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ORIGINAL RESEARCH

Lower extremity injuries in U.S. national fencing team members and U.S. fencing Olympians

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ABSTRACT

Introduction: Fencing is growing rapidly in popularity and competitiveness with fencers beginning at a younger age and competing in more tournaments. Even though fencing has a low risk of time-loss injury, fencers are inevitably going to experience injuries if proper athletic training and prevention does not occur. We aim to describe and compare the lower extremity injuries experienced by fencers that have trained at the highest level in the sport. We hypothesized that athletes who fenced longer would suffer more knee and hip injuries and report lower IKDC and HOS scores.

Methods: This is an epidemiology study distributed to members of the U.S. national team and Olympic team from 1980 to 2018. The electronic survey included questions regarding age, weapon, number of years fencing, number of national and Olympic teams, injuries on the dominant and nondominant hip and knee, time missed due to injury, and methods for treatment. The survey also included the International Knee Demographic Committee (IKDC) and Hip Outcome Score (HOS).

Results: There were 153 national team members between July 1980 and July 2018, 110 with contact information. A total of 77 athletes submitted the survey, consisting of 30 females and 47 males. Female fencers had more hip injuries and lower IKDC and HOS scores than their male counterparts. In total, there were 71 injuries to the dominant (front) knee and 28 injuries to the nondominant (back) knee. There were 32 dominant hip injuries and 5 nondominant hip injuries. Saber fencers reported the most dominant and nondominant hip and knee injuries.

Conclusion: The intense, repetitive and asymmetrical movements involved in fencing affect the weight bearing leg and the nondominant leg in all weapons. Special attention should be paid to female fencers as they experience more hip and knee injuries resulting in impaired joint function.

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Fencing injuries; lower limb fencing injuries; Olympic fencers; elite fencing injuries

Introduction

Fencing is one of the only four sports that has been included in every modern Olympic Games [1,2]. The sport has experienced a tremendous growth in popularity within the United States, with the registered members of the U.S. Fencing Association (USFA) nearly tripling from 14,000 in 1999 to over 40,000 in 2019 [1]. Concomitantly, fencers have begun training at younger ages and competing in more tournaments. Although previous literature has demonstrated fencing to have a low risk of time-loss injury, the increased participation at younger ages pushes the fencing community to understand rates and mechanisms of injury in order to optimize training and minimize injury risk [3,4].

Often compared to physical chess, fencing is a sport that requires a combination of athleticism, strategy and stamina. It is comprised of three weapons: foil, saber, and epee. Each weapon has its own blade, target area, and rules associated with earning a touch. Saber is the fastest weapon, requiring athletes to start, stop, and change direction at a rapid pace. Foil and epee utilize a cat-and-mouse strategy, requiring a slower speed throughout the bout and more explosive attacks in the sagittal plane.

All fencers begin in an 'engarde' stance with the feet shoulder with apart, the front foot pointing forward and the back foot perpendicular under the hip for stability, creating an L shape (Figure 1a). To move forward, or advance, the fencer lifts the front foot first to take a step followed by the back foot. To move backward, or retreat, the fencers lift the back foot first followed by the front. To finish an attack, the fencer uses a powerful lunge, kicking the front foot forward and straightening the back leg (Figure 1b). Most importantly, the hand holding the weapon must be the same side as the weight bearing leg (e.g. right-handed fencers must have their right leg in front).

The strength, power, explosive forces, and power absorption in combination with asymmetrical body movements place high physiological demands on the body [5,6]. As a result of these repetitive movement, fencers are susceptible to lower extremity injuries from overuse [7]. Nevertheless, the literature is relatively scant on fencing injuries. Some European studies have analyzed fencing epidemiology and have shown that the most common area of injury is the lower extremity, compared to the back and upper extremities. However, there is no available literature on elite American fencing injuries. We aimed to

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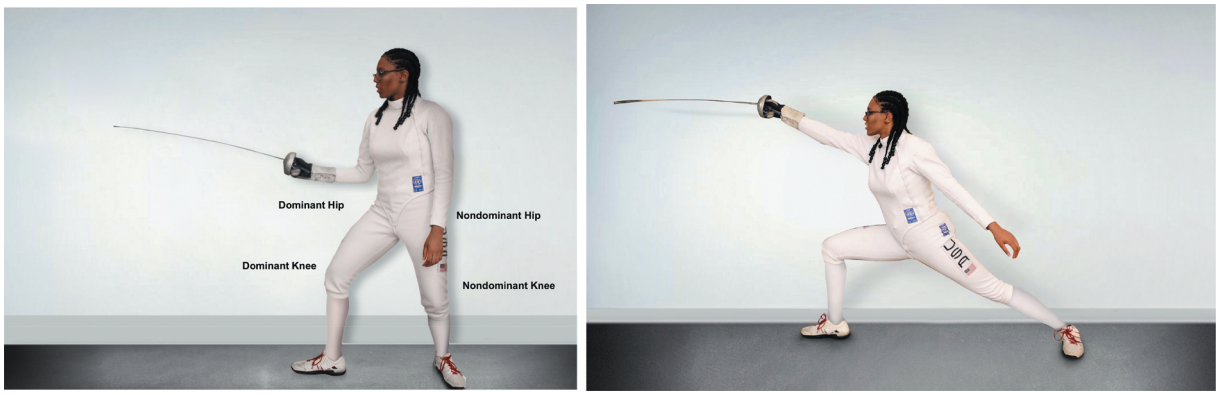

Figure 1. (a) Right-handed epee fencer in 'en garde' position, (b) Right-handed epee fencer in a lunge.

describe and compare the lower extremity injuries, time lost and treatment of the injuries experienced by fencers that have trained at the highest level in order to identify points of intervention for injury mitigation and prevention. Furthermore, we hypothesized that athletes who fenced longer would suffer more knee and hip injuries and report lower IKDC and HOS scores.

Methods

This was an epidemiological study of lower extremity injuries in U.S. national team members and Olympians from 1980 to 2018. The Institutional Review Board at our academic center and the U.S. Fencing Association approved this study. National team members were defined as the top four fencers on the national points list at the end of the season, who competed in World Championships or in the Olympics if the Olympics occurred that year.

Survey design

A 50-question open-ended and multiple-choice survey was electronically distributed via SurveyMonkey to each member of the U.S. National team and Olympic team. The U.S. Fencing Association provided the names of each national team member and Olympian during this timeframe along with available e-mail addresses. The survey included demographic information, such as age, weapon, sex, hand dominance, number of years fencing, number of national teams, and number of Olympic teams. Four reminder e-mails were sent within a two-month period.

Athletes were surveyed about dominant and nondominant hip and knee injuries during or in relation to their fencing career. Athletes were also asked about treatment methods and the time lost from fencing due to an injury: 1–4 weeks, 1 – 3 months, 3–6 months, or 6–12 months. The dominant knee and hip were defined as the joint belonging to the fencer's front leg in fencing position (Figure 1a). Athletes were also asked about additional lower extremity injuries.

The International Knee Demographic Score (IKDC) and Hip Outcome Score (HOS) were also collected. The IKDC consists of questions pertaining to knee symptoms (7 items), function (2 items), and sports activities (2 items). The score ranges from 0 to 100, with 100 representing the highest level of function and lowest level of symptoms. The validity and reliability of the IKDC has been tested numerous times [8–12]. The Hip Outcome Score (HOS) consists of questions pertaining to activities of daily living (17 items) and sports (9 times). Similar to the IKDC, the HOS score ranges from 0 to 100, with 100 representing the highest level of function [13–15].

Statistical analysis

Statistical analysis was performed using SPSS statistical software version 24 (IBM, Armonk, NY). Continuous variables were compared using the Wilcoxon rank sum test and one-way Anova. The findings were considered significant at $p < 0.05$. Continuous variables are presented as mean, standard deviation, and range. Categorical variables are presented as frequency and percentage.

Results

Demographics

There were 153 national team members between July 1980 and July 2018. Contact information was available for 110 athletes. Of the 110 athletes contacted, a total of 77 athletes submitted the survey. Among the athletes, 47 were males and 30 were females. The mean age and body mass index (BMI) of

Table 1. Demographic information (n = 77).

Age (years)	38.6 ± 11.9
Body Mass Index (kg/m^2)	24.9 ± 4.4
Years Fencing	16.7 ± 4.7
Olympic Teams	1.0 ± 1.3
National Teams	5.4 ± 4.1
Weapon	
Saber	29 (37.7%)
Epee	23 (29.9%)
Foil	20 (26.0%)
Foil and Epee	5 (6.5%)
Sex	
Female	30 (39.0%)
Male	47 (61.0%)

(* Age, BMI, years fencing, Olympic and national teams are reported as mean ± standard deviation.)

Table 2. Patient reported outcomes by fencing weapons and gender.

	N	IKDC Score	HOS Score
Female			
All	30	84.9 ± 17.6	94.1 ± 9.2
Foil	13	84.8 ± 18.7	93.4 ± 8.6
Epee	5	85.4 ± 9.8	99.8 ± 0.6
Saber	8	90.2 ± 16.6	96.1 ± 4.5
Foil and Epee	4	71.8 ± 26.3	82.4 ± 15.6
Male			
All	47	92.1 ± 10.1	98.3 ± 5.6
Foil	8	97.1 ± 4.4	99.3 ± 1.8
Epee	18	85.1 ± 14.6	98.7 ± 2.8
Saber	21	91.0 ± 11.3	96.7 ± 6.4

a.Reported values are means with standard deviations.
b.IKDC (International Knee Demographic Score) and HOS (Hip Outcome Score) are scored out of 100.

the athletes were 38.6 ± 11.9 years and 24.9 ± 4.4 kg/m^2, respectively (Table 1).

Patient reported outcomes

There was no correlation between number of Olympic and national teams and IKDC or HOS score. There was no statistically significant difference in PRO scores between weapons. Female fencers had lower PRO scores than their male counterparts (Table 2). Overall, the cohort of female fencers showed a statistically significant lower IKDC (84.9 vs 92.1, p = 0.04) and HOS Score (94.1 vs 98.3, p = 0.03) than male fencers.

Injury classification

Dominant knee injuries were more common than nondominant knee injuries. In total, there were 71 injuries to the dominant (front) knee and 28 injuries to the nondominant (back) knee (Table 3). Fifty-three (69%) fencers had at least one injury to the dominant (front) knee. Undiagnosed knee pain was the most common diagnosis in both knees, followed by meniscus injury (tear/degeneration). There were no reports of multiple injuries to the nondominant knee.

In total, there were 32 dominant (front) hip injuries and 5 nondominant (back) hip injuries. Twenty-four (31%) fencers reported at least one dominant hip injury (Table 4). Muscle strain was the most common diagnosis in dominant hips, whereas muscle strain and labral tears were the most common in nondominant hips.

Additionally, males reported 55% of knee injuries and female reported 77% of hip injuries. There was no correlation between age or number of national teams and number of dominant and nondominant injuries in either cohort.

Incidence by weapon

Overall, there were 50 injuries reported among saber fencers, 34 injuries in foil, 33 injuries in epee, and 20 injuries in joint foil and epee fencers. Saber fencers reported the most injuries in all categories. Saber fencers consisted of 35% of dominant knee injuries, 36% of nondominant knee injuries, 33% of dominant hip injuries, and 80% of nondominant hip injuries (Table 3, 4). Epee fencers had the second highest number of dominant and nondominant knee injuries (Table 3). Foil fencers reported the second highest number dominant hip injuries (Table 4). No foil fencers reported an injury to the nondominant hip.

Table 3. Knee injuries by fencing weapon.

	Total N	Foil	Epee	Saber	Foil and Epee
Dominant Knee Injury					
Undiagnosed knee pain	26	6 (23.1%)	9 (34.6%)	10 (38.5%)	1 (3.8%)
Meniscus tear	7	2 (28.6%)	2 (28.6%)	2 (28.6%)	1 (14.3%)
Patellofemoral pain syndrome	7	2 (28.6%)	2 (28.6%)	0 (0.0%)	3 (42.9%)
IT band syndrome	6	1 (16.7%)	2 (33.3%)	2 (33.3%)	1 (16.7%)
Osteoarthritis	5	1 (20%)	1 (20%)	2 (40%)	1 (20%)
Patellar/quad tendinitis/bursitis	5	(0 (0%)	2 (40%)	3 (60%)	0 (0%)
Loose bodies, Osteochondral lesion	5	1 (20%)	0 (0%)	3 (66.6%)	1 (20%)
Patellar instability	3	2 (66.6%)	0 (0%)	0 (0%)	1 (33.3%)
Osgood Schlatter	3	2 (66.6%)	0 (0.0%)	1 (33.3%)	0 (0%)
Ligament injury	2	0 (0.%)	1 (50%)	1 (50%)	0 (0%)
Fracture	2	1 (50%)	0 (0%)	1 (50%)	0 (0%)
Total	71	18 (25.4%)	19 (26.8%)	25 (35.2%)	9 (12.7%)
Nondominant Knee Injury					
Undiagnosed knee pain	9	1 (11.1%)	2 (22.2%)	3 (33.3%)	3 (33.3%)
Meniscus injury	7	3 (42.9%)	1 (14.3%)	1 (14.3%)	2 (28.6%)
IT band syndrome	4	1 (25%)	0 (0%)	3 (75%)	0 (0%)
Ligament injury	3	0 (0.0%)	2 (66.6%)	1 (33.3%)	0 (0%)
Osteoarthritis	2	1 (50%)	0 (0%)	1 (50%)	0 (0%)
Patellar tendinitis	2	0 (0%)	1 (50%)	1 (50%)	0 (0%)
Patellofemoral pain syndrome	1	0 (0%)	1 (100%)	0 (0%)	0 (0%)
Total	28	6 (21.4%)	7 (25%)	10 (35.8%)	5 (17.9%)

Management of injury

Time loss injuries

Few injuries required athletes to miss an extended amount of time during the season. Meniscus injury, patellar/quadriceps tendinitis/bursitis, and ligament injury were the biggest time loss injuries. More than 50% of the athletes with these injuries missed 1–6 months of practice per injury. Examining the athletes who missed 1–6 months of practice, only four athletes (5%) had surgery (meniscus repair and patellar fracture). An additional 20–43% of the athletes with the previously listed injuries missed 6–12 months of a season. Only two athletes who missed 6–12 months required surgery (ACL reconstruction and meniscus repair). The majority of patients with undiagnosed knee pain, PFPS, and IT band syndrome did not miss any part of a season. The remaining knee injuries required athletes to miss less than 1 month the season.

Table 4. Hip injuries by fencing weapon.

	Total N	Foil	Epee	Saber	Foil and Epee
Dominant Hip Injury					
Muscle strain	13	1 (7.7%)	2 (15.4%)	8 (61.5%)	2 (15.4%)
Labral tear	6	4 (66.7%)	1 (16.7%)	0 (0%)	1 (16.7%)
Impingement	4	2 (50%)	1 (25%)	1 (25%)	0 (0%)
Osteoarthritis	4	3 (75%)	0 (0%)	1 (25%)	0 (0%)
Fracture	2	0 (0%)	1 (50%)	1 (50%)	0 (0%)
Snapping hip syndrome	2	0 (0%)	1 (50%)	0 (0%)	1 (50%)
General pain	2	0 (0%)	0 (0%)	0 (0%)	2 (10%)
Total	33	10 (30.3%)	6 (18.2%)	11 (33.3%)	6 (18.2%)
Non Dominant Hip Injury					
Labral tear	2	0 (0%)	1 (50%)	1 (50%)	0 (0%)
Muscle strain	2	0 (0%)	0 (0%)	2 (100%)	0 (0%)
Bursitis	1	0 (0%)	0 (0%)	1 (50%)	0 (0%)
Total	5	0 (0%)	1 (20%)	4 (80%)	0 (0%)

Among hip injuries, 33% of labral tears and 25% of impingement cases required surgery and caused athletes to miss 3–6 months of the season. The remaining hip injuries required athletes to miss less than 1 month of practice or occurred after the cessation of their fencing career.

Non operative treatment

The most commonly utilized treatment options for knee injury were physical therapy, ice, OTC medications, and PT modalities (KT tape, knee brace, and stim therapy). The most common treatment methods for hip injury were physical therapy, ice, and OTC medications. PT modalities utilized for hip injuries consisted of KT tape, massage, acupuncture, and stim therapy.

Operative treatment

There were 11 knee injuries (11%) requiring operative treatment (Table 5). The length of postoperative PT required ranged from 3 to 24 months. Ninety percent of the patients reported improvement or feeling completely pain free postoperatively. Five hip injuries required surgery and 100% of the patients felt that their symptoms were alleviated.

Additional injuries

Ankle sprains were the most common injury after knee and hip injuries, occurring in 20% of the athletes. Fifty-six percent of all fencers who reported ankle sprain suffered multiple ankle sprains. Twenty-five percent of the fencers with a history of ankle sprains reported bilateral ankle sprains. Saber fencers experienced the highest number of additional ankle injuries, followed by foil then epee.

Table 5. Operative treatment.

Knee Operations	N	Procedure	PT (months)	Improvement
Undiagnosed knee pain	1	Arthroscopy	3	4
Ligament tear	1	ACL Reconstruction	24	4
Meniscus tear	3	Meniscectomy Meniscus Repair (2)	4.3 (3–6)	3.3 (1–5)
Synovial cyst	1	Arthroscopy	3	1
Patellar chondromalacia	1	Debridement	6	4
Osteochondral lesion	1	Debridement	3	3
Patellar fracture	1	ORIF	3	4
Loose Bodies	2	Debridement	3.5 (1–6)	4.5 (4–5)
Hip Operations				
Labral Tear	2	Labral Repair	15 (6–24)	4
Osteoarthritis	1	Total Hip Arthroplasty	6	4
Snapping hip syndrome	1	Labral Repair	3	5
Impingement	1	Labral Repair	24	2

*Improvement scale: 1- no improvement, 2- slight, 3- somewhat, 4- very, 5- completely pain free.

Discussion

While several studies have examined the epidemiology of fencing injuries, this is the first published epidemiologic study of injuries fencers face after years of competing at the highest possible level in the United States [2,3,16–18]. In comparison to other contact sports, the lower extremity injury rate is low among professional fencers indicating fencing is a relatively safe sport [19–22]. Although fencing is a classified contact sport, the incidence of traumatic injuries is minimal. Notably, 11% of knee injuries and 31% of hip injuries required operative treatment.

Our hypothesis was that athletes who fenced longer and at a higher level, represented by the number of national and international teams, would experience more knee and hip injuries and report lower IKDC and HOS scores. Our results determined that there was no correlation between the length of a fencing career and joint function or number of injuries. However, specific associations between injury pattern, gender, and fencing weapon were found.

Our study determined saber fencers reported the highest amount of lower extremity injuries. The fast pace of saber fencing requires athletes to start, stop, and change direction very rapidly. This aggressive and dynamic movement may be the cause of saber fencers suffering the greatest number of injuries. Foil and epee fencers may face less injuries because their bouts move at a slower speed and occur over a longer period of time.

Our findings were comparable to the existing literature. Park et al. and Harmer et al. similarly determined saber fencers experienced the most lower extremity injury when studying the international arena [16,23]. These results differ from a 1991 Italian study which reported foil fencers with the highest incidence [24]. Harmer et al. also found the knee to be the most common site of injury during national competitions in the United States. [2]. Furthermore, additional studies have documented ankle

injuries as the most common in fencers after knee and hip injuries [16,23].

It has been shown that fencing injuries occurred more frequently during training sessions (range 77–95%) than competition [16,23]. While previous fencing studies related the cause of most injuries to technical problems such as incorrect body alignment and poor coordination, this explanation likely does not apply to athletes at the Olympic level [25]. Instead, it is more likely that injuries may arise from the unique unilateral nature and overuse aspects of the sport. Whole body strengthening programs and cross-training may help to reduce muscle imbalances [26,27]. In fact, numerous athletes in our study increased swimming and weight training to strengthen their muscles after injury occurrence.

Additionally, women reported lower IKDC and HOS scores and a vast majority of the hip injuries. It has been shown in several sports, female athletes have more hip and knee injuries than males because anatomical differences in the pelvic area evoke different mechanical responses [28,29]. An increased Q angle increases femoral anteversion and the angle of knee valgus, putting female athletes more at risk for patellofemoral injuries or knee injuries in general [28,30–33]. Our study did not obtain measurements to help determine a relationship between lower extremity anatomy and fencing injuries. Future studies could explore a possible correlation.

It should be noted national team members arguably have the best medical access of all fencers. The United States Fencing Association provides medical coverage for national team members and Olympians and has partnerships with hospitals and physical therapy centers in addition to the facilities at the United States Olympic Training Center. With this in mind, future studies should look at fencers who are on the cusp of qualifying for the national team and ranked 5–8 on the national points list. These fencers are often training at the same elite level and traveling to the same competitions but may not have the same medical access, opportunities for injury prevention, or rehabilitation after an injury has occurred.

Limitations

Our study has several limitations. First, data for our study were self-reported and may be subject to recall bias. This may impact the number of injuries, time lost, or treatment methods reported. A stronger study would have utilized the athlete's electronic health records to have a more reliable diagnosis and timing of events. Unfortunately, there are no cohesive electronic medical databases in fencing as the athletes do not exclusively train at one facility. Second, there may have been a component of selection bias as all athletes were not able to be reached. We believe, however, that since the majority of athletes did respond, they are representative of the population as a whole. Future directions include examining the epidemiology of injuries in sub-elite, collegiate, and recreational fencers.

Conclusion

The strength, power, explosive forces, and power absorption in combination with asymmetrical movements involved in fencing place high physiological demands on the body. These intense, repetitive motions not only affect the weight bearing leg, which is more susceptible to injury, but can have consequences on the nondominant leg as well in all weapons. While there was no correlation between the length of a fencing career and joint function or number of injuries, there are weapon and sex-specific trends. Special attention should be paid to female fencers as they experience more hip and knee injuries resulting in impaired joint function. As fencing continues to grow, it is imperative for anyone managing these athletes to understand the risk factors involved in injury generation.

Declaration of interest

No potential conflict of interest was reported by the authors.

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