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The Prevalence and Incidence of Fencing Injuries and Associated Risk Factors: A Systematic Review and Meta-Analysis

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Abstract

Objective: To summarize the prevalence, incidence, and factors associated with fencing injuries among able-bodied (AFs) and wheelchair fencers (WFs). **Data Sources:** Literature was searched on 7 databases from inception to June 30, 2023. Two independent reviewers screened abstracts and full texts, extracted data, and conducted risk of bias assessments and meta-analyses. Studies were included if they reported the prevalence/incidence of fencing injuries/pain, and associated factors with relevant statistics in AFs or WFs. The quality of evidence of all factors was evaluated by GRADE. **Main Results:** In total, 19 out of 298 identified studies were included. These included studies demonstrated very low to moderate methodological quality. Eight included studies investigated the prevalence of fencing injuries in 1151 AFs, while 11 studies reported its incidence in 164 485 AFs and 14 WFs. The prevalence of fencing injuries in AFs ranged from 51.5% to 92.8%. Professional fencers had higher injury rates than nonprofessional counterparts. Moderate-quality evidence supported that older age, more fencing experiences, and Functional Movement Screen scores <15 were independently related to a higher prevalence of fencing injuries among nonprofessional AFs. Very low-quality evidence showed that male sabreurs, higher competitive levels, and regular involvement in fitness programs were associated with more fencing injuries in AFs. Very low-quality evidence suggested that older age and sabreurs were risk factors for fencing injuries in AFs, while poor trunk control was a risk factor for fencing injuries in WFs. **Conclusions:** This is the first systematic review and meta-analysis to reveal the high prevalence and incidence of fencing injuries among AFs and WFs. However, the insufficient evidence regarding risk factors for these injuries highlights the importance of conducting prospective studies to investigate potential environmental, physical, and psychological risk factors for fencing injuries among AFs and WFs. Future research should also investigate the mechanisms underlying fencing injuries in AFs and WFs.

Key Words: epidemiology, fencing injury, risk factors, fencers

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BACKGROUND

Foil, épée, and saber are three classical fencing styles in modern fencing competitions including the Olympic games.[1] Given the repetitive, impulsive, and asymmetrical nature of sport fencing, able-bodied (AFs) and wheelchair fencers (WFs) are vulnerable to sustaining musculoskeletal injuries.[2,3] Because AFs need to rapidly propel their body and weapon to engage opponents using footwork and bladework techniques,[4] repetitive practice and/or competitions may expose their legs to large impact forces, resulting in lower-extremity injuries.[5,6] Similarly, WFs

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are required to substitute their trunk for the pivoting role of footwork in AFs to transmit ground reaction force[7,8] and to assist reaching movements during wheelchair fencing.[9–11] Poor trunk control may hinder WFs in performing powerful weapon-arm movements.[12] To compensate for the truncated kinetic chain, WFs rely on their upper limb muscles to generate repetitive powerful arm movements, heightening the risk of upper extremity overuse injuries.[7]

In addition to the obvious differences in biomechanics and injury patterns between AFs and WFs, fencers using different fencing weapons may experience varying injury risk. The épée (770 grams) is heavier than the saber (500 grams),[13] potentially posing a different risk to the weapon-arm. Furthermore, because elite sabreurs perform more explosive attacking and defensive movements (eg, lunges and retreats) with shorter bouts of action and more long-lasting recovery periods than épéeists,[14] the relative risk of fatigue and injury in these fencers may differ. Therefore, understanding the prevalence and incidence of fencing injuries and associated factors in different fencers is critically important.

Two prior literature reviews[2,13] revealed that injury rates in AFs were higher during national and international competitions. Lower limbs were the predominant injured sites (knee and ankle), followed by upper limbs (wrist, hand, fingers).[2,13] Ligament sprains and muscle strains were the most common types of fencing injuries.[2,13] However, these reviews did not summarize relevant risk factors. Therefore, the current systematic review and meta-analysis aimed to summarize the evidence regarding the prevalence/incidence of fencing injuries, and the associated factors and risk factors in AFs and WFs, which can help develop tailored prevention and treatment strategies for these fencers.

METHODS

The review protocol was registered with PROSPERO (registration number: CRD42021291248). This review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[14] (**Supplemental Digital Content 1**, http://links.lww.com/JSM/A516).

Literature Search

AMED, CINAHL, Embase, Medline, PsycINFO, and SPORTDiscus were searched from inception to June 30, 2023. Search strings involved 6 sets of keywords and medical subject headings: (1) fencing sport, (2) prevalence or incidence, (3) risk or prognostic factors, (4) injuries and/or pain, (5) able-bodied and wheelchair fencers, and (6) professional levels (Table 1). There were no language restrictions in the searches. Backward and forward citation tracking were conducted. The corresponding authors of the included studies were contacted by emails to identify relevant omitted articles.

Study Selection

Cross-sectional, cohort, and case–control studies were eligible for inclusion if they (1) involved AFs and/or WFs, (2) reported fencing-related injuries or pain, (3) identified factors associated with fencing injuries or pain, and (4) reported relevant statistics (eg, odds ratio (OR), relative risk (RR), or hazard ratio). Two reviewers (S.C.Y.W. and J.R.C.) independently screened titles and abstracts according to the selection criteria (Table 1). Unresolved disagreements were adjudicated by a third reviewer (A.Y.L.W.). Relevant full-texts were retrieved. The same procedures were repeated for full-text screening. Kappa coefficients were calculated to evaluate the between-reviewer agreements (S.C.Y.W. and J.R.C.) at each stage of screening.

Risks of Bias Assessments

Two independent reviewers (S.C.Y.W. and J.R.C.) assessed the methodological quality of the included studies

TABLE 1. The Search Strategies and Selection Criteria

Frame	Selection Criteria	Keywords
Population	They were able-bodied (AFs) and wheelchair fencers (WFs) regardless of the age, sex, professional levels, competing status (training or competition), and the types of sport-related injuries	#1 Fencing OR Fencer* OR Sport fencing OR Women's fencing OR Foils OR Foilsman OR epee OR epeeist* OR Duelist* OR Saber OR Sabreur*
Exposure	They had any sport-related fencing injuries or pain	#2 Pain OR Injur* OR Injuries from sport OR Athletic injuries OR Sports injur* OR Wound* OR Overuse OR Non-traumatic OR Traumatic
Comparison	They were not the sport fencers such as patients with breast cancer participated in adapted fencing or people engaged in Japanese fencing (Kendo) or historical fencing	—
Outcome	1. The primary article provided prevalence and incidence of sport-related fencing injuries or pain. (e.g., injury percentage, injury per 1000 athletic exposures (AE)*, injury per 1000 hours of participation) 2. The primary article provided statistical information (e.g., unadjusted or adjusted odds ratios, relative risks, mean difference, or hazard ratio) for potential associated risk factors and prognostic factors that related to the increased prevalence/incidence of fencing-related injuries or pain	#3 & #4 Prevalence OR Incidence OR Risk OR Epidemiolog* OR Etiolog*
Study design	Cross-sectional, prospective, or retrospective studies that reported prevalence, incidence, associated/risk/prognostic factors for fencing-related injuries and pain	—

1AE = an opportunity for an athlete to incur an injury; for fencing, 1 bout has 2AEs for 2 fencers.

depending on the study designs. Cross-sectional studies were evaluated with *Appraisal tool for Cross-Sectional Studies* (AXIS).[15] Cohort studies were rated with the *Quality In Prognosis Studies* (QUIPS) tool.[16] Any discrepancies in the rating were resolved by the third reviewer (A.Y.L.W.). Kappa coefficient was calculated to evaluate the between-reviewer agreement.

Data Extraction

Two reviewers (S.C.Y.W. and J.R.C.) independently extracted data from the included studies using a standardized table. Study characteristics (eg, authors, year of publication, study design) and participants' information (age, fencing weapons, professional levels), definitions of fencing injuries or pain, period of measurements, the prevalence and incidence of fencing-related injuries/pain (eg, injury per 1000 athletic exposures (AEs) or percentage), potential risk factors and the corresponding statistics (eg, unadjusted or adjusted ORs, RRs, mean difference, or hazard ratios), and durations of follow-ups were extracted. If occurrences were not directly presented, the rates would be derived from the raw data. Likewise, if the effect sizes were not reported but the raw data wwere available, the former would be calculated using RevMan5.4 (Cochrane Collaboration, London, UK). Definitions of professional and nonprofessional fencers, associated factors, risk factors, and prognostic factors in this review are shown in **Supplemental Digital Content 2** (see http://links.lww.com/JSM/A517).

Data Synthesis

Meta-analyses were conducted using random effect models in RevMan5.4.,[17] showing pooled effects (eg, ORs or RRs) and the corresponding 95% confidence intervals in forest plots. Statistical heterogeneity was classified as low ($I^2 < 40\%$), moderate ($I^2 = 40\%$-60%), or substantial ($I^2 > 60\%$).[18] If data could not be pooled because of clinical heterogeneity (eg, different follow-up durations), a narrative summary was provided.[18]

Four subgroup analyses of factors associated with fencing injuries or pain were planned: (1) AFs versus WFs, (2) professional versus nonprofessional levels, (3) males versus females, and (4) adults (older than 19 years of age) versus adolescents (aged 10-19 years). A sensitivity analysis was planned to re-examine the results after removing low-quality studies.

Quality of Evidence

Quality of evidence of each risk factor was assessed by the modified Grading of Recommendation Assessments, Development and Evaluation (GRADE) for observational studies.[17] Evidence was classified as high, moderate, low, or very low.[17] (**Supplemental Digital Content 3 and 4**, http://links.lww.com/JSM/A518 and http://links.lww.com/JSM/A519).

RESULTS

Database searches yielded 298 citations after removing duplicates. Eighteen out of 37 full-text articles were included in this review. One additional relevant article was identified from the reference list of an included study (Figure 1).

Study Characteristics

Seven included cross-sectional,[19–25] 1 retrospective,[26] and 11 prospective studies[7,27–36] were published between 1990 and 2022 (Table 2). Their sample sizes ranged from 15 to 85 685. The cross-sectional studies involved 1096 fencers (510 females, 563 males, and 23 representing both sexes), a retrospective study involved 55 fencers of both sexes, and the prospective studies involved 164 499 fencers (68 642 females, 95 651 males, and 206 representing both sexes). Fencers' ages ranged from 8 to 70 years. Eighteen included studies[19–36] only recruited AFs. Only 1 study[7] involved both AFs and WFs.

Risk of Bias Assessments

The included studies demonstrated high (n = 12) and moderate (n = 7) risk of bias (Tables 3 and 4). The most common risk of bias in cross-sectional studies was not taking actions to minimize/categorize nonrespondents, no nonrespondents' description, and no sample size justification. Cohort studies commonly did not report drop-out participants' characteristics.

Prevalence and Incidence of Fencing-Related Injuries/Pain

Six cross-sectional studies[19,20,22,23,25,26] reported the prevalence of fencing-related injuries (1 study[23] classified knee pain as an injury), while 2 included cross-sectional studies[21,24] reported the prevalence of pain in AFs (Table 5). Ten cohort studies[7,27,29–36] investigated the incidence of fencing injuries (1 study[28] classified patellofemoral pain syndrome (PFPS)/general pain as injuries) in AFs (Table 5). Only 1 included prospective study[7] reported the incidence of fencing injuries among both AFs and WFs (Table 5). Given the heterogeneous definitions of fencing injuries/pain in the included studies, no relevant meta-analyses nor direct comparisons of prevalence or incidence of fencing injuries/pain were conducted.

The prevalence of fencing injuries in AFs ranged from 51.5% (24-month prevalence) among nonprofessional AFs[19] to 92.8% (12-month prevalence) among professional AFs.[25] Likewise, the prevalence of fencing-related pain ranged from 13.3% (point prevalence) in nonprofessional AFs[24] to 100% (lifetime prevalence) in professional AFs.[21] Although the prevalence was affected by professional levels, definitions of injuries, and body regions, nonprofessional AFs seemed to have lower prevalence than professional AFs.[19,25]

Five studies[27,28,33,35,36] reported the total incidence rate of an AF population (%). Five included studies[29–32,34] reported the incidence as number of injuries per 1000 AEs (1AE = an opportunity for an athlete to incur an injury; for fencing, 1 bout has 2AEs for 2 fencers). Three studies[7,29,31] reported the incidence as the number of injuries per 1000 hours of participation, whereas 1 study[31] defined incidence as injuries per person-year.

The observation period for determining cumulative incidence of AF injuries ranged from 15 days to 5 years. The cumulative incidence of fencing injuries in AFs varied from 0.8% (new time loss injuries during a 15-day Olympic games) to 45.7% (new time loss injuries for 12 months). The 12-month incidence of injury during training and competitions among male AFs with mixed levels was 0.16% and 1.57%, respectively.[27] The incidence of penetrating hand injury for

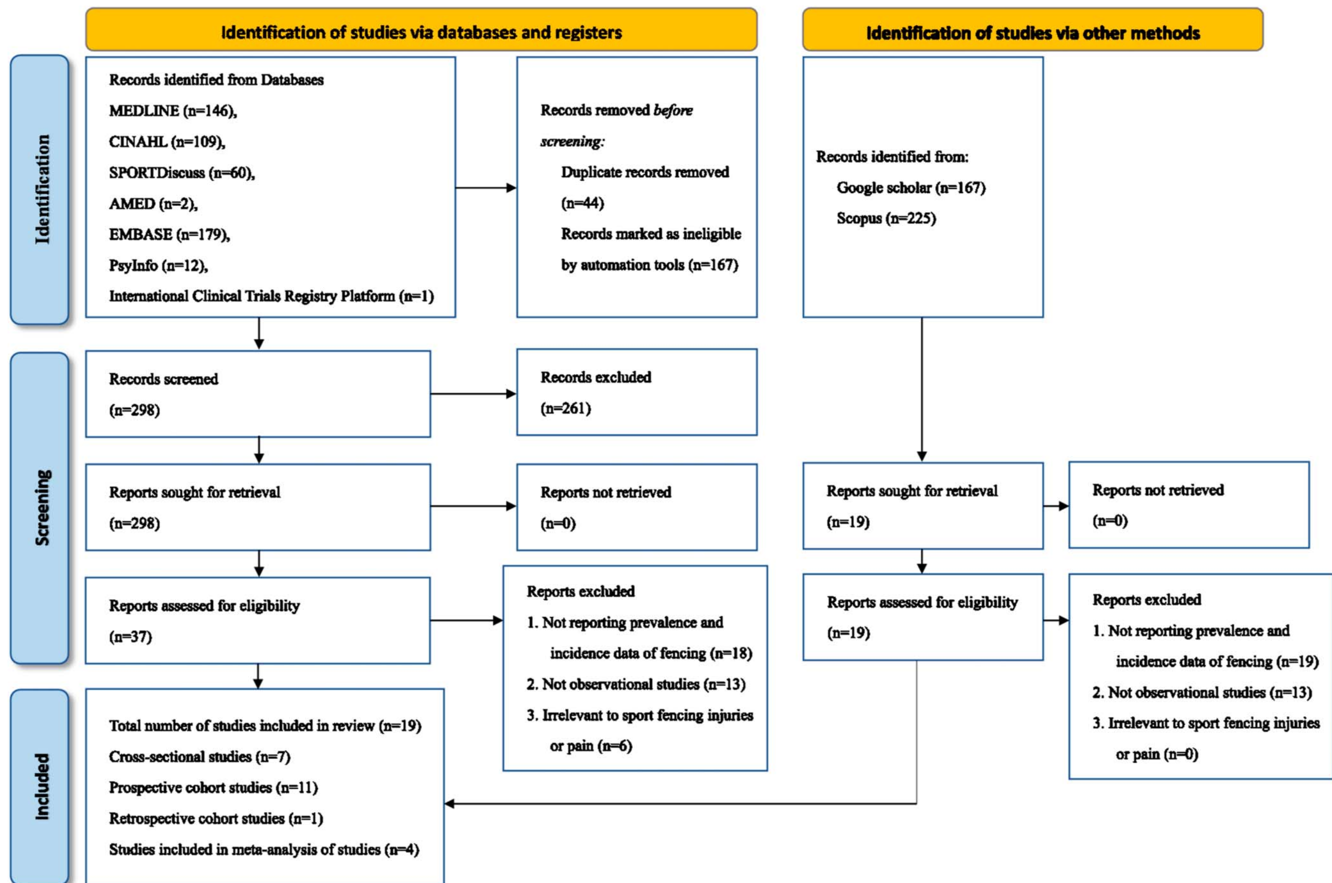


Figure 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 flow diagram.[14]

saber AFs was 0.013 per 1000 AEs.[32] The incidence of fencing injuries among professional foil AFs varied from 2.4 to 5.1 injuries per 1000 hours of participation.[7,29] The incidence of time loss injuries among professional AFs ranged from 0.27 to 13.7 injuries per 1000 AEs,[29,31,34] while nonprofessional AFs sustained 2.04 fencing injuries per 1000 AEs.[30] Fencing injuries in foil WFs was 3.9 per 1000 hours of participation.[7] The incidence of fencing injuries in saber, épée, and foil AFs was 3.3, 3.2, and 2.7 injuries per person-year, respectively.[31]

Injury Profile in AFs and WFs

Seven included studies[7,19,22,26,29,31,34] investigated the injured site distribution in AFs and WFs (Table 6). Lower limbs were most frequently injured (56.1% and 54.0%), followed by upper limbs (24.0% and 27.9%), torso (18.7% and 17.3%), and head (0.61% & 0.9%) in both professional and nonprofessional AFs.[7,19,22,29,31,34] One included study[7] found that upper limb injuries (ie, elbow/forearm and shoulder) were the most common fencing injuries (73.8%) in WFs, followed by torso (25.3%) and head (1.1%).

Potential Associated Factors and Risk Factors for Fencing Injuries

Three cross-sectional studies[19,20,22] investigated 10 potential factors associated with increased rates of fencing injuries in AFs (ie, age, sex, years of fencing, competitive levels, fencing weapons, warm up, cool down, participation in fitness program, Functional Movement Screen scores, and Y-balance test results). Two prospective studies[29,34] examined the risk factors (age, sex, and fencing weapons) associated with fencing injuries in AFs (Table 7), while 1 prospective study[7] investigated risk factors (wheelchair bound and trunk control) for fencing injuries in professional WFs (Table 7). No included studies investigated factors associated with fencing-related pain in AFs or WFs. The quality of evidence for these factors ranged from "moderate" (n = 3) to "very low" (n = 14) (**Supplemental Digital Content 3 and 4**, http://links.lww.com/JSM/A518 and http://links.lww.com/JSM/A519).

Age

Moderate-quality evidence supported that older age was associated with more fencing injuries among nonprofessional AFs (n = 584, unadjusted odd ratios (UORs) ranging from 1.53 to 3.68) (Table 7).[19] Likewise, moderate-quality evidence substantiated that professional AFs in the senior division had a higher risk of time-loss fencing injuries than those in the junior/cadet division (n = 86 686, unadjusted relative risks (URRs) ranging from 1.74 to 5.56) (Table 7).[29]

Sex

There was very low-quality evidence from a mixed cohort of professional and nonprofessional AFs that females were

TABLE 2. Descriptive Characteristics of 19 Included Studies

Study Information		Study Details		Outcomes	Risk Factor Categories	
Author (Year), Country	Design	Sample Size, (AF/WF: F, M)	Fencing Types & Fencing Professional Levels & Career Years	Sport Fencing Injury/Pain	Associated/Risk Factors	
Lambert et al (2022),[26] German	Cross-sectional	AF 55 (mixed sex)	Nonspecific type, a mix of professional (competitive) and nonprofessional (recreational) fencers	Injury	NR	
Chung et al (2020),[19] Korea	Cross-sectional	AF 584 (F 276, M 308)	Foil F 88, M 88; Épée F 107, M 111; Saber F 81, M 109, nonprofessional fencers	Injury	Associated factors	Fencing weapon types; years of fencing experience
Prakash et al (2019),[20] India	Cross-sectional	AF 113 (F 34, M 79)	Foil 29; Épée 51; Saber 33, a mix of professional and nonprofessional fencers	Injury	Associated factors	Age; cool-down; fencing weapon types; fitness participation; sex; levels of fencing; warm-up; years of fencing experience
Fett et al (2017),[21] German	Cross-sectional	AF 23 (mixed sex)	Nonspecific type, professional (elite) fencers	Pain	NR	
Zhou et al (2016),[22] China	Cross-sectional	AF 30 (F 18, M 12)	Foil M 5, F 4; Épée M 4, F 8; Saber M 3, F 6, professional (elite) fencers	Injury	Associated factors	Movement function tests (e.g., FMS & YBT)
Pavlidou et al (2012),[23] Greece	Cross-sectional	AF 121 (F 59, M 62)	Nonspecific type, professional (elite)	Injury	NR	
Nejati et al (2011),[24] Iran	Cross-sectional	AF 45 (All F)	Nonspecific type, nonprofessional (amateur) fencers	Pain	NR	
Trautmann et al (2008),[25] German	Cross-sectional	AF 180 (F 78, M 102)	Foil M,12, F 56; Épée M 78, F 5; Saber M 12, F 17, professional (elite) fencers	Injury	NR	
Lhee et al (2021),[36] Korea	Retrospective cohort	AF 24 (F 12, M 12)	Nonspecific type, professional (elite) fencers	Injury	NR	
Park et al (2021),[27] Korea	Prospective cohort	AF 137 (All M)	Nonspecific type, nonprofessional fencers (middle/high school/ university) M 116, professional M 21	Injury	NR	
Thompson et al (2021),[28] United States	Prospective cohort	AF 77 (F 30, M 47)	Foil F 13, M 8, Épée F 5, M 8; Saber F 8 M 21; Foil & Saber F 4, professional (elite) fencers	Injury	NR	
Harmer (2019),[29] International	Prospective cohort	AF 85,686 (F 37 817, M 47 869)	Foil M 14,949, F 11,496; Épée M 19.069, F 14,938; Saber M 13,851, F 11,383, professional and elite fencers	Injury	Risk factors	Age; fencing weapon type; sex
Walrod et al (2019),[30] United States	Prospective cohort	AF 28 (F 9, M 19)	Nonspecific type, nonprofessional (beginner/ intermediate) collegiate fencers	Injury	NR	
Park et al (2017),[31] Korea	Prospective cohort	AF 15 (F 8, M 7) [Annual average]	Foil, Épée, Saber#, professional (elite) fencers	Injury	NR	
Harmer (2015),[32] United States	Prospective cohort	[Pre-2011] AF 34 (F 5, M 29) [In 2011–2014] AF: 21 (F 8, M 13)	[Pre-2011] Saber M 29, M 5, [professional (elite) fencers 19, nonprofessional (beginner/intermediate) fencers 15] [Years 2011-2014] Saber M 13 M 8, [professional (elite) fencers 17, nonprofessional (beginner/ intermediate) fencers 4]	Injury	NR	

TABLE 2. Descriptive Characteristics of 19 Included Studies *(Continued)*

Study Information		Study Details		Outcomes	Risk Factor Categories	
Author (Year), Country	Design	Sample Size, (AF/ WF: F, M)	Fencing Types & Fencing Professional Levels & Career Years	Sport Fencing Injury/Pain	Associated/Risk Factors	
Chung et al (2012),[7] Hong Kong	Prospective cohort	AF 10 (All M) WF 14 (F 7, M 7)	AF: Foil M 10, F 0; WF: Foil M 7, F 7, professional (elite) fencers/fencing experience: AF: 10.2 ± 3.8; WF: 10.1 ± 5.3	Injury	Risk factors	Fencer classifications (e.g., WF vs AF; WF category B VS A)
Junge et al (2009),[33] International	Prospective cohort	AF 206 (mixed sex)	Nonspecific type, professional (elite) fencers	Injury	NR	
Harmer (2008),[34] United States	Prospective cohort	AF 78,223 (F 30740, M 47483)	Foil M 19,077, F 12,792; Épée M 16,605, F 10,399; Saber M 11,801, F 7,549, professional and elite fencers	Injury	Risk factors	Fencing weapon type; sex
Lanese et al (1990),[35] United States	Prospective cohort	AF 24 (F 6, M 18)	Nonspecific type, nonprofessional (beginner/ intermediate) fencers	Injury	NR	

associated with a lower 24-month prevalence of fencing injuries than males (n = 113, UOR = 0.22) (Table 7).[20] Conversely, very low-quality evidence supported that female professional AFs were 3.6 times more likely to sustain thigh strain than male AFs in the future.[29] However, very low-quality evidence from a meta-analysis of 2 prospective studies showed that sex was unrelated to future time-loss fencing injuries among professional AFs (n = 164 909, URR = 0.98, 95% CI, 0.52–1.85) (Table 7, Figure 2).[29,34]

Years of Fencing Experiences

There was moderate-quality evidence that nonprofessional AFs with 5 years or more fencing experiences had a higher 24-month prevalence of fencing injuries than those with <2 years of experiences (n = 584, UOR: ranging from 4.08 to 5.12) (Table 7).[19] Similarly, moderate-quality evidence suggested that nonprofessional AFs with 5 to 6 years of fencing experiences had a higher 24-month prevalence than those with 3 to 4 years of experiences (Table 7).[19]

Competitive Levels

There was very low-quality evidence that AFs participating in international competitions were 14 times more likely to have a higher 24-month prevalence of fencing injuries than university-level AFs (Table 7).[20] However, very low-quality evidence showed that international-level AFs had nonsignificant but higher odds of sustaining fencing injuries in the past 24 months than national-level AFs. Similarly, national-level AFs had a nonsignificant higher odds of injury than university-level AFs (Table 7).[20]

Fencing Weapons

Very low-quality evidence from 3 meta-analyses showed that weapon styles (foil, épée, or saber) were unrelated to the 24-month prevalence of fencing injuries among nonprofessional AFs (Table 7, Figure 3A–C).[19,20] Likewise, very low-quality evidence from 2 meta-analyses revealed that fencing weapons (foil vs épée, and saber vs foil) did not affect 5-year cumulative incidence of time-loss fencing injuries in professional AFs (Table 7, Figure 4A, B).[29,34] However, low-quality evidence from a meta-analysis showed that compared with professional épée AFs, professional saber AFs were 1.9 times more likely to have a higher 5-year cumulative incidence of time-loss fencing injuries (Table 7, Figure 4).[29,34]

Warm-Up, Cool-Down, Participating in Fitness Programs

Although an included study[20] investigated whether warm-up was a factor associated with fencing injuries in AFs, no result was reported. Very low-quality evidence showed that cool down was not associated with the 24-month prevalence of fencing injuries in professional or nonprofessional AFs.[20] Very low-quality evidence suggested that professional/ nonprofessional AFs who regularly participated in fitness programs were more likely to have a higher 24-month prevalence of fencing injuries than those irregularly participated in fitness programs (n = 113, UOR = 48.3; 95% CI, 6.0-390.5) (Table 7).[20]

Functional Movement Screening Scores

There was very low-quality evidence that lower Functional Movement Screen scores (FMS scores ≤15) were associated with a higher point prevalence of fencing injuries among professional AFs (n = 30, UOR = 20). However, very low-quality evidence supported that the Y-balance test results of professional AFs were unrelated to their 24-month prevalence of fencing injuries (Table 7).[22]

Disability Levels

Very low-quality evidence substantiated that professional WFs were more likely to sustain fencing injuries than professional AFs (URR ranging from 2.2 to 13.6) (Table 7).[7] Very low-quality evidence also showed that professional WFs with poor trunk control displayed higher risks of fencing injuries than those with good trunk control (URR ranging from 1.8 to 5.0) (Table 7).[7]

TABLE 3. Risk of Bias Assessments of the Included Studies by the Appraisal Tool for Cross-Sectional Studies on Eight Cross-Sectional Studies[15]

Studies	Objective and Study Design			Study Participation						Handling of Nonrespondents				Outcome Measures			Statistical Analysis			Reporting							Overall Risk
Original Item Number	**1**	**2**	**S**	**3**	**4**	**5**	**6**	**20**	**S**	**7**	**13***	**14**	**S**	**8**	**9**	**S**	**10**	**11**	**S**	**12**	**15**	**16**	**17**	**18**	**19***	**S**	
Lambert et al (2022)[26]	Y	Y	L	Y	Y	Y	Y	Y	L	N	N	N	M	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	L	Moderate
Chung et al. (2020)[19]	Y	Y	L	Y	Y	Y	Y	Y	L	N	N	N	M	Y	Y	L	Y	Y	L	Y	Y	Y	Y	N	N	M	Moderate
Prakash et al (2019)[20]	Y	Y	L	Y	Y	Y	Y	Y	L	N	N	N	M	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	L	Moderate
Fett et al. (2017)[21]	Y	Y	L	Y	Y	Y	Y	Y	L	N	N	N	M	Y	Y	L	Y	Y	L	Y	Y	Y	Y	Y	N	L	Moderate
Zhou et al. (2016)[22]	Y	Y	L	Y	Y	Y	Y	NS	M	N	N	N	M	Y	Y	L	Y	Y	L	Y	Y	Y	Y	N	N	M	Moderate
Pavlidou et al. (2012) [23]	Y	Y	L	Y	Y	Y	Y	NS	M	N	N	N	M	Y	Y	L	Y	Y	L	Y	Y	Y	Y	N	N	M	Moderate
Nejati et al. (2011)[24]	Y	Y	L	Y	Y	Y	Y	NS	M	N	N	N	M	Y	Y	L	N	N	H	Y	Y	Y	Y	Y	N	L	High
Trautmann & Rosenbaum (2008)[25]	Y	Y	L	Y	Y	Y	Y	Y	L	N	N	N	M	Y	Y	L	N	Y	M	Y	Y	Y	Y	Y	N	L	Moderate
Percentage of included studies that have ‘Yes’/‘no’ bias	100	100		100	100	100	100	62.5		0	0	0		100	100		75	87.5		100	100	100	100	62.5	0		

Abbreviations: AXIS = Appraisal Tool for Cross-Sectional Studies; H = High; L = Low; M = Moderate; N = No; NS: Not stated; Y = Yes

Introduction
1. Were the aims/objectives of the study clear?

Methods
2. Was the study design appropriate for the stated aim(s)?
3. Was the sample size justified?
4. Was the target/reference population clearly defined? (Is it clear who the research was about?)
5. Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?
6. Was the selection process likely to select subjects/participants who were representative of the target/reference population under investigation?
7. Were measures undertaken to address and categorize nonresponders?
8. Were the risk factor and outcome variables measured appropriate to the aims of the study?
9. Were the risk factor and outcome variables measured correctly using instruments/measurements that had been trialed, piloted, or published previously?
10. Is it clear what was used to determine statistical significance and/or precision estimates? (e.g., *P* values, CIs)
11. Were the methods (including statistical methods) sufficiently described to enable them to be repeated?

Results
12. Were the basic data adequately described?
13. Does the response rate raise concerns about nonresponse bias?
14. If appropriate, was information about nonresponders described?
15. Were the results internally consistent?
16. Were the results for the analyses described in the methods, presented?

Discussion
17. Were the authors’ discussions and conclusions justified by the results?
18. Were the limitations of the study discussed?

Others
19. Were there any funding sources or conflicts of interest that may affect the authors’ interpretation of the results?
20. Was ethical approval or consent of participants attained?

**No indicate no risk of bias.*

TABLE 4. Risk of Bias Assessments of the Included Studies (QUIPS for 11 Cohort Studies).[16]

Study	Study Participation								Study Attrition					Prognostic Factor Measurements						Outcome Measurements				Study Confounding								Statistical Analysis and Reporting				Overall
	1	2	3	4	5	6	7	S	1	2	3	4	S	1	2	3	4	5	S	1	2	3	S	1	2	3	4	5	6	7	S	1	2	3	S	
Lhee et al. (2021)[36]	Y	Y	Y	Y	Y	Y	Y	**L**	Y	U	N	N	H	Y	Y	Y	Y	U	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	Y	Y	N	**M**	Y	Y	Y	**L**	High
Thompson et al. (2021)[28]	Y	Y	Y	Y	Y	Y	Y	**L**	Y	U	N	U	H	Y	Y	Y	Y	U	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	U	Y	Y	**M**	Y	Y	Y	**L**	High
Park et al. (2021)[27]	Y	Y	Y	Y	N	Y	P	**M**	Y	U	N	N	H	Y	Y	Y	Y	U	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	Y	U	N	**M**	Y	Y	Y	**L**	High
Harmer (2019)[29]	Y	Y	Y	Y	Y	Y	Y	**L**	Y	U	N	N	H	Y	Y	Y	Y	N	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	U	Y	Y	**M**	Y	Y	Y	**L**	High
Walrod et al. (2019)[30]	Y	Y	Y	Y	Y	Y	Y	**L**	Y	U	N	U	H	Y	Y	Y	Y	U	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	U	Y	Y	**M**	P	Y	Y	**L**	High
Park et al (2017)[31]	Y	Y	Y	Y	Y	Y	Y	**L**	Y	U	N	N	H	Y	Y	Y	Y	U	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	Y	Y	Y	**L**	Y	Y	Y	**L**	High
Harmer (2015)[32]	Y	Y	Y	Y	Y	Y	Y	**L**	Y	U	N	N	H	Y	Y	Y	Y	U	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	U	Y	Y	**M**	Y	Y	Y	**L**	High
Chung et al. (2012)[7]	Y	N	Y	Y	Y	Y	Y	**M**	Y	U	N	N	H	Y	Y	Y	Y	N	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	U	Y	Y	**M**	Y	Y	Y	**L**	High
Junge et al. (2009)[33]	Y	Y	Y	Y	Y	Y	Y	**L**	Y	U	N	N	H	Y	Y	Y	Y	U	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	N	U	N	**H**	Y	Y	Y	**L**	High
Harmer (2008)[34]	Y	Y	Y	Y	Y	Y	Y	**L**	Y	U	N	N	H	Y	Y	Y	Y	N	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	U	Y	Y	**M**	Y	Y	Y	**L**	High
Lanese et al. (1990)[35]	Y	Y	Y	Y	N	Y	Y	**M**	Y	U	N	N	H	Y	Y	Y	Y	U	**M**	Y	Y	Y	**L**	Y	Y	Y	Y	U	Y	Y	**M**	Y	Y	Y	**L**	High

Abbreviations: H = High; L = Low; M = Moderate; N = No; P = Partial; U = Unsure; Y = Yes

1. Study Participation
1.1 The source population or population of interest is adequately described for key characteristics.
1.2 The sampling frame and recruitment are adequately described, including methods to identify the 1.3 Sample sufficient to limit potential bias (number and type used, e.g., referral patterns in health care).
1.4 Period of recruitment is adequately described.
1.5 Place of recruitment (setting and geographic location) is adequately described.
1.6 Inclusion and exclusion criteria are adequately described (e.g., including explicit diagnostic criteria or "zero time" description).
1.7 There is adequate participation in the study by eligible individuals.
1.8 The baseline study sample (i.e., individuals entering the study) is adequately described for key characteristics.
2. Study attrition
2.1 Response rate (i.e., proportion of study sample completing the study and providing outcome data) is adequate.
2.2 Attempts to collect information on participants who dropped out of the study are described.
2.3 Reasons for loss to follow-up are provided.
2.4 Participants lost to follow up are adequately described for key characteristics; there are no important differences between key characteristics and outcomes in participants who completed the study and those who did not.
3. Prognostic Factor Measurements
3.1 A clear definition or description of "PF" is provided (e.g., including dose, level, duration of exposure, and clear specification of the method of measurement).
3.2 Method of PF measurement is adequately valid and reliable to limit misclassification bias (e.g., may include relevant outside sources of information on measurement properties, also characteristics, such as blind measurement and limited reliance on recall).
3.3 The method and setting of PF are the same for all study participants.
3.4 Adequate proportion of the study sample has complete data for PF variable.
3.5 Appropriate methods of imputation are used for missing "PF" data.
4. Outcome Measurements
4.1 A clear definition or outcome is provided, including duration of follow-up and level and extent of the outcome construct.
4.2 The method of outcome measurement used is adequately valid and reliable to limit misclassification bias (e.g., may include relevant outside sources of information on measurement properties, also characteristics, such as blind measurement and confirmation of outcome with valid and reliable test).
4.3 The method and setting of the outcome measurement are the same for all study participants.
5. Study Confounding
5.1 All-important confounders, including treatments, are measured.
5.2 Clear definitions of the important confounders measured are provided (e.g., including dose, level, and duration of exposures).
5.3 Measurement of all important confounders is adequately valid and reliable (e.g., may include relevant outside sources of information on measurement properties, also characteristics, such as blind measurement and limited reliance on recall).
5.4 The method and setting of confounding measurement are the same for all study participants.
5.5 Appropriate methods are used if imputations used for missing confounder data.
5.6 Important potential confounders are accounted for in the study design (e.g., matching for key variables, stratification, or initial assembly of comparable groups).
5.7 Important potential confounders are accounted for in the analysis (i.e., appropriate adjustment.)
6. Statistical Analysis and Reporting
6.1 There is sufficient presentation of data to assess the adequacy of the analysis.
6.2 The strategy for model building (i.e., inclusion of variables in the statistical model) is appropriate and is based on a conceptual framework or model; the selected statistical model is adequate for the design of the study.
6.3 There is no selective reporting of the results

TABLE 5. Prevalence and Incidence of Sport-Related Injuries and Pain in Able-Bodied and Wheelchair Fencers

Study Information			Study Details			Outcomes		Overall Prevalence/Incidence Rates (%)	
Author (Year)	Design	Data Collection Method	Sample Size, (AF/WF: F, M)	Mean Age ± SD and/ or Range	Fencing Type & Level (Professional/ nonprofessional)/ Fencing Career Years	Definition of Sport Injury or Pain and Period of Measurement	Results	Sport Injury	Pain
Lambert et al. (2022)[26]	Cross-sectional	Self-reported survey in combat sports athletes including fencers	AF: 55 (nonspecific sex)	Nonspecific age	Nonspecific type, a mix of professional (competitive) and nonprofessional (recreational) fencers	Injury was defined as musculoskeletal problems causing a break in training or competition for >3 weeks in a 4-year Olympic cycle (2012–2016)	With time-loss injuries: 51 out of 55 competitive and recreational fencers	48-month prevalence 92.7%	NR
Chung et al. (2020)[19]	Cross-sectional	Questionnaires in Korean fencers in middle school, high school, collegiate, and adult teams	AF: 584 (F 276, M 308)	Range: 14–40 year	Foil F 88, M 88; Épée F 107, M 111; Saber F 81, M 109, nonprofessional fencers (middle school, high school, college, and adult teams)	Injury was defined as the inability to participate in training or competition for ≥ 24 h within the past 2 years to 2016	With body injuries: 301 out of 584 Korean fencers	24-month prevalence 51.5%	NR
Prakash et al (2019)[20]	Cross-sectional	Scheduled questionnaire in Indian fencers in joint-university fencing games	AF: 113 (F 34, M 79)	Range: 18-26 year	Foil 29; Épée 51; Saber 33, a mix of professional and nonprofessional fencers in joint university fencing games during 2016–2017	Definition not mentioned	With body injury: 14 out of 113 Indian fencers	24-month prevalence 12.4%	NR
Fett et al. (2017)[21]	Cross-sectional†	Questionnaires in German elite fencers	AF: 23 (nonspecific sex)	Mean age: 22.1	Nonspecific type, professional (elite) fencers	Back pain was defined as pain, ache, or discomfort in an area of the human body such as neck, upper back and lower back on lifetime (pain at least once in life), 12-month, 3-month, and point prevalence and during the last 7 days to 2015	With back pain: Lifetime: All 23 German elite fencers 12-month: 22 out of 23 elite fencers 3-month: 18 out of 23 elite fencers The last 7 days: 8 out of 23 elite fencers	NR	Lifetime prevalence: 100% 12-month prevalence: 95.7% 3-month prevalence: 78.3% Last 7 days prevalence: 34.8%
Zhou et al. (2016)[22]	Cross-sectional	Survey in Chinese elite fencers	AF: 30 (F 18, M 12)	23.53 ± 3.37	Foil M 5, F 4; Épée M 4, F 8; Saber M 3, F 6, professional (elite) fencers, training before RIO 2016 Olympic game	Injury was diagnosed by team physicians before RIO 2016 Olympics (nonspecific period)	With body injuries: 21 out of 30 Chinese elite fencers	Point prevalence: 70%	NR
Pavlidou et al. (2012)[23]	Cross-sectional	Questionnaires in fencing clubs and	AF: 121 (F 59, M 62)	18 ± 1.07	Nonspecific type, professional (elite)	Injury was defined as musculoskeletal knee dysfunctions-injury in	With knee dysfunctions injuries and pain:	12-month prevalence: 27.3% [knee pain is	NR

TABLE 5. Prevalence and Incidence of Sport-Related Injuries and Pain in Able-Bodied and Wheelchair Fencers *(Continued)*

Study Information			Study Details			Outcomes		Overall Prevalence/Incidence Rates (%)	
Author (Year)	Design	Data Collection Method	Sample Size, (AF/WF: F, M)	Mean Age ± SD and/ or Range	Fencing Type & Level (Professional/ nonprofessional)/ Fencing Career Years	Definition of Sport Injury or Pain and Period of Measurement	Results	Sport Injury	Pain
		National Greek team of fencing			fencers, training during 2010-2011	fencers by using 2000 IKDC form (nonspecific period)	33 out of 121 Greek elite and advanced fencers	classified as one of the injury types in knee]	
Nejati et al. (2011)[24]	Cross-sectional†	Survey in sport medicine board in Iran	AF: 45 (All F)	19.06 ± 1.4 Range: 15-35	Nonspecific type, nonprofessional (amateur) fencers	Patellofemoral pain (PFPS) was defined as a spectrum of processes characterized by retropatellar pain or peripatellar pain arising from overuse and overload or from biomechanical or muscular changes in the patellofemoral joint before 3rd. Iranian Sports Olympiad (nonspecific period)	With PFPS: 6 out 45 Iranian female fencers	NR	Point prevalence: 13.3%
Trautmann et al (2008)[25]	Cross-sectional	Questionnaire at fencing clubs and competitions for the elite and advanced Germany fencers	AF 180 (F 78, M 102)	21.1 ± 8.4	Foil M,12, F 56; Épée M 78, F 5; Saber M 12, F 17, professional (elite) fencers	Injury was defined as fencing injury of foil, épée, and saber junior and adult elite fencers among national and international competitions in 2007	With body injuries: 167 out of 180 elite and advanced Germany fencers	12-month prevalence: 92.8%	NR
Lhee et al. (2021)[36]	Retrospective cohort†	IOC injury reported form for elite South Korean athletes during 2018 Asian Games	AF 24 (F 12, M 12)	Nonspecific age	Nonspecific type, professional (elite) fencers	Injury was defined as any medical condition that received medical attention, including musculoskeletal complaints and concussions, regardless of its impact on participation in training or competition	With body injuries: 7 out of 24 elite South Korean fencers	16-day incidence: 29.2%	NR
Park et al. (2021)[27]	Prospective cohort†	Online questionnaires investigating Korean male elite athletes' injury occurrence experience from middle school, high school,	AF 137 (All M)	Nonspecific age	Nonspecific type, nonprofessional fencers (middle/high school/ university) M 116, professional M 21	Injury was defined as time loss injury that fail to participate in competitions or trainings for at least 24 hours within 12 months	With body injuries: 53 out of 116 nonprofessional Korean male fencers 9 out of 21 professional Korean male fencers	1-yr cumulative incidence Total time-loss injuries: 45.7% (non-professional) 42.9% (professional)	NR

TABLE 5. Prevalence and Incidence of Sport-Related Injuries and Pain in Able-Bodied and Wheelchair Fencers *(Continued)*

Study Information			Study Details			Outcomes		Overall Prevalence/Incidence Rates (%)	
Author (Year)	Design	Data Collection Method	Sample Size, (AF/WF: F, M)	Mean Age ± SD and/or Range	Fencing Type & Level (Professional/nonprofessional)/Fencing Career Years	Definition of Sport Injury or Pain and Period of Measurement	Results	Sport Injury	Pain
		university, and professional level				during period of 2018–2019		A mix of professional and nonprofessional fencers: Training: 0.16% Competition: 1.57%	
Thompson et al. (2021)[28]	Prospective cohort	Survey in US Olympic teams and national teams	AF: 77 (F 30, M 47)	38.6 ± 11.9	Foil F 13, M 8, Épée F 5, M 8; Saber F 8 M 21; Foil & Saber F 4, professional (elite) fencers	Lower extremity injury was defined as "dominant* and non-dominant" knee and hip injuries in US national and Olympic teams during period of 1980–2018	With time-loss body injuries and pain: Dominated knee injuries: 53 out of 77 US elite fencers Dominated hip injuries: 24 out of 77 US elite fencers	1-yr cumulative incidence Dominated knee injury: 68.8% Dominated hip injury: 31.1% [Pain is classified as one of the injury types in knee or hip (e.g., PFPS or general pain)]	NR
Harmer[29] (2019)	Prospective cohort	Official score sheets of international competitions documented exposure and time-loss injury data	AF 85,686 (F 37 817, M 47 869)	Range: FIE competitions for junior (20) and for seniors (nonspecific age) Cadet World Championships (13–17)	Foil M 14 949, F 11 496; Épée M 19.069, F 14 938; Saber M 13 851, F 11 383, professional and elite fencers	Injury was defined as time-loss injury that occurred during a bout and resulted in the athlete withdrawing from the competitions during period of 2010–2014	With body injuries: 176 injuries in 637 776 AE in professional and elite international fencers	5-year cumulative incidence Total time-loss injuries 0.27/1000 AE 0.41/1000 athletes/yr* 5.1/1000 hours of participation*	NR
Walrod et al. (2019)[30]	Prospective cohort	Medical record from athletic trainers for collegiate fencers in an US university	AF 28 (F 9, M 19)	Nonspecific age	Nonspecific type, nonprofessional (beginner/intermediate) collegiate fencers	Injury was defined as injury that sustained while training and completing for the college fencing team, excluded general medical condition during a year of 2017	With body injuries: 16 injuries in 7840 AE in collegiate US fencers	1-yr cumulative incidence Reported injury rate = 2.43/1000 AE Our calculated injury rate = 2.04/1000 AE	NR
Park et al (2017)[31]	Prospective cohort	IOC injury report form for Korean fencers documented by 3 sport medicine specialists in 2008–10, 2010–12, 2013–15	AF 15 (F 8, M 7) [Annual average]	Nonspecific age	Foil, Épée, Saber‡, professional (elite) fencers	Injury was defined as acute or chronic musculoskeletal signs and symptoms owing to fencing activities during competitions and training sessions from the period of 2008 to 2015	With body injuries: 1176 injuries in elite Korean fencers	Annual incidence: 3.9 injuries/year (total) 3.3 injuries/year (saber) 3.2 injuries/year (épée) 2.7 injuries/year (foil) Training: 3.0 injuries/1000 hours (total) 3.7 injuries/1000 hours (saber)	NR

TABLE 5. Prevalence and Incidence of Sport-Related Injuries and Pain in Able-Bodied and Wheelchair Fencers *(Continued)*									
Study Information			Study Details			Outcomes		Overall Prevalence/Incidence Rates (%)	
Author (Year)	Design	Data Collection Method	Sample Size, (AF/WF: F, M)	Mean Age ± SD and/ or Range	Fencing Type & Level (Professional/ nonprofessional)/ Fencing Career Years	Definition of Sport Injury or Pain and Period of Measurement	Results	Sport Injury	Pain
								3.0 injuries/1000 hours (épée) 2.5 injuries/1000 hours (foil) Injuries per 1000 AE: 13.7 injuries/1000 AE (total) 14.1 injuries/1000 AE (male) 13.1 injuries/1000 AE (female)	
Harmer[32] (2015)	Prospective cohort	Surveillance systems of US and FIE and snowball sampling	[Pre-2011] AF: 34 (F 5, M 29) [In 2011-2014] AF: 21 (F 8, M 13)	Range: [pre-2011] 7-26 [In 2011-2014] 12-60	[Pre-2011] Saber M 29, M 5, [professional (elite) fencers 19, nonprofessional (beginner/intermediate) fencers 15] Years 2011-2014 Saber M 13 M 8, [professional (Elite) fencers 17, nonprofessional (beginner/intermediate) fencers 4]	Injury was defined as penetrating hand injury caused by unbroken blade during period of pre-2011 and 2011-April 2014	With body injuries: 4 injuries in 299 008 AE involving 38 860 saber fencers (2 exposure-based surveillance systems pre-2011 and 2011-April 2014) in beginner/intermediate/ elite US and international fencers	0.013/1000 AE Or 1 event per 37313 bouts	NR
Chung et al. (2012)[7]	Prospective cohort	Monthly interview with Hong Kong elite foil fencers	AF:10 (All M) WF:14 (F 7, M 7)	AF: 27.0 ± 5.5 WF: 28.6 ± 6.8	AF: Foil M 10, F 0 WF: Foil M 7, F 7, professional (elite) fencers/fencing experience: AF: 10.2 ± 3.8 WF: 10.1 ± 5.3	Injury was defined as trauma occurring during a training/competition and prohibited the athlete from continuing fencing activity at least 1 day during period of 2006-2009	With body injuries: AF: 62 injuries in 25 699-hour exposure in elite Hong Kong foil fencers WF: 95 injuries in 24 664-hour exposure in elite Hong Kong foil fencers	3-year cumulative incidence AF: 2.4/1000 h WF: 3.9/1000 h	NR
Junge et al (2009)[33]	Prospective cohort†	Standardized injury report form reported by physician and medical officers of the national teams	AF: 206 (nonspecific sex)	Nonspecific age	Nonspecific type, professional (elite) fencers	Injury was defined as any musculoskeletal complaint (traumatic and overuse) newly incurred due to competition and/or training during 2008 Beijing Olympic game	With body injuries: 5 out of 206 elite international fencers	15-day cumulative incidence Total injuries 2.4% Time-loss injuries 0.8%	NR

TABLE 5. Prevalence and Incidence of Sport-Related Injuries and Pain in Able-Bodied and Wheelchair Fencers *(Continued)*

Study Information			Study Details			Outcomes		Overall Prevalence/Incidence Rates (%)	
Author (Year)	Design	Data Collection Method	Sample Size, (AF/WF: F, M)	Mean Age ± SD and/ or Range	Fencing Type & Level (Professional/ nonprofessional)/ Fencing Career Years	Definition of Sport Injury or Pain and Period of Measurement	Results	Sport Injury	Pain
						that received medical attention regardless of the consequences with respect to absence from competition or training			
Harmer[34] (2008)	Prospective cohort	Athletic trainers evaluated and documented all time-loss injuries for professional and elite US fencers	AF: 78,223 (F 30740, M 47,483)	Range: 8–70	Foil M 19 077, F 12 792; Épée M 16 605, F 10 399; Saber M 11 801, F 7,549, professional and elite fencers	Injury was defined as time-loss injury that occurred during a fencing bout, was not caused by medical condition, and resulted in the athlete withdrawing from an event during period of 2001-2006 seasons	With body injuries: 184 injuries in 610 271 AE in professional and elite US fencers	5-year cumulative incidence 0.30 per 1000 AE	NR
Lanese et al. (1990)[35]	Prospective cohort†	Medical record from athletic and student trainers for collegiate fencers in an US university	AF 24 (F 6, M 18)	Nonspecific age	Nonspecific type, nonprofessional (beginner/intermediate) fencers	Injury was defined as a traumatic medical problem due to sport participation and resulting in loss of time from practice or competition during the period of 1 academic year	With body injuries: 8 out of 24 intercollegiate US fencers	1-yr cumulative incidence 33.3%	NR

** The joint belonging to the fencer's front leg in fencing position. Refer to online supplementary material for calculation.*
† Mixed sport study.
‡ Numbers of injured fencers not provided.
AF, able-bodied fencers; AE, athletic exposure = one athletic exposure equal to 1 opportunity for 1 athlete to incur an injury, 1 bout has 2 AE for 2 fencers; F, female; FIE, Fédération Internationaled' Escrime (FIE); IKDC, international knee documentation committee; M, male; NR, not reported; PFPS, patellofemoral pain; QL, quality level; dominated knee and hip; WF, wheelchair fencers.

TABLE 6. Injury Distribution by Types and Locations (Body Regions)

Group	Injury Site	Professional Fencing Level	Authors (Year)	Injured Body Part	No. of Injuries (% in Each Study)	Total Injuries (%)
AF	Head	Professional and nonprofessional*	Lambert et al. (2022)[26]	Head	0 (0)	0 (0)
		Non-professional	Chung et al. (2020)[19]	Head and face	12 (0.9)	12 (0.9)
		Professional and elite	Harmer (2019)[29]	Head	6 (3.4)	10 (0.61)
			Park (2017)[31]	Head and face	NA (0)	
			Harmer (2008)[34]	Head	4 (2.17)	
	Torso	Professional and nonprofessional*	Lambert et al. (2022)[26]	Back and front torso	28 (55)	28 (55)
		Nonprofessional	Chung et al. (2020)[19]	Neck, sternum, ribs, back, abdomen, waist	225 (17.3)	225 (17.3)
		Professional and elite	Harmer (2019)[29]	Back	8 (4.6)	305 (18.7)
			Park et al (2017)[31]	Neck, cervical spine, sternum/ribs, thoracic spine/upper back, abdomen, lumbar spine, lower back	257(21.9)	
			Zhou et al. (2016)[22]	Waist	10 (29.4)	
			Chung et al. (2012)[7]	Spine	9 (14.5)	
			Harmer (2008)[34]	Neck/throat, back	21 (11.4)	
	Upper limb	Professional and nonprofessional*	Lambert et al. (2022)[26]	Shoulder and upper extremity	3 (6)	3 (6)
		Nonprofessional	Chung et al. (2020)[19]	Shoulder, upper arms, elbow, forearm, wrist, hand	363 (27.9)	363 (27.9)
		Professional and elite	Harmer (2019)[29]	Shoulder, arm, elbow, forearm, wrist/hand, fingers	27 (15.5)	392 (24.0)
			Park et al (2017)[31]	Shoulder/clavicle, upper arms, elbow, forearm, wrist, hand, finger, thumb	310 (26.4)	
			Zhou et al. (2016)[22]	Shoulder, wrist	9 (26.5)	
			Chung et al. (2012)	Shoulder/arm, elbow, forearm, wrist/hand, fingers	10 (16.1)	
			Harmer (2008)[34]	Shoulder, arm, elbow, forearm, wrist/hand, fingers	36 (19.6)	
	Lower limb	Professional and nonprofessional*	Lambert et al. (2022)[26]	Knee and lower extremity	19 (47)	19 (47)
		Nonprofessional	Chung et al. (2020)[19]	Hip, pelvis, thigh/groin, knee, calf, ankle, foot	704 (54.0)	704 (54.0)
		Professional and elite	Harmer (2019)[29]	Hip, thigh, knee, leg, ankle, toes	131 (75.3)	915 (56.1)
			Park et al (2017)[31]	Pelvic/sacrum/buttock, hip, groin, thigh, knee, lower leg, Achilles, ankle, foot/toe	609 (51.8)	
			Zhou et al. (2016)[22]	Knee, ankle	15 (44.1)	
			Chung et al. (2012)[7]	Hip, thigh, pelvis, knee, ankle, lower leg	43 (69.4)	
			Harmer (2008)[34]	Hip, thigh, knee, leg, ankle, foot, toes	117 (63.6)	
	Others	Professional and elite	Harmer (2019)[29]	Nonspecific location	2 (1.15)	8 (0.49)
			Harmer (2008)[34]	Nonspecific location	6 (3.26)	
WF	Head	Professional and elite	Chung et al. (2012)[7]	Head	1 (1.1)	1 (1.1)
	Torso	Professional and elite	Chung et al. (2012)[7]	Cervical, thoracic, lumbar, trunk	24 (25.3)	24 (25.3)
	Upper limb	Professional and elite	Chung et al. (2012)[7]	Shoulder, upper arm, elbow, forearm, hand, finger	70 (73.8)	70 (73.8)

** A mixed levels study with professional (international elite, international, national, regional) and nonprofessional (recreational) fencers.*
AF, able-bodied fencers; WF, wheelchair fencers.

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ♁♁♁♁ ♁♁♁ ♁♁ ♁
Demographics								
	A cross-sectional study							
Age	Chung et al. (2020)[19]	Injured group: MS (n = 80); HS (n = 104); CA (n = 117) Noninjured group: MS (n = 146); HS (n = 79); CA (n = 58) Nonprofessional fencers MS: middle school students; HS: high school students CA: college students and adults 24-month prevalence	CA: MS (UOR: 3.68)	$P < 0.0001$; 95% CI, 2.43-5.58	Increased odds	NA	An associated factor	♁♁♁
			CA: HS (UOR: 1.53)	$P = 0.516$; 95% CI, 1.00-2.35	Increased odds	NA	An associated factor	♁♁♁
			HS:MS (UOR = 2.40)	$P < 0.0001$; 95% CI, 1.61-3.58	Increased odds	NA	An associated factor	♁♁♁
	A prospective cohort study							
	Harmer (2019)[29]	85 686 able-bodied fencers Time-loss injuries, = 175/ 637,776 AE (=0.27/1000 AE) Junior division (age ≤20 years) Cadet division (age 13-17 years) Senior division (age >17 years) No information of time-loss injuries for each age group Professional and elite fencers 5-year cumulative incidence	Senior: Junior/cadet (URR = 1.74)	95% CI, 1.25-2.43	Increased risk	NA	A risk factor	♁
		Time-loss injuries due to knee sprains Junior/Cadet 2 injuries Senior 17 injuries Professional and elite fencers 5-year cumulative incidence	Senior: Junior/Cadet (URR = 5.56)	95% CI, 1.28-24.06	Increased risk	NA	A risk factor	♁
		Time-loss injuries due to thigh strain Junior/Cadet 4 injuries Senior 18 injuries Professional and elite fencers 5-year cumulative incidence	Senior: Junior/Cadet (URR = 2.94)	95% CI, 1.00-8.69	Increased risk	NA	A risk factor	♁
		Time-loss injuries due to sprain: Junior/Cadet 18 injuries	Senior: Junior/Cadet (URR = 1.93)	95% CI, 1.13-3.29	Increased risk	NA	A risk factor	♁

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers *(Continued)*

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ♁♁♁♁ ♁♁♁ ♁♁ ♁
		Senior 53 injuries Professional and elite fencers 5-year cumulative incidence						
		Time-loss injuries due to strain: Junior/Cadet 7 injuries Senior 28 injuries Professional and elite fencers 5-year cumulative incidence	Senior: Junior/Cadet (URR = 2.62)	95% CI, 1.14-5.99	Increased risk	NA	A risk factor	♁
	A cross-sectional study							
Sex	Prakash et al (2019)[20]	113 able-bodied fencers; M (n = 40), F (n = 73) Injured fencers: M (n = 10), F (n = 4) A mix of professional and nonprofessional fencers, 24-month prevalence	Female: Male (UOR = 0.22)	95% CI, 0.06-0.74	Decreased odds	NA	A protective factor	♁
	Prospective cohort studies							
	Harmer (2008)[34]	78 223 able-bodied fencers (foil, épée, and saber) Time-loss injuries (n = 184) M: 98/369 993 (=0.26/1000 AE) F: 86/240,278 (=0.36/1000 AE) Professional and elite fencers 5-year cumulative incidence	Female: Male (URR = 1.35)	P = 0.04 95% CI, 1.01-1.81	Increased risk	Meta-analysis Female: Male RR = 0.98, 95% CI, 0.52-1.85, I^2 = 89%	Not a risk factor	♁
	Harmer (2019)[29]	85,686 able-bodied fencers (foil, épée, and saber) Time-loss injuries: 175/637,776 AE (=0.27/1000 AE) Time-loss injuries: M:113/355,766 AE (=0.32/1000 AE) F: 63/282,010 AE (=0.22/1,000 AE) Professional and elite fencers 5-year cumulative incidence	Female: Male (URR = 0.70)	P = 0.03 95% CI, 0.52-0.96	Decreased risk			
	Harmer (2008)[34]	78,223 able-bodied fencers (foil, épée, and saber)	Sprain Female: Male (URR = 1.24)	P = 0.46	No relation	NA	Not a risk factor	♁

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers *(Continued)*

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ♁♁♁♁ ♁♁♁ ♁♁ ♁
		Time-loss injuries: Sprain: M (n = 26); F (n = 21) Professional and elite fencers 5-year cumulative incidence Strain: M (n = 25); F (n = 23) Professional and elite fencers 5-year cumulative incidence Contusion: M (n = 14); F (n = 8) Professional and elite fencers 5-year cumulative incidence Subluxation/dislocation: M (n = 9); F (n = 5) Professional and elite fencers 5-year cumulative incidence Fracture: M (n = 3); F (n = 5) Professional and elite fencers 5-year cumulative incidence Laceration: M (n = 1) F (n = 0) Professional and elite fencers 5-year cumulative incidence Puncture: M (n = 1); F (n = 4) Professional and elite fencers 5-year cumulative incidence Rupture: M (n = 2); F (n = 4) Professional and elite fencers 5-year cumulative incidence Cramp/Spasm: M (n = 6); F (n = 3) Professional and elite fencers 5-year cumulative incidence		95% CI, 0.70-2.21				
			Strain Female: Male (URR = 1.42)	P = 0.23 95% CI, 0.80-2.50	No relation	NA	Not a risk factor	♁
			Contusion Female: Male (URR = 0.88)	P = 0.77 95% CI, 0.37-2.10	No relation	NA	Not a risk factor	♁
			Subluxation/dislocation Female: Male (URR = 0.85)	P = 0.78 95% CI, 0.29-2.55	No relation	NA	Not a risk factor	♁
			Fracture Female: Male (URR = 2.57)	P = 0.20 95% CI, 0.61-10.74	No relation	NA	Not a risk factor	♁
			Laceration NA	NA	NA	NA	Not a risk factor	♁
			Puncture Female: Male (URR = 6.16)	P = 0.10 95% CI, 0.69-55.11	No relation	NA	Not a risk factor	♁
			Rupture Female: Male (URR = 3.08)	P = 0.19 95% CI, 0.56-16.81	No relation	NA	Not a risk factor	♁
			Cramp/Spasm Female: Male (URR = 0.77)	P = 0.71 95% CI, 0.19-3.08	No relation	NA	Not a risk factor	♁
	Harmer (2019)[29]	85 686 able-bodied fencers (foil, épée, and saber) 176 time-loss injuries (foil, épée, and saber) M (n = 113), F (n = 63)	Thigh strain Female: Male (URR = 3.56)	95% CI, 1.21-10.52	Increased risk	NA	A risk factor	♁

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers *(Continued)*

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ⊕⊕⊕⊕ ⊕⊕⊕ ⊕⊕ ⊕
		Time-loss injuries in thigh strain: M (n = 18); F (n = 4) Professional and elite fencers 5-year cumulative incidence						
		Time-loss injuries due to knee rupture: M (n = 4), W (n = 7) Professional and elite fencers 5-year cumulative incidence	Knee rupture Female: Male (URR = 2.21)	95% CI, 0.65-7.56	No relation	NA	Not a risk factor	⊕
	Harmer (2019)[29]	85,686 able-bodied fencers (foil, épée, and saber) Time-loss injuries 175/637,776 AE (n = 0.27/1000 AE) Foil-related time-loss injuries: M: 42/111,292 AE (=0.38/1000 AE) F: 23/85,308 AE (=0.27/1000 AE) Épée-related time-loss injuries: M: 24 /141,332 AE (=0.17/1000 AE) F: 19/111,460 AE (=0.17/1000 AE) Saber-related time-loss injuries M: 47/103,142 AE (=0.46/1000 AE) F: 21/85,242 AE (=0.25/1000 AE) Professional and elite fencers 5-year cumulative incidence	Female Foil: Male Foil (URR = 0.71)	P = 0.19 95% CI, 0.43-1.19	No relation	NA	Not a risk factor	⊕
			Female Épée: Male Épée (URR = 1.00)	P = 1.00 95% CI, 0.55-1.82	No relation	NA	Not a risk factor	⊕
			Female Sabreurs: Male Sabreurs (URR = 0.54)	P = 0.02 95% CI, 0.32-0.90	Decreased risk	NA	A protective factor	⊕
	A cross-sectional study							
Years of fencing experience	Chung et al. (2020)[19]	584 able-bodied fencers (foil, épée, and saber) Nonprofessional fencers 24-month prevalence	3–4 years: ≤2 years (UOR = 2.94)	P < 0.0001 95% CI, 1.90-4.55	Increased odds	NA	An associated factor	⊕⊕⊕
			5-6 years: ≤2 years (UOR = 4.08)	P < 0.0001 95% CI, 2.32-7.18	Increased odds	NA	An associated factor	⊕⊕⊕
			5–6 years: 3–4 years (UOR = 1.39)	P = 0.26 95% CI, 0.79-2.45	No relation	NA	Not an associated factor	⊕⊕⊕
			6 years: ≤2 years (UOR = 5.12)	P < 0.0001	Increased odds	NA	An associated factor	⊕⊕⊕

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers *(Continued)*

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ⊕⊕⊕⊕ ⊕⊕⊕ ⊕⊕ ⊕
				95% CI, 3.24-8.09				
			6 years: 3-4 years (UOR = 1.74)	P = 0.02 95% CI, 1.10-2.76	Increased odds	NA	An associated factor	⊕⊕⊕
			> 6 years: 5–6 years (UOR = 1.25)	P = 0.44 95% CI, 0.70-2.24	No relation	NA	Not an associated factor	⊕⊕⊕
	A cross-sectional study							
Competitive levels	Prakash et al (2019)[20]	113 able-bodied fencers Injured group: International (n = 7), national (n = 6), university (n = 1) Noninjured group: International (n = 18), national (n = 45), university (n = 36) A mix of professional and nonprofessional fencers 24-month prevalence	International: University (UOR = 14)	P = 0.02 95% CI, 1.60-122.66	Increased odds	NA	An associated factor	⊕
			International: National (UOR = 2.92)	P = 0.09 95% CI, 0.86-9.88	No relation	NA	Not an association factor	⊕
			National: University (UOR = 4.80)	P = 0.16 95% CI, 0.55-41.70	No relation	NA	Not an association factor	⊕
Types of fencing								
	Cross-sectional studies							
Fencing weapons	Chung et al. (2020)[19]	584 able-bodied fencers (foil, Épée, and saber) Injured group: Foil (n = 102) Épée (n = 96) Saber (n = 103) Noninjured group: Foil (n = 74) Épée (n = 122) Saber (n = 87) Nonprofessional fencers, 24-month prevalence	Foil: Épée (UOR = 1.75)	P = 0.01 95% CI, 1.16-2.61	Increased odds	Results of meta-analysis: Foil: Épée OR = 1.31, 95% CI, 0.53-3.27, I^2 = 48%	Not an associated factor	⊕
	Prakash et al (2019)[20]	113 able-bodied fencers; Injured group: Foil (n = 3) Épée (n = 8) Saber (n = 3) Noninjured group: Foil (n = 26) Épée (n = 43)	Foil: Épée (UOR = 0.62)	P = 0.51 95% CI, 0.15-2.55	No relation			

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers *(Continued)*

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ♁♁♁♁ ♁♁♁ ♁♁ ♁
		Saber (n = 30) A mix of professional and on-professional fencers 24-month prevalence						
	Chung et al. (2020)[19]	584 able-bodied fencers (Foil, Épée, Saber) Injured group: Foil (n = 102) Épée (n = 96) Saber (n = 103) Noninjured group: Foil (n = 74) Épée (n = 122) Saber (n = 87) Nonprofessional fencers 24-month prevalence	Foil: Saber (UOR = 1.16)	P = 0.47 95% CI, 0.77-1.76	No relation	Results of meta-analysis: Foil: Saber OR = 1.16, 95% CI, 0.78-1.14 $I^2 = 0$	Not an associated factor	♁
	Prakash et al (2019)[20]	113 able-bodied fencers; Injured group: Foil (n = 3) Épée (n = 8) Saber (n = 3) Noninjured group: Foil (n = 26) Épée (n = 43) Saber (n = 30) A mix of professional and nonprofessional fencers 24-month prevalence	Foil: Saber (UOR = 1.15)	P = 0.87 95% CI, 0.21-6.22	No relation			
	Chung et al. (2020)[19]	584 able-bodied fencers (Foil, Épée, and Saber) Injured group: Foil (n = 102) Épée (n = 96) Saber (n = 103) Non-injured group: Foil (n = 74) Épée (n = 122) Saber (n = 87) Nonprofessional fencers 24-month prevalence	Saber: Épée (UOR = 1.50)	P = 0.04 95% CI, 1.02-2.22	Increased odds	Results of meta-analysis: Saber: Épée OR = 1.13, 95% CI, 0.46-2.79, $I^2 = 48\%$	Not an associated factor	♁
	Prakash et al (2019)[20]	113 able-bodied fencers Injured group: Foil (n = 3), Épée (n = 8), Saber (n = 3) Noninjuried group: Foil (n = 26), Épée (n = 43), Saber (n = 30)	Saber: Épée (UOR = 0.54)	P = 0.39 95% CI, 0.13-2.19	No relation			

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers *(Continued)*

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ♁♁♁♁ ♁♁♁ ♁♁ ♁
		A mix of professional and nonprofessional fencers 24-month prevalence						
	Prospective cohort studies							
	Harmer (2019)[29]	85 686 able-bodied fencers (foil, épée, and saber) Time-loss injuries 175/637,776 AE (n = 0.27/ 1000 AE) Time-loss injuries: Foil: 65/196,600 AE (=0.33/ 1000 AE) Épée: 43/252,792 AE (=0.17/ 1000 AE) Saber: 68/188 384 AE (=0.36/ 1000 AE) Professional and elite fencers 5-year cumulative incidence	Foil: Épée (URR = 1.94)	P = 0.0007 95% CI, 1.32-2.86	Increased Risk	Results of meta-analysis Foil: Épée RR = 1.45, 95% CI, 0.83-2.55, I^2=78%	Not a risk factor	♁
	Harmer[34] (2008)	78 223 able-bodied fencers (foil, épée, and saber) Time-loss injuries: Foil: 68/249 590 AE (=0.27/ 1000 AE) Épée 52/209 371 AE (=0.25/ 1000 AE) Saber 64/151 310 AE (=0.43/ 1000 AE) Professional and elite fencers 5-year cumulative incidence	Foil: Épée (URR = 1.10)	P = 0.6153 95% CI, 0.76-1.57	No relation			
	Harmer (2019)[29]	85 686 able-bodied fencers (foil, épée, and saber) Time-loss injuries 175/637,776 AE (n = 0.27/ 1000 AE) Time-loss injuries: Foil: 65/196,600 AE (=0.33/ 1000 AE) Épée: 43/252,792 AE (=0.17/ 1000 AE) Saber: 68/188,384 AE (=0.36/ 1000 AE) Professional and elite fencers 5-year cumulative incidence	Saber: Foil (URR = 1.09)	P = 0.61 95% CI, 0.78-1.53	No relation	Results of meta-analysis Saber: Foil RR = 1.30, 95% CI, 0.92-1.84, I^2 = 51%	Not a risk factor	♁

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers *(Continued)*

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ♁♁♁♁ ♁♁♁ ♁♁ ♁
	Harmer (2008)[34]	78 223 able-bodied fencers (foil, épée, and saber) Time-loss injuries: Foil: 68/249,590 AE (=0.27/ 1000 AE) Épée 52/209,371 AE (=0.25/ 1000 AE) Saber 64/151,310 AE (=0.43/ 1000 AE) Professional and elite fencers 5-year cumulative incidence	Saber: Foil (URR = 1.55)	P = 0.00 95% CI, 1.10-2.18	Increased risk			
	Harmer[29] (2019)	85,686 able-bodied fencers (foil, épée, and saber) N = 175 time-loss injuries, AE = 637,776 (=0.27/1000 AE) Time-loss injuries: Foil: 65/196,600 AE (=0.33/ 1000 AE) Épée: 43/252,792 AE (=0.17/ 1000 AE) Saber: 68/188,384 AE (=0.36/ 1000 AE) Professional and elite fencers 5-year cumulative incidence	Saber: Épée (URR = 2.12)	P = 0.0001 95% CI, 1.45-3.11	Increased risk	Results of meta-analysis Saber: Épée RR = 1.89, 95% CI, 1.45-2.46, $I^2 = 0$	A risk factor	♁♁
	Harmer (2008)[34]	78,223 able-bodied fencers (foil, épée, and saber) Time-loss injuries: Foil: 68/249,590 AE (=0.27/ 1000 AE) Épée 52/209 371 AE (=0.25/ 1000 AE) Saber 64/151 310 AE (=0.43/ 1000 AE) Professional and elite fencers 5-year cumulative incidence	Saber: Épée (URR = 1.70)	P = 0.00 95% CI, 1.18-2.46	Increased risk			
Warm up, cool down, and participation in fitness program								
	A cross-sectional study							
Warm up	Prakash et al (2019)[20]	113 able-bodied fencers Injured group: Regular (n = 14), Irregular (n = 0) Noninjured group: Regular (n = 96) Irregular (n = 3)	Cannot be calculated	Cannot be calculated	Cannot be determined	NA	Not an associated factor	♁

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers *(Continued)*

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ⊕⊕⊕⊕ ⊕⊕⊕ ⊕⊕ ⊕
		A mix of professional and nonprofessional fencers (n = 113) 24-month prevalence						
Cool down	Prakash et al (2019)[20]	113 able-bodied fencers Injured group: Regular (n = 7), Irregular (n = 7) Noninjured group: Regular (n = 34), Irregular (n = 65) A mix of professional and nonprofessional fencers (n = 113) 24-month prevalence	Regular cool down: Irregular cool down (UOR = 1.91)	P = 0.26 95% CI, 0.62-5.90	No relation	NA	Not an associated factor	⊕
Participation in a fitness program	Prakash et al (2019)[20]	113 able-bodied fencers Injured group: Regular (n = 13), Irregular (n = 1) Noninjured group: Regular (n = 21), Irregular (n = 78) A mix of professional and nonprofessional fencers (n = 113) 24-month prevalence	Regular fitness program: Irregular fitness program (UOR = 48.29)	P = 0.0003 95% CI, 5.97-390.50	Increased odds	NA	An associated factor	⊕
Functional movement screening tool results								
	A cross-sectional study							
FMS≤15	Zhou et al. (2016)[22]	N = 30 able-bodied fencers (Foil, Épée. Saber) Injured group: FMS ≤15 (n = 15) FMS>15 (n = 6) Noninjured group: FMS ≤15 (n = 1) FMS>15 (n = 8) Professional and elite fencers Point prevalence	FMS ≤15: FMS>15 (UOR = 20) *Fencers who got FMS≤15 were associated with sport-related injury	P = 0.01 95% CI, 2.04-196.38	Increased odds	NA	An associated factor	⊕
YBT (X > 4 cm, Y, Z > 6 cm)	Zhou et al. (2016)[22]	N = 30, able-bodied fencers (Foil, Épée, Saber) Injured group: YBT (X > 4 cm, Y, Z > 6 cm) (n = 16); YBT (X ≤ 4 cm, Y, Z ≤ 6 cm) (n = 5) Noninjured group: YBT (X > 4 cm, Y, Z > 6 cm) (n = 4); (X ≤ 4 cm, Y, Z ≤ 6 cm) (n = 5) Professional and elite fencers	YBT (X > 4 cm, Y, Z > 6 cm): YBT (X ≤ 4 cm, Y, Z ≤ 6 cm) UOR = 4 *Fencers with bilateral differences in YBT results in various directions exceeding the thresholds (X > 4 cm, and Y, Z	P = 0.10 95% CI, 0.76-20.92	No relation	NA	Not an associated factor	⊕

TABLE 7. Potential Associated Factors and Risk Factors of Fencing-Related Injuries and Pain Among Able-Bodied Fencers and Wheelchair Fencers *(Continued)*

Variables	Study (Author(s), year)	Total Number (N) of Participants/Person Injuries Details of injured fencers	Statistics of Injury/Pain Adjusted/Unadjusted OR = AOR/UOR Adjusted/Unadjusted Relative Risk (RR) = ARR/URR	Probability (P); 95% CIs	Association with Sport-Related Injuries and Pain	Pooled for Meta-Analysis	Effects: A Risk Factor/An Associated Factor/A Protective factor	Quality of Evidence: ♁♁♁♁ ♁♁♁ ♁♁ ♁
		Point prevalence	> 6 cm) were not associated with more fencing injuries					
Presence of disability								
	A prospective study							
Wheelchair fencers	Chung et al,[7] (2012)	10 AFs and 14 WFs Time-loss injuries (at least 1 d): Time-loss injuries (at least 1 d): Able-bodied: 62/25 699 hours (=2.41/1000 hours) Wheelchair: 95/24 664 hours (=3.85/1000 hours) Professional fencers 3-year cumulative incidence	Minor injuries: WFs: AFs URR = 2.4	$P < 0.05$ 95% CI, 1.6-3.6	Increased risk	NA	A risk factor	♁
			Muscle strain WFs: AFs URR = 2.2	$P < 0.05$ 95% CI, 1.3-3.6	Increased risk	NA	A risk factor	♁
			Shoulder injury WFs: AFs URR = 13.6	$P < 0.05$ 95% CI, 3.4-17.8	Increased risk	NA	A risk factor	♁
			Elbow injury WFs: AFs URR = 5.9	$P < 0.05$ 95% CI, 2.5-17.2	Increased risk	NA	A risk factor	♁
Absence of trunk control in wheelchair fencers								
	A prospective study							
Wheelchair fencers	Chung et al., (2012)[7]	10 AFs and 14 WFs Time-loss injuries (at least 1 d): WF category A (with active trunk control): 40/13 368 hours (=3.00/1000 hours) WF category B (without active trunk control): 55/11 296 h =4.87/1000 hours Professional fencers 3-year cumulative incidence	Muscle strain Category B: Category A URR = 1.8	$P < 0.05$ 95% CI, 1.1-3.3	Increased risk	NA	A risk factor	♁
			Shoulder injury Category B: Category A URR = 5.0	$P < 0.05$ 95% CI, 1.8-16.9	Increased risk	NA	A risk factor	♁

Remarks.

Functional Movement Screen (FMS)[22]: FMS is a screening tool used to evaluate 7 functional patterns in individuals with no current pain complaint or musculoskeletal injury. Seven functional patterns are (1) deep squat (2) hurdle step (3) inline lunge (4) shoulder mobility (5) active straight-leg raise (6) trunk stability push up (7) rotary stability.

Y-balance test (YBT)[37]: YBT is a screening tool used to assess lower-extremity balance and neuromuscular control to predict lower-extremity injury. Participants stand on the center footplate, with the distal aspect of the right foot at the starting line. While sustaining single leg stance on the right leg, the participant reached with the free limb in the anterior (X), posteromedial (Y), and posterolateral directions (Z) in relation to the stance foot by pushing the indicator box as far as possible. Fencers who had YBT difference (X > 4 cm, Y, Z > 6 cm) were associated with sport-related injury.

Quality of evidence.

High: ♁♁♁♁ It is very confident that the true effect lies close to that of the estimate of the effect

Moderate: ♁♁♁ It is moderately confident that the true effect is likely to be close to the estimate of the effect, but it is possible that they may be substantially different.

Low: ♁♁ There is limited confidence in the effect estimate. The estimate of the effect may be substantially different from the true effect

Very low: ♁ There is very little confidence in the effect estimate; the estimate of effect is likely to be substantially different from the true effect

Conflicting evidence: Inconsistent findings.

AE, athletic exposure; AFs, able-bodied fencers; AOR, adjusted odds ratio. ARR: adjusted relative risk; CA, college students and adults. CI, confidence intervals; FMS, functional movement screening score; HS, high school students; I^2, I-square test; MS, middle school students; NA, not applicable; P, probability; UOR, unadjusted odds ratio; URR, unadjusted relative risk; WFs, wheelchair fencers; YBT, Y-balance test.

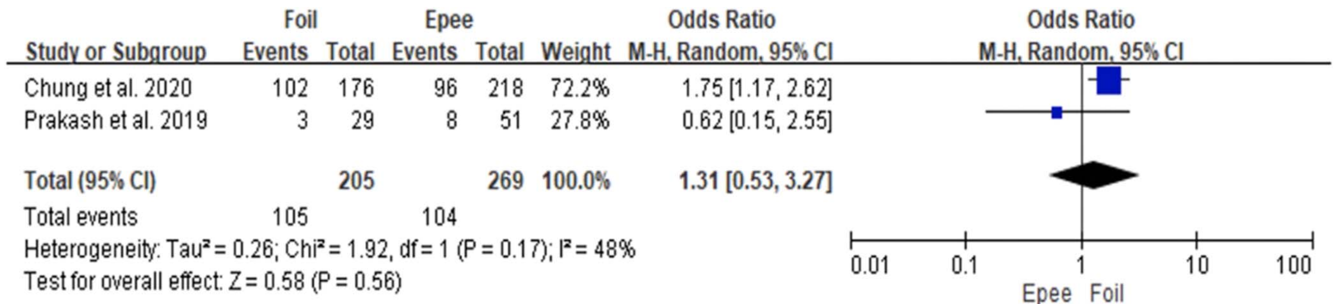
Figure 2. A meta-analysis of the effects of sex on time-loss fencing injuries among professional able-bodied fencers.

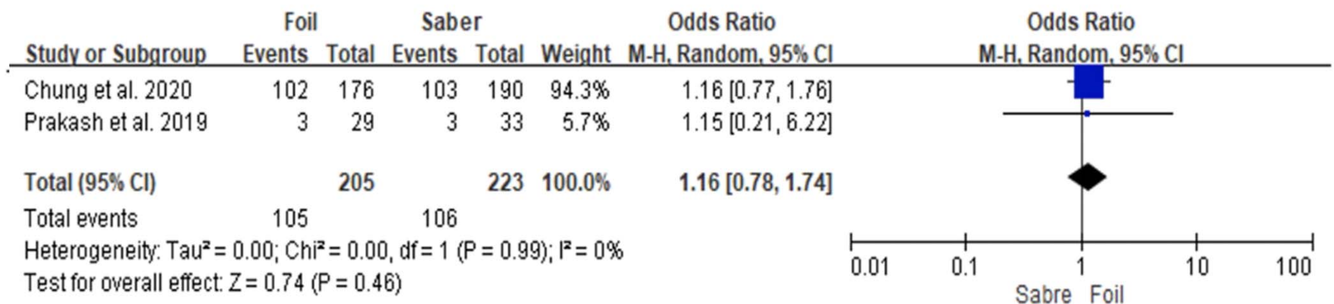
Subgroup/Sensitive Analysis

The planned subgroup/sensitivity analyses were not conducted because of insufficient information from the included studies.

DISCUSSION

This is the first systematic review and meta-analysis to summarize the prevalence/incidence of fencing injuries/pain, and factors associated with increased fencing injuries/pain in AFs and WFs. Professional fencers displayed higher prevalence/incidence of fencing injuries than nonprofessional fencers. Lower-extremity injuries (>50%) were most prevalent among AFs, while WFs were at risk of upper-extremity injuries (>70%). High prevalence of fencing-related back pain and PFPS were also reported. Moderate-quality evidence supported that older age and more years of fencing experiences were related to a higher 24-month prevalence of fencing injuries among nonprofessional AFs. Very low-quality





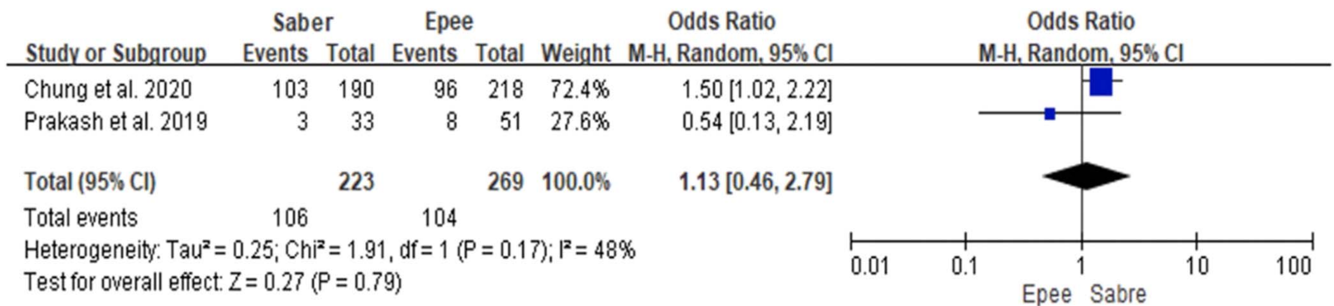


Figure 3. A, Meta-analyses of odds ratios for having a higher 24-month prevalence of fencing injury because of different fencing weapons: Foil versus épée. B, Meta-analyses of odds ratios for having a higher 24-month prevalence of fencing injury due to different fencing weapons: Foil versus saber. C, Meta-analyses of odds ratios for having a higher 24-month prevalence of fencing injury due to different fencing weapons: saber versus épée.

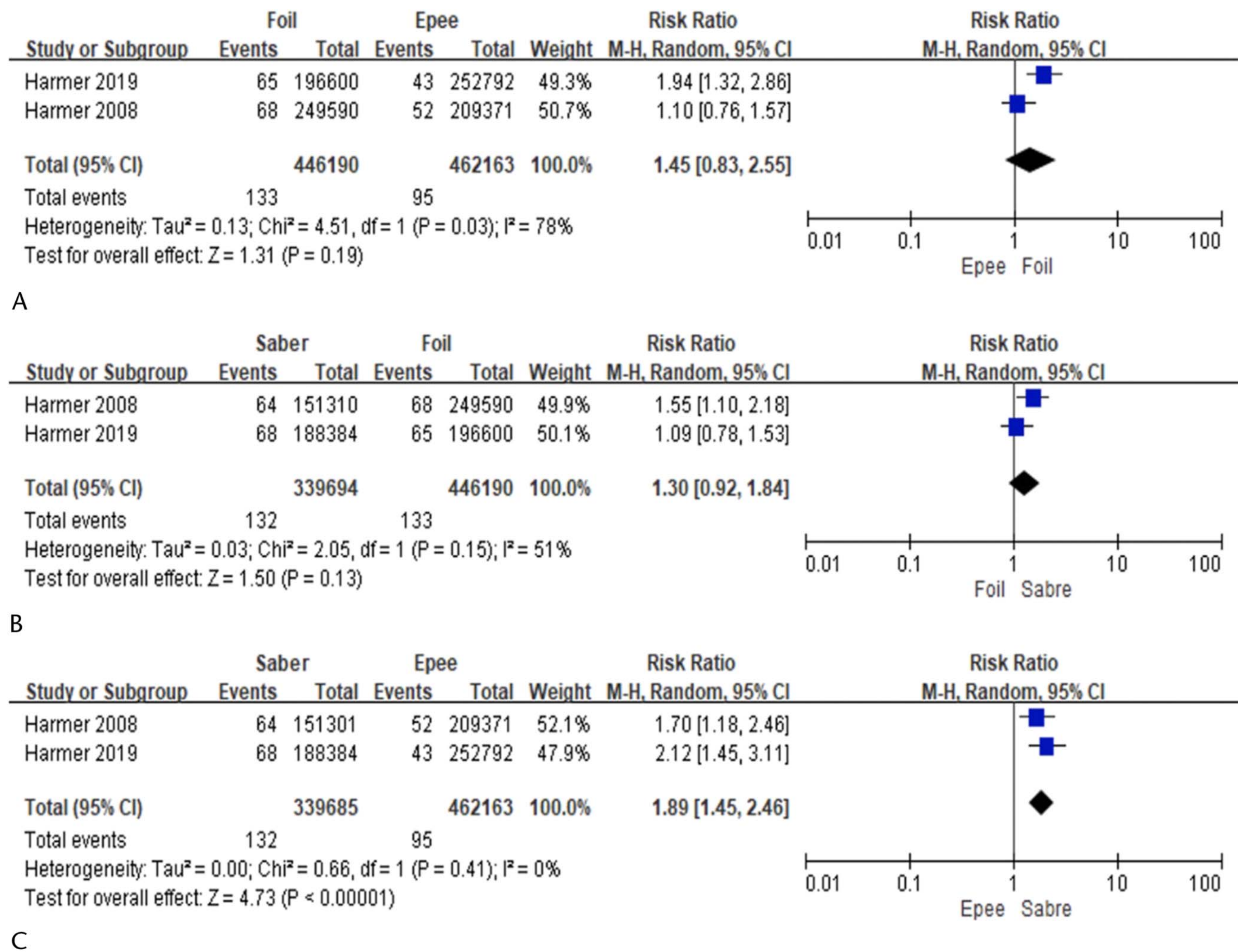


Figure 4. A, A meta-analysis of odds ratios for having a higher 5-year cumulative incidence of time-loss fencing injuries due to different fencing weapons: Foil versus épée. B, A meta-analysis of odds ratios for having a higher 5-year cumulative incidence of time-loss fencing injuries due to different fencing weapons: saber versus foil. C, A meta-analysis of odds ratios for having a higher 5-year cumulative incidence of time-loss fencing injuries due to different fencing weapons: saber versus épée.

evidence showed that AFs competing in international games and regular participation in fitness programs were associated with a higher 24-month prevalence of fencing injuries in professional/nonprofessional AFs. Very low-quality evidence substantiated that FMS scores $\leq$15 were associated with a higher point prevalence of fencing injuries in AFs. Furthermore, very low-quality evidence supported that older age, male sabreurs, and sabreur per se were risk factors for fencing injuries among professional AFs, while professional WFs with poor trunk control had a higher risk of fencing injuries.

Older AFs were more likely to sustain sports-related injuries, regardless of professional levels. The higher injury rate in older AFs may be attributed to higher competition levels, longer sport-participation time, and/or overuse injuries. Because age and years of fencing experiences are irreversible factors, future injury prevention strategies may focus on older or more experienced fencers.

Although very low-quality evidence suggested that female AFs were more likely to sustain thigh strain than male AFs, 2 included prospective studies reported inconsistent results regarding the risk of fencing injuries in professional female AFs.[29,34] Our meta-analysis also revealed no significant between-sex differences in time-loss injuries.[29,34] Although compared with male AFs, female AFs perform fencing lunges with greater hip adduction, knee abduction/adduction, and ankle eversion ranges of motion, and greater patellofemoral contact force,[38,39] which may increase the risk of anterior cruciate ligament injuries[40] or overuse knee injuries and PFPS in female AFs,[41,42] our findings suggest that other factors (eg, physique, fencing skills, professional levels, and fencing weapons) may offset the association between sex and fencing injuries.

Sabreurs are more likely to sustain sports-related injuries than épéeists. Given that the weight of a saber (500 grams) is comparable with that of an épée (770 grams),[43] the weapon weight is unlikely to increase the risk of the weapon-arm injuries. The more lower-extremity injuries in sabreurs may be ascribed to the fast-paced saber fencing, frequent changes in directions, and sudden movements.[28] Time-motion analyses showed that elite sabreurs performed more explosive attacking and defensive movements (eg, lunges and retreats) with

short bouts of action and long-lasting recovery periods (work: recovery [W:R] ratio = 1:6) than épéeists (W:R = 1:1).[44] During elimination bouts, sabreurs need to use more anaerobic power in the fencing events, which increases their risk of neuromuscular fatigue. Because muscle fatigue may affect peripheral and central proprioception, the compromised dynamic balance and respective compensatory movements may increase the risk of falls and lower limb injuries in saber AFs.[45–47] Future studies should quantify the cumulative effects of neuromuscular fatigue on fencing injuries in various styles of fencers.

Only 1 included cross-sectional study[20] investigated the associations between warm-up, cooldown, or regular participation in fitness programs and fencing injuries. It showed that only regular involvements in fitness programs were associated with more fencing injuries. However, as the reported OR had a large 95% CI, future large-scale prospective studies are warranted to validate this finding.

Although FMS test assesses athletes' (eg, American football players) compensatory movement patterns and dynamic balance, which may predict their injury risk, this test is not tailored for evaluating fencing-specific movements.[48] Therefore, FMS scores alone could not predict injuries in elite fencers.[49] Although 1 included study involving 30 professional AFs revealed that FMS score ≤15 was associated with a higher point prevalence of fencing injuries, this finding should be interpreted with caution. Likewise, the nonsignificant association between YBT results and point prevalence of fencing injuries in professional AFs[22] might have been confounded by age, sex, and types of sports.[37] Future studies may investigate using dynamic balance tests (eg, the Dynamic Leap and Balance Test) to identify high-risk fencers.[50]

Mechanical Consideration for Increased Lower Limb Injuries/Pain in AFs

The high prevalence of lower limb injuries in AFs is likely to be related to the repetitive asymmetrical movements. Prior biomechanical research has proposed potential mechanisms underlying the higher prevalence of injuries on front leg of AFs.[28,29] Able-bodied fencing involves diverse asymmetrical leg movement patterns that may cause thigh, knee, and ankle injuries.[2,51,52] To prevent excessive front knee extension during the acceleration phase of the lunge and to exert a strong braking force of the forward moving lower leg at landing, the hamstrings of the dominant leg need to contract eccentrically,[2,52,53] which increase the risk of hamstrings strain during lunging.[54] In addition, the dominant leg of elite AFs may experience extremely high eccentric forces during lunging because AFs have significantly larger thigh muscle size in the front leg than in the rear leg.[54] Furthermore, AFs are prone to sustaining hamstrings strains because they often use the quadriceps more than hamstrings.[55]

The PFPS in AFs may result from excessive valgus forces and repeated weight bearing during lunging,[56–58] weak core or gluteal muscles,[59,60] or the tightness of quadriceps, hamstrings, and/or gastrocnemius.[61] Weak vastus medialis oblique may cause the patella mal-tracking in the femoral trochlea, causing PFPS.[62]

Ankle injuries in AFs may be associated with excessive loading during lunging.[19] Research showed that the torque of ankle dorsiflexors in elite sabreurs was approximately 20% higher in the front leg than in the back leg, implicating excessive loading on the ankle of the dominant leg during lunging.[63,64] Compared with novice fencers, elite fencers inclined their center of gravity more anteriorly to effectively propel their body during lunging.[65] This may heighten their risk of ankle injuries after slip-and-fall accidents.[65]

Mechanical Consideration for Increased Upper Limb Injuries/Pain in WFs

Foil WFs with poor trunk control were more likely to have upper-extremity injuries than AFs[7] The footwork of AFs serves as a pivot base to transmit the ground reaction force to the entire body.[8] However, the sequential activation in WFs is interrupted by the absence of lower body movements. The truncated kinetic chain in WFs with poor trunk control is over-compensated by repetitive movements of upper limbs, yielding shoulder and elbow overuse injuries.[7,12]

Clinical Implications

Research has used motion capture and machine learning technologies to identify abnormal lower limb biomechanics in AFs,[38] and to distinguish novice AFs from elite AFs.[66] Clinicians may use wearable accelerometers and electromyography to identify abnormal fencing biomechanics, and develop personalized workout regimens for fencers.[38,67] In addition, fencing functional training or specific training programs[68] targeting neuromuscular control, movement symmetry, balance, proprioception, and lower-limb agility of AFs[69,70] may enhance dynamic balance and prevent fencing injuries.[71,72]

Wearable accelerometers and electromyographic sensors can be used to evaluate the functional capacities and neuromuscular coordination of upper limbs and trunk of WFs.[73] Trunk weakness or instability can increase the risk of overuse and acute injuries in WFs. Surface electromyography can help identify muscle weaknesses or compensatory muscle activities in WFs so as to tailor training to improve trunk stability and fencing performance, and to reduce their injury risk.[74] Given the high prevalence of upper limb injuries in WFs, proper neuromuscular coordination assessments, psychomotor exercises, and shoulder strengthening exercises should be incorporated to the training regimens.[75,76]

Future Studies

Although multiple cross-sectional studies suggested that biomechanics of fencing may increase the risk of injuries,[77–79] previous epidemiological studies[20,29,30,34,35] that investigated risk factors for fencing injuries did not consider biomechanical factors. Likewise, environmental factors (eg, fencing shoes, protecting equipment, or flooring),[64] or anthropometric (eg, arm span) and morphologic (eg, somatotype) characteristics of fencers,[54] and psychological factors (eg, stress or mental fatigue)[80,81] may also be associated with fencing injuries, yet they were not considered in the included studies. Future prospective studies should consider the abovementioned factors to determine the risk factors for fencing injuries. Furthermore, fencing-specific screening tools should be developed to identify high-risk fencers and implement proper injury prevention programs to lower the risk of fencing injuries.[80,81]

Limitations and Future Directions

The current review had several limitations. First, definitions of professional levels, fencing-related injury, and injury incidence were heterogeneous. The diverse definitions precluded the pooling of data. Therefore, an international consortium should be formed to include different stakeholders (eg, International Fencing Federation and International Olympic Committee, researchers, fencers, and clinicians) to standardize the definition of common terminologies to enable comparisons across studies.[82] Second, the included studies mainly used self-reported questionnaires to identify factors associated with fencing injuries, which might be affected by subjectivity/recall bias. Third, subgroup analyses were precluded because the included studies were heterogeneous (eg, different age, a mix of female and male fencers, different fencing weapons, variable definitions of professional levels, diverse measurements of prevalence/incidence). Fourth, the included studies only used bivariate analyses to identify factors associated with fencing-related injury/pain without considering confounders. Future studies should include multivariate analyses to identify independent associated factors, risk factors, or prognostic factors for fencing injuries or pain. Fifth, only a small-scale prospective study[7] investigated the incidence of injury and associated risk factors in elite wheelchair foil fencers, hence further studies of WFs are warranted.

CONCLUSIONS

This is the first systematic review to synthesize evidence regarding prevalence, incidence, and injury-related factors for fencing injuries/pain in AFs and WFs. Clinicians and coaches should be aware that AFs and WFs are at risk of lower-extremity injuries and upper-extremity injuries, respectively. WFs may be more likely to sustain fencing injuries than AFs. Sex, years of fencing experiences, levels of fencing, and regular participation in fitness programs, and FMS scores ≤ 15 were factors associated with a higher prevalence of fencing injuries in AFs. Although older ages and sabreurs were risk factors for fencing injuries in AFs, WFs with poor trunk control had a higher risk of fencing injuries. Future research should quantify the impacts of biomechanical, environmental, and psychological factors on the risk of fencing injuries in AFs and WFs so that tailored preventive strategies can be developed.

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