurred to the same body part, to the same area, or to an unrelated area.[17] In addition to injury location they consider the time frame between the first subsequent injury and the index injury.[17] This framework requires athletes to be monitored over the course of long periods of time to gain insight into the time course and relation between injuries. Longitudinal study design aims to collect data on the same subjects at multiple different time points to observe the natural course of development.[18] One of the defining features of longitudinal study design is the ability to analyze causal relationships between events in an ordered fashion.[19] In the context of an athletic career that could span decades, the acquisition of longitudinal data is pertinent to obtaining the scope of an injury career. For organizations with access to a sports medicine team, such as the National Collegiate Athletic Association (NCAA) or professional teams, reporting accurate and reliable information is often required and therefore a viable source for longitudinal studies on MSI.

SIC models have been used to identify subsequent injury trends in major sports but certain sports that are underrepresented, such as women's field hockey, lack research under such models.[20] While field hockey has origins tracing back 4,000 years, it first became popular at public schools in England in the late 19th century, with the first draft of official rules coming in 1876. The sport made its Olympic debut in 1908; however, it wasn't until the 1980 Olympics that women's field hockey made its debut. The FIH (Fédération Internationale de Hockey) was founded in 1924, and the IFWHA (International Federation of Women's Hockey Associations) was founded three years later in 1927. In 1982 the two organizations merged to form the current

FIH.[21] According to the FIH database there are currently 140 member associations worldwide. Currently, in the US, there are 263 active collegiate teams with over 5,000 female athletes.[22] Therefore, the scarcity of literature in field hockey, and women's sports overall,[23] leaves a void that could potentially benefit many young athletes, in a historic and internationally renowned sport.

The current but limited literature suggests that the most common injuries in women's field hockey are lower limb injuries, primarily lateral ankle sprains, followed by upper body injuries due to stick, ball, or player contact.[24,25] It has been speculated that the bent over posture and use of sticks exposes athletes hands, head, and face to injury by getting caught between sticks, players and sticks, or players and the ground, especially when there is congestion around the goal.[25] In 2007, a study by Rauh et al showed that high school girls field hockey players were more likely to suffer three or more injuries, than the other four sports (basketball, soccer, volleyball, and softball) in the study; however, said injuries were less likely to require surgery or result in lost time.[26] To our knowledge, the only studies that have been conducted with NCAA women's field hockey in regards to musculoskeletal injuries are Dick et al in 2007[25] and Nedimyer et al in 2021.[27] While both studies use longitudinal data from the NCAA's *Injury Surveillance Program* (ISP), neither study used SIC. In 2018, in a systematic review of field hockey injuries, Barboza et al[28] attempted to describe injury rates in field hockey of all levels, and of the studies that met inclusion criteria (22) many of them were not conducted longitudinally, some of the data were not recorded by sports medicine professionals, and none of the studies used SIC. While they were able to come to some preliminary conclusions, the major finding of the review was that researchers need to come to a consensus regarding field hockey injury surveillance in order to produce more reliable findings. In 2020, in a systematic review by Bitchell et al they searched for all studies that utilized a SIC model, and out of the 51 studies that met the criteria for data extraction, only one was conducted specifically on female sports and said study was not on women's field hockey.[20] Therefore, the gap in the literature warrants more research on MSI using female athletes under SIC models to assist in the development of injury prevention strategies.

Researchers and sport organizations, including the IOC continue to revise categorization of subsequent injuries to improve reliability and validity of injury data.[8] Current literature on field hockey injuries is not only scarce but also lacks longitudinal studies under SIC models, and does not focus exclusively on women. Therefore, the purpose of this investigation was to describe the longitudinal characteristics of subsequent musculoskeletal injuries suffered by a NCAA collegiate women's field hockey team. Furthermore, we wanted to investigate if the index injury was a significant predictor of an athlete's total injuries suffered in their collegiate career.

Methods

Participants

A de-identified dataset of a women's collegiate field hockey team (convenience sample) that competed at an NCAA Division I institution. The dataset contained 810 musculoskeletal injuries suffered between 2008 and 2024 across 124 athletes (*M*age = 20.02; SD = 1.37).

Protocol

This study was conducted under the authorization of the existing omnibus Institutional Review Board (IRB) protocol (#21.0866). The primary objective of data collection was for clinical and practical applications; therefore, retrospective data were repurposed for research in accordance with the provisions of our existing omnibus IRB. The IRB's ethical guidelines were strictly adhered to, ensuring the protection and confidentiality of all participant data. This research was executed in full compliance with the ethical standards of the *International Journal of Exercise Science.*[29]

More particularly, data included the date the injury was suffered, injury diagnosis (e.g., strain, sprain, tendinopathy), injury body part (e.g., knee, forearm), and body area (e.g., lower extremity, torso, upper extremity). Injury diagnoses that could be categorized within neural or medical were removed to focus on the occurrence of musculoskeletal injury. Subsequent classifications for each injury were appended to the dataset based on location and diagnosis as described per consensus guidelines.[10] Though descriptions of contact vs. non-contact injuries were not recorded, it was assumed that injuries diagnosed as contusions involved external contact by nature. They were removed as subsequent injuries to keep focus on non-contact injuries, bringing the total injuries analyzed down to 655 (124 index injuries and 531 subsequent injuries).

The data were collected using an electronic medical record (EMR) system, which documented the date of injury, injury diagnosis, injury body part, and body area. Injuries were reported by medical staff. The EMR facilitated the categorization and classification of injuries according to established guidelines.

Statistical Analysis

Injury classifications were described using frequency and relative proportion while the total number of injuries suffered by each athlete and days between the index injury and first subsequent injury were described using median and IQR. Furthermore, we wanted to investigate the ability of index injury characteristics to predict the number of injuries an athlete would suffer in their career. The index injury data were fit onto the total number of injuries suffered using a 2-parameter negative binomial regression with an auxiliary OLS regression to estimate alpha. Data analyses were conducted using Python v. 3.11.5 and the Statsmodel package v. 0.14.0.

Results

Out of 531 subsequent injuries, a) 308 (58.00%) were classified as subsequent – local area, b) 197 (37.10%) as subsequent nonlocal, c) 22 (4.14%) as recurrent, and d) 4 (0.75%) as subsequent – local body part (See Table 1). Index injuries comprised 46 different injuries, with the top five most frequent injuries presented in Table 2. Of the most frequent index injuries, ankle sprains (OR = 4.00, 95% CI [1.14, 13.99]), hamstring strains (OR = 4.17, 95% CI [1.80, 9.66]), and back strains (OR = 2.72, 95% CI [1.13, 6.53]) were significant predictors of career injury total, while shin splints and hip flexor strains were not. The overall model was found to be significant (df = 91, $\chi 2 = 124$, $p = < 0.001$), indicating that the index injury may influence the number of injuries an athlete may suffer in a career. Model results for the top five most frequent injuries can be found in Table 2. The interquartile range for the days between the index injury and subsequent injury is 167 days, with the 25th percentile at 23 days, the median at 69 days, and the 75th percentile at 190 days (See Table 3). Figure 1 visually represents the percentage of first subsequent injuries over time.

Table 1. Classification and frequency of injuries among collegiate women's field hockey players.

Injury Classification	Frequency (%)
Recurrent	22 (4.14%)
Subsequent – Local Body Part	4 (0.75%)
Subsequent – Local Area	308 (58.00%)
Subsequent – Nonlocal	197 (37.10%)

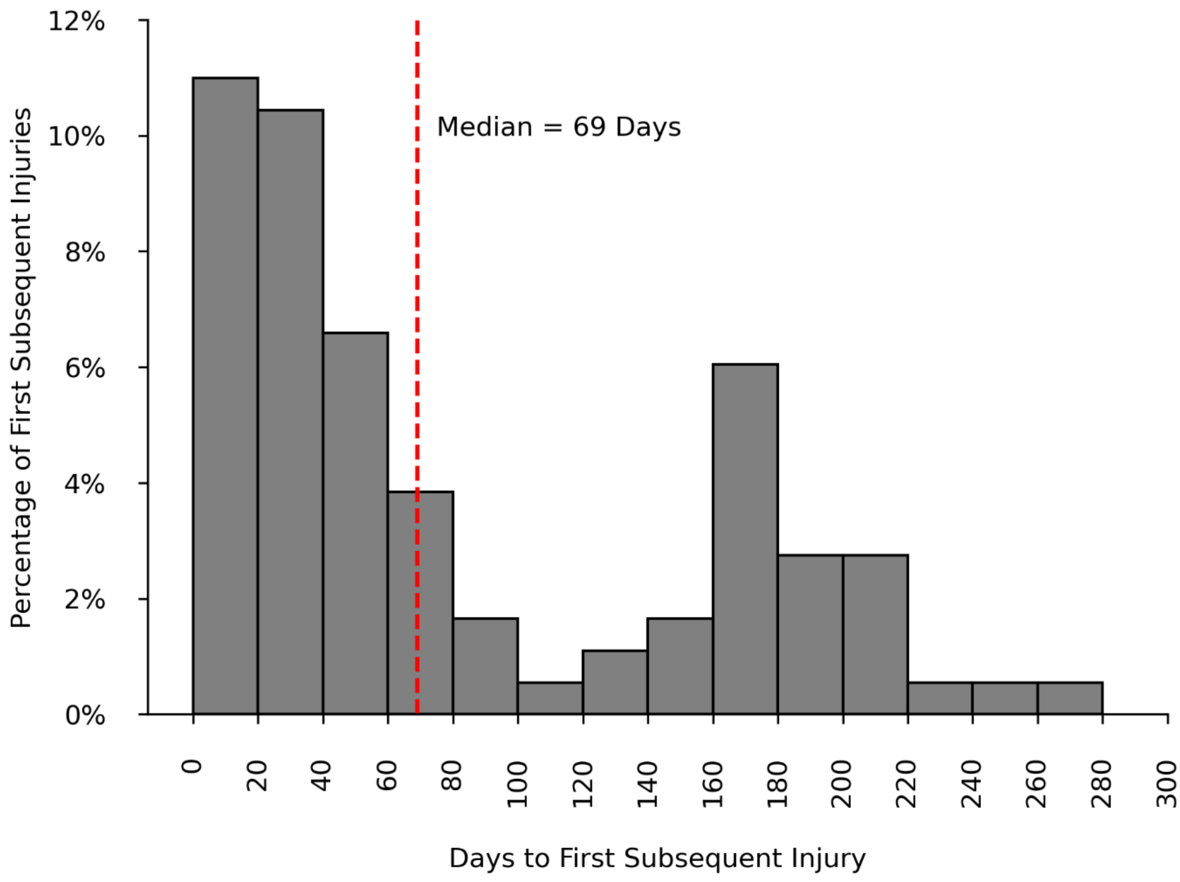

Figure 1. Distribution of days to first subsequent injury among collegiate women's field hockey.

In more detail, the red dashed line indicates the median time to the first subsequent injury, which is 69 days. This means that half of the first subsequent injuries occurred within 69 days of the initial injury. In addition, this histogram shows that the majority of first subsequent injuries occur within the first 80 days, with a peak in the initial 40 days. The frequency of subsequent injuries declines after the initial peak but shows another smaller peak around 120 to 140 days.

Table 2. Frequency and statistical analysis of common injuries among collegiate women's field hockey players.

Injury	Frequency (%)	Beta Coefficient	Standard Error (±)	p-Value
Ankle Sprain	13 (10.5%)	1.386	0.639	0.030*
Shin Splints	11 (8.87%)	0.780	0.435	0.073
Hamstring Strain	9 (7.26%)	1.427	0.429	0.001*
Hip Flexor Strain	8 (6.45%)	0.916	0.488	0.060
Back Strain	7 (5.65%)	0.999	.448	0.026*

Table 3. Descriptive statistics of injury metrics among collegiate women's field hockey players.

Measure	IQR	25%	Median	75%
Days to Subsequent Injury	167	23	69	190
Career Injury Total	5	2	4	7

Discussion

Our study provides several important insights into the nature of subsequent musculoskeletal injuries in collegiate women's field hockey. The key findings reveal that a majority of subsequent injuries are nonlocal, meaning they occur in different locations within or outside the index injury body area. Notably, very few (4.89%) subsequent injuries were classified as recurrent or subsequent to the local body part.

The high proportion (37.1%) of nonlocal subsequent injuries may indicate compensatory movement patterns or altered biomechanics following an initial injury.[30,31] Athletes might unconsciously adjust their movements to protect the injured area, thereby placing additional stress on other body part.[30,31] This hypothesis aligns with previous research suggesting that incomplete rehabilitation and return-to-play protocols can contribute to compensatory injuries.[32] While our study's findings are similar to those found in the existing literature, in that most of the subsequent injuries reported were put into a category that implies little or no relation to the index injury (subsequent nonlocal, and subsequent local area), our study shows less recurrent injuries (4%) than other studies that use similar SIC models.[33,34] For example a study conducted on professional rugby by Williams et al[34] reported 16% of subsequent injuries as recurrent and 14% as subsequent local, similarly another study reported 14% of subsequent injuries as recurrent and 15% as subsequent local.[33] An important caveat to that is, our study delineated between subsequent local area (upper extremity, torso, lower extremity) and subsequent local body part (knee, forearm, ankle etc.) which may imply more or less relation to the index injury based on clinical judgement and proximity to index injury.[16,20] Nonetheless our study showed the largest portion of subsequent injuries were categorized as subsequent local area (58%) and the smallest portion as subsequent local body part (0.75%) followed by recurrent (4%) implying that most SI occur outside of the tissues responsible for the index injury in collegiate women's field hockey. Of the existing literature that uses SIC, the aforementioned studies were the only ones that didn't focus on concussions, and used SIC terminology, and none of them involved field hockey athletes at any level or gender highlighting the underrepresentation of field hockey and inconsistent methodology of SIC.[20,28]

Timing is a critical factor in injury prevention[12] and our analysis showed that 50% of all subsequent injuries occurred within 69 days of the index injury, similar to another study where 42% of their subsequent injuries occurred within 2 months of RTP.[34] This period may represent a critical window for monitoring and intervention to prevent further injuries. The initial peak in subsequent injuries within the first 40 days may underscore the importance of cautious and well-managed return-to-play protocols.[35] Furthermore, there is a noticeable uptick in injuries around 180 days. This pattern may relate to athletes resuming full training intensity (e.g., spring training) or starting a new competitive season, periods known for increased physical demand and higher injury risk;[35,36] therefore this secondary peak around 180 days may suggest another critical period for injury prevention efforts. Other studies that use similar SIC models[37,38] do not typically report injuries in the context of "days to first subsequent injury" and to our knowledge, there are no other studies that have identified this secondary peak at around 180 days. As suggested by Bitchell et al[20], previous studies that have used SIC are often inconsistent in their methodology in that many data were taken only from athletes participating in games or championship events, and data collection often does not occur during the preseason and offseason leaving clinicians to rely on retrospective methods of data collection. This further highlights the importance of longitudinal data collection in SIC that is reported by qualified healthcare professionals who have worked with the same athletes for an extended period.[20]

Certain index injuries, such as ankle sprains, hamstring strains, and back strains, were significant predictors of an athlete's total career injuries. This may suggest that the severity and nature of the initial injury can have a long-lasting impact on an athlete's susceptibility to future injuries.[12] The significant predictive value of certain index injuries suggests that these injuries may disrupt an athlete's training and competition schedule more severely, leading to deconditioning or improper healing.[39] For example, ankle sprains and hamstring strains are known to affect mobility and stability, potentially causing secondary injuries as the athlete attempts to return to their sport.[30,31] This finding aligns with studies by Paterno et al, who demonstrated similar trends in different sports, where initial severe injuries like ACL tears increase the likelihood of subsequent injuries, including contralateral injuries.[40]

Our findings highlight the necessity of applying SIC models in field hockey to better understand injury patterns and develop targeted prevention strategies. Current literature on field hockey injuries is not only scarce but also lacks longitudinal studies under SIC models and does not focus exclusively on women.[25,27] The scarcity of research on MSI in women's field hockey[28] leaves a gap that our study begins to fill, providing valuable data to inform injury prevention strategies and rehabilitation protocols. Researchers and sport organizations, including the IOC, continue to revise categorization of subsequent injuries to improve the reliability and validity of injury data.[8] Therefore, continued research using SIC models in underrepresented sports, like field hockey, is essential to improve athlete health and performance.

Several limitations should be acknowledged. The accuracy of the injury classification may be influenced by how data were recorded in the EMR system[16] Inconsistent recording practices could affect the validity of the findings.[16,20] The exclusion of concussions and contusions might have impacted the overall injury profile.[11,41] Moreover, the findings are based on data from a single NCAA Division I institution (convenience sample), which may limit the generalizability to other levels of competition or geographic regions. Despite these limitations, our study provides valuable insights into the longitudinal characteristics of subsequent musculoskeletal injuries in collegiate women's field hockey.

The study emphasizes the need for robust longitudinal data and standardized injury reporting protocols to enhance the reliability of findings. Future research should focus on investigating the biomechanical and physiological factors contributing to nonlocal injuries (e.g. including the role of concussions and contusions in subsequent injury patterns), ensuring consistent and accurate recording of injuries in EMR systems to differentiate between new and recurrent injuries, and developing and refining return-to-play protocols to mitigate the risk of subsequent injuries, particularly within the critical window identified in this study.[34] By addressing these areas, we can enhance athlete health and performance at all levels of sport, by improving injury prevention and management strategies across multidisciplinary support structures including sports medicine, sports science, strength and conditioning, as well as coach and athlete education.

References

1. Patel DR, Baker RJ. Musculoskeletal injuries in sports. *Primary Care: Clinics in Office Practice*. 2006;33(2):545-579. https://doi.org/10.1016/j.pop.2006.02.001

2. Van Mechelen W. The severity of sports injuries. *Sports Med*. 1997;24(3):176-180. https://doi.org/10.2165/00007256-199724030-00006

3. Hägglund M, Waldén M, Magnusson H, Kristenson K, Bengtsson H, Ekstrand J. Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. *Br J Sports Med*. 2013;47(12):738-742. https://doi.org/10.1136/bjsports-2013-092215

4. Musculoskeletal Health. World Health Organization. July 14, 2022. Accessed July 10, 2024. https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions

5. Nonfatal Sports- and Recreation-Related Injuries Treated in Emergency Departments—United States, July 2000–June 2001. *JAMA*. 2002;288(16):1977. https://doi.org/10.1001/jama.288.16.1977-JWR1023-3-1

6. Goes RA, Lopes LR, Cossich VRA, et al. Musculoskeletal injuries in athletes from five modalities: a cross-sectional study. *BMC Musculoskelet Disord*. 2020;21(1):122. https://doi.org/10.1186/s12891-020-3141-8

7. Van Mechelen W, Hlobil H, Kemper HCG. Incidence, Severity, aetiology and prevention of sports injuries: A review of concepts. *Sports Med*. 1992;14(2):82-99. https://doi.org/10.2165/00007256-199214020-00002

8. International Olympic Committee Injury and Illness Epidemiology Consensus Group, Bahr R, Clarsen B, et al. International Olympic Committee Consensus Statement: Methods for recording and reporting of epidemiological data on injury and illness in sports 2020 (including the STROBE extension for sports injury and illness surveillance (STROBE-SIIS)). *Orthopaed J Sports Med*. 2020;8(2):232596712090290. https://doi.org/10.1177/2325967120902908

9. Hammond LE, Lilley JM, Pope GD, Ribbans WJ. Considerations for the interpretation of epidemiological studies of injuries in team sports: Illustrative examples. *Clin J Sport Med*. 2011;21(2):77-79. https://doi.org/10.1097/JSM.0b013e318201a7ab

10. De Visser H, Reijman M, Heijboer M, Bos P. Risk factors of recurrent hamstring injuries: A systematic review. *Br J Sports Med*. 2012;46(2):124-130. https://doi.org/10.1136/bjsports-2011-090317

11. Biese KM, Kliethermes SA, Watson AM, et al. Musculoskeletal injuries and their association with previous concussion history: A prospective study of high school volleyball and soccer players. *Am J Sports Med*. 2021;49(6):1634-1641. https://doi.org/10.1177/0363546521997116

12. Toohey LA, Drew MK, Cook JL, Finch CF, Gaida JE. Is subsequent lower limb injury associated with previous injury? A systematic review and meta-analysis. *Br J Sports Med*. 2017;51(23):1670-1678. https://doi.org/10.1136/bjsports-2017-097500

13. Fuller CW, Bahr R, Dick RW, Meeuwisse WH. A Framework for recording recurrences, reinjuries, and exacerbations in injury surveillance. *Clin J Sport Med*. 2007;17(3):197-200. https://doi.org/10.1097/JSM.0b013e3180471b89

14. Emery CA, Meeuwisse WH. Risk factors for injury in indoor compared with outdoor adolescent soccer. *Am J Sports Med*. 2006;34(10):1636-1642. https://doi.org/10.1177/0363546506288018

15. Emery CA, Meeuwisse WH, McAllister JR. Survey of sport participation and sport injury in Calgary and area high schools. *Clin J Sport Med*. 2006;16(1):20-26. https://doi.org/10.1097/01.jsm.0000184638.72075.b7

16. Dick R, Agel J, Marshall SW. National Collegiate Athletic Association injury surveillance system commentaries: introduction and methods. *J Athl Train*. 2007;42(2):173-182.

17. Hamilton GM, Meeuwisse WH, Emery CA, Shrier I. Subsequent injury definition, classification, and consequence. *Clin J Sport Med*. 2011;21(6):508-514. https://doi.org/10.1097/JSM.0b013e31822e8619

18. Van Mechelen W, Mellenbergh G. Problems and solutions in longitudinal research: From theory to practice. *Int J Sports Med*. 1997;18(S 3):S238-S245. https://doi.org/10.1055/s-2007-972721

19. Deschenes EP. Longitudinal research designs. In: Kempf KL, ed. *Measurement Issues in Criminology*. Springer New York; 1990:152-166. https://doi.org/10.1007/978-1-4613-9009-1_7

20. Bitchell CL, Varley-Campbell J, Robinson G, Stiles V, Mathema P, Moore IS. Recurrent and subsequent injuries in professional and elite sport: A systematic review. *Sports Med - Open*. 2020;6(1):58. https://doi.org/10.1186/s40798-020-00286-3

21. FIH. The History of FIH & Hockey. Accessed May 20, 2024. https://www.fih.hockey/about-fih/history

22. NCSA. Your complete list of colleges with field hockey teams. Accessed May 20, 2024. https://www.ncsasports.org/field-hockey/colleges

23. Smith ES, McKay AKA, Ackerman KE, et al. Methodology review: A protocol to audit the representation of female athletes in sports science and sports medicine research. *Int J Sport Nutr Exerc Metab*. 2022;32(2):114-127. https://doi.org/10.1123/ijsnem.2021-0257

24. Murtaugh K. Injury patterns among female field hockey players: *Med Sci Sports Exerc*. 2001;33(2):201-207. https://doi.org/10.1097/00005768-200102000-00005

25. Dick RW, Hootman JM, Agel J, Vela L, Marshall SW, Messina, Renee. Descriptive epidemiology of collegiate women's field hockey injuries: National Collegiate Athletic Association injury surveillance system, 1988-1989 through 2002-2003. *J Athl Train*. 2007;42(2):211-220.

26. Ruah MJ, Macera CA, Ji M, Wiksten DL. Subsequent injury patterns in girls' high school sports. *J Athl Train*. 2007;42(4):486-489.

27. Nedimyer AK, Boltz AJ, Robison HJ, Collins CL, Morris SN, Chandran A. Epidemiology of injuries in National Collegiate Athletic Association women's field hockey: 2014–2015 through 2018–2019. *J Athl Train*. 2021;56(7):636-642. https://doi.org/10.4085/1062-6050-428-20

28. Barboza SD, Joseph C, Nauta J, Van Mechelen W, Verhagen E. Injuries in field hockey players: A Systematic review. *Sports Med*. 2018;48(4):849-866. https://doi.org/10.1007/s40279-017-0839-3

29. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. *Int J Exerc Sci*. 2019;12(1):1-8. https://doi.org/10.70252/EYCD6235

30. Orchard JW. Intrinsic and extrinsic risk factors for muscle strains in Australian football. *Am J Sports Med*. 2001;29(3):300-303. https://doi.org/10.1177/03635465010290030801

31. Verrall GM, Slavotinek JP, Barnes PG, Fon GT, Spriggins AJ. Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging. *Br J Sports Med*. 2001;35(6):435-439. https://doi.org/10.1136/bjsm.35.6.435

32. Waldén M, Hägglund M, Ekstrand J. High risk of new knee injury in elite footballers with previous anterior cruciate ligament injury. *Br J Sports Med*. 2006;40(2):158-162. https://doi.org/10.1136/bjsm.2005.021055

33. Moore IS, Mount S, Mathema P, Ranson C. Application of the subsequent injury categorisation model for longitudinal injury surveillance in elite rugby and cricket: intersport comparisons and inter-rater reliability of coding. *Br J Sports Med*. 2018;52(17):1137-1142. https://doi.org/10.1136/bjsports-2016-097040

34. Williams S, Trewartha G, Kemp S, et al. Subsequent Injuries and Early Recurrent Diagnoses in elite Rugby Union Players. *Int J Sports Med*. 2017;38(10):791-798. https://doi.org/10.1055/s-0043-114862

35. Bengtsson H, Ekstrand J, Waldén M, Hägglund M. Few training sessions between return to play and first match appearance are associated with an increased propensity for injury: A prospective cohort study of male professional football players during 16 consecutive seasons. *Br J Sports Med*. 2020;54(7):427-432. https://doi.org/10.1136/bjsports-2019-100655

36. Agel J, Schisel J. Practice injury rates in collegiate sports. *Clin J Sport Med*. 2013;23(1):33-38. https://doi.org/10.1097/JSM.0b013e3182717983

37. Moore IS, Ranson C, Mathema P. Injury Risk in International Rugby Union: Three-Year Injury Surveillance of the Welsh National Team. *Orthopaed J Sports Med*. 2015;3(7):232596711559619. https://doi.org/10.1177/2325967115596194

38. Pearce CJ, Brooks JHM, Kemp SPT, Calder JDF. The epidemiology of foot injuries in professional rugby union players. *Foot Ankle Surg*. 2011;17(3):113-118. https://doi.org/10.1016/j.fas.2010.02.004

39. Hewett TE, Di Stasi SL, Myer GD. Current concepts for injury prevention in athletes after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2013;41(1):216-224. https://doi.org/10.1177/0363546512459638

40. Paterno MV, Rauh MJ, Schmitt LC, Ford KR, Hewett TE. Incidence of second ACL injuries 2 years after primary ACL reconstruction and return to sport. *Am J Sports Med*. 2014;42(7):1567-1573. https://doi.org/10.1177/0363546514530088

41. Brooks MA, Peterson K, Biese K, Sanfilippo J, Heiderscheit BC, Bell DR. Concussion increases odds of sustaining a lower extremity musculoskeletal injury after return to play among collegiate athletes. *Am J Sports Med*. 2016;44(3):742-747. https://doi.org/10.1177/0363546515622387