*Original Research*

# Epidemiological Characteristics of Foot and Ankle Injuries in 2 Professional Ballet Companies

## A 3-Season Cohort Study of 588 Medical Attention Injuries and 255 Time-Loss Injuries

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**Background:** The foot and ankle are often reported as the most common sites of injury in professional ballet dancers; however, epidemiological research focusing on foot and ankle injuries in isolation and investigating specific diagnoses is limited.

**Purpose:** To investigate the incidence rate, severity, burden, and mechanisms of foot and ankle injuries that (1) required visiting a medical team (medical attention foot and ankle injuries; MA-FAIs) and (2) prevented a dancer from fully participating in all dance-related activities for at least 24 hours after the injury (time-loss foot and ankle injuries; TL-FAIs) in 2 professional ballet companies.

**Study Design:** Descriptive epidemiological study.

**Methods:** Foot and ankle injury data across 3 seasons (2016-2017 to 2018-2019) were extracted from the medical databases of 2 professional ballet companies. Injury-incidence rate (per dancer-season), severity, and burden were calculated and reported with reference to the mechanism of injury.

**Results:** A total of 588 MA-FAIs and 255 TL-FAIs were observed across 455 dancer-seasons. The incidence rates of MA-FAIs and TL-FAIs were significantly higher in women (1.20 MA-FAIs and 0.55 TL-FAIs per dancer-season) than in men (0.83 MA-FAIs and 0.35 TL-FAIs per dancer-season) (MA-FAIs, $P = .002$; TL-FAIs, $P = .008$). The highest incidence rates for any specific injury pathology were ankle impingement syndrome and synovitis for MA-FAIs (women 0.27 and men 0.25 MA-FAIs per dancer-season) and ankle sprain for TL-FAIs (women 0.15 and men 0.08 TL-FAIs per dancer-season). *Pointe* work and jumping actions in women and jumping actions in men were the most common mechanisms of injury. The primary mechanism of injury of ankle sprains was jumping activities, but the primary mechanisms of ankle synovitis and impingement in women were related to dancing *en pointe*.

**Conclusion:** The results of this study highlight the importance of further investigation of injury prevention strategies targeting *pointe* work and jumping actions in ballet dancers. Further research for injury prevention and rehabilitation strategies targeting posterior ankle impingement syndromes and ankle sprains are warranted.

**Keywords:** foot and ankle injury; injury epidemiology; ballet; sports medicine

Injuries are commonplace in professional ballet. It has been reported that 95% of all dancers in a professional classical ballet company sought medical consultation over a 5-year period.[28] The injury incidence rates in professional ballet companies have been reported in the literature; one study reported that medical attention and time-loss injury incidence rates in professional ballet were 3.1-3.9 and 1.1-1.2 per 1000 hours, respectively.[25] Another study reported that the injury incidence per dancer per annum was 1.10.[32]

With respect to the loss of dance time due to injury, one study determined that 35% of time-loss injuries resulted in >28 days of modified dance training.[25] Another study reported that total number of days lost per 1000 hours of dance was 30.2 days.[1] Time lost to injury may affect career progression of the dancer and/or income-generating opportunities for both the dancer and the ballet company.[14]

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The foot and ankle are often reported as the most common site of injury in professional ballet dancers, accounting for up to 62% of all injuries,[8,14,28,30,32,38] and several descriptive reviews and case series on foot and ankle injuries in ballet dancers have been reported.[††] However, detailed information regarding the epidemiological characteristics of foot and ankle injuries in ballet dancers, such as the incidence rate of each diagnosis and its effect on dancer health, is limited. Compared with injury epidemiological studies across all body regions among professional ballet dancers,[1,22,25,28,32,39] there is a lack of epidemiological research focusing on foot and ankle injuries in isolation. A detailed epidemiological analysis focusing on foot and ankle injuries in professional ballet will provide additional insights to target specific injury-prevention strategies and improve the treatment of foot and ankle injuries.

The aims of this study were to investigate the incidence rate, severity, burden, and mechanism of foot and ankle injuries, accounting for both medical attention and time-loss injuries, across 3 consecutive seasons in 2 professional ballet companies.

## METHODS

### Study Design and Participants

This study was an evaluation of data collected prospectively over 3 seasons (2016-2017 to 2018-2019) across 2 professional ballet companies. In both companies, seasons began in August and included a 1-week break at the midseason and a 5-week summer break at the conclusion of the season. One company was a touring company that performed 142 ± 8 shows of 13 ± 5 different productions each season, taking place at either the home theater or touring venues across the United Kingdom, Japan, and United States. This company used a sprung touring floor that was laid for home and touring venues to create a consistent performance surface. The second company was a resident company, performing 135 ± 2 shows per season in a single venue, in addition to a month-long touring period, across 11 ± 0 different productions. One company consisted of 58 ± 1 dancers per season and the other consisted of 93 ± 5 dancers per season. Included were dancers across the ranks of principal, principal character artist, first soloist, soloist, first artist, artist, and apprentice. The protocol for this study received ethics committee approval, in accordance with the Declaration of Helsinki. There was no patient or public involvement in the design, conduct, or reporting of this study.

### Data Collection

In-house, chartered physical therapists prospectively recorded injuries within 24 hours of onset using a standardized injury assessment form (Smartabase Version 6.5.11; Fusion Sport). Injury diagnosis was recorded using Version 10 of the Orchard Sports Injury Classification System (OSICS)[31] and entered by the physical therapist who assessed the injury. The mechanism of each injury and the type of footwear were also recorded. Dance exposure hours were not collected across both companies, and thus, exposure was expressed as dancer-seasons.

### Definition of Terms

*Medical attention injuries* were defined as "any musculoskeletal complaint that required medical attention from a physiotherapist."[10] *Time-loss injuries* were defined as "any injury that prevented a dancer from taking a full part in all dance-related activities that would normally be required of them for a period equal to or greater than 24 hours after the injury was sustained."[1] *Injury severity* was defined as the number of days lost as a result of each time-loss injury.[1] *Injury burden* was defined as the total number of time-loss days per dancer-season.

### Data Analysis

Injury data were extracted from each company's online data management system, anonymized, and combined. Soloists and first soloists were combined as "soloists," and artists and first artists were combined as "artists." Foot and ankle injury data were extracted using the OSICS diagnosis codes. Medical attention and time-loss injuries were then classified by body part, pathology type, and diagnosis.[4] The incidence rates (per dancer-season) of medical attention foot and ankle injuries (MA-FAIs) and time-loss foot and ankle injuries (TL-FAIs) by anatomic region, tissue type, and diagnosis were calculated by dividing grouped injury count by the number of dancers each year. Median severity and burden were calculated for time-loss injuries.

[††]References 5, 11, 15, 17, 20, 21, 33–35, 41.

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TABLE 1
Number of Dancers, Medical-Attention Injuries, and Time-Loss Injuries Across 3 Consecutive Seasons[a]

| | 2016-2017 | | | 2017-2018 | | | 2018-2019 | | |
|---|---|---|---|---|---|---|---|---|---|
| | n | MA | TL | n | MA | TL | n | MA | TL |
| Female dancers | 79 | 126 | 55 | 78 | 125 | 59 | 79 | 116 | 47 |
| Principal | 12 | 20 | 11 | 13 | 27 | 10 | 11 | 20 | 7 |
| Character principal | 1 | 0 | 0 | 3 | 0 | 0 | 3 | 3 | 1 |
| Soloist | 23 | 36 | 14 | 20 | 29 | 11 | 22 | 28 | 6 |
| Artist | 37 | 62 | 26 | 37 | 64 | 36 | 39 | 62 | 32 |
| Apprentice | 6 | 8 | 4 | 5 | 5 | 2 | 4 | 3 | 1 |
| Male dancers | 71 | 68 | 25 | 71 | 79 | 36 | 77 | 74 | 33 |
| Principal | 17 | 11 | 5 | 15 | 14 | 5 | 15 | 12 | 4 |
| Character principal | 3 | 0 | 0 | 5 | 1 | 0 | 5 | 0 | 0 |
| Soloist | 21 | 21 | 9 | 19 | 24 | 12 | 20 | 18 | 13 |
| Artist | 24 | 32 | 11 | 26 | 30 | 13 | 33 | 39 | 16 |
| Apprentice | 6 | 4 | 0 | 6 | 10 | 6 | 4 | 5 | 0 |

[a]MA, medical attention injuries; TL, time-loss injuries.

Incidence rate, median severity, and burden are presented with 95% CI. These analyses were conducted using MATLAB (MathWorks).

## Statistical Analysis

Poisson generalized linear mixed models were used to calculate incidence rates for overall MA-FAIs and TL-FAIs using the *lme4* R package.[6] The output variable was the count of MA-FAIs and TL-FAIs, offset by the number of seasons completed by each individual. Sex, rank, company, and sex × rank interaction were included as fixed factors, whereas dancer identity was included as a random factor. Main effects of the generalized linear mixed model were compared using the *anova* function from the *car* R package. Estimated marginal mean incidence rates across each fixed factor were extracted to calculate incidence rate per dancer-season using the *emmeans* R package. Post hoc pairwise comparisons were used to determine statistical differences across fixed factor levels. False discovery rate adjustment was used to account for multiple comparisons, and significance was set at $P < .025$ to account for multiple outcomes. Statistical analysis was conducted in R (Version 4.1.2; R Foundation for Statistical Computing).

## RESULTS

A total of 455 dancer-seasons (women, 236; men, 219) were analyzed across the 2 companies (Table 1). There were 588 MA-FAIs (women, 367; men, 221). Among them, 255 injuries were classified as TL-FAIs (women, 161; men, 94) and resulted in 15,325 days of modified training (women, 8857 days; men, 6468 days). This means 43% of MA-FAIs required some modification of dance activity but 57% of those did not.

## Incidence Rate

The incidence rates of foot medical-attention injuries and ankle medical-attention injuries were 0.71 (95% CI, 0.60-0.82) and 0.84 (95% CI, 0.72-0.97) injuries per female dancer-season, respectively, and 0.40 (95% CI, 0.30-0.52) and 0.61 (95% CI, 0.49-0.72) injuries per male dancer-season, respectively (Table 2). The incidence rates of foot time-loss injuries and ankle time-loss injuries were 0.30 (95% CI, 0.22-0.38) and 0.39 (95% CI, 0.22-0.56) injuries per female dancer-season, respectively, and 0.19 (95% CI, 0.00-0.41) and 0.24 (95% CI, 0.1-0.34) injuries per male dancer-season, respectively (Table 3).

A main effect of sex was observed for both MA-FAIs (women, 1.20 per dancer-season [95% CI, 0.98-1.46] vs men, 0.83 per dancer-season [95% CI, 0.67-1.03]; $P = .002$) and TL-FAIs (women, 0.55 per dancer-season [95% CI, 0.42-0.72] vs men, 0.35 per dancer-season [95% CI, 0.26-0.48]; $P = .008$). We found no effect of rank on MA-FAI incidence rate ($P = .056$). We found an effect of rank on TL-FAI incidence rate ($P = .007$); however, post hoc analysis revealed no significant pairwise comparisons after multiplicity adjustment. We observed no effect of company on MA-FAIs ($P = .056$) or TL-FAIs ($P = .960$).

## Severity and Burden of Time-Loss Injuries

The median severities of foot time-loss injuries and ankle time-loss injuries were 24 (95% CI, 10-35) and 23 (95% CI, 11-46) days, respectively, in women and 22 (95% CI, 7-53) and 41 (95% CI, 17-56) days, respectively, in men (Table 3). The median burdens of foot time-loss injuries and ankle time-loss injuries were 14.7 (95% CI, 6.4-22.9) and 22.9 (95% CI, 9.2-36.7) days per dancer-season, respectively, in women and 12.1 (95% CI, 1.8-33.3) and 17.6 (95% CI, 0.0-24.2) days per dancer-season, respectively, in men. The severity and burden of TL-FAIs by anatomic region, pathology type, and diagnosis are described in Table 3. Figure 1 illustrates the injury burden of TL-FAIs by anatomic region and tissue and pathology type.

## Injury Classification, Mechanism, and Footwear

Table 4 shows the number and percentage of MA-FAIs and TL-FAIs by classification, mechanism of injury, and footwear. Figure 2 shows the mechanism of MA-FAIs and TL-FAIs of the common injury types.

## DISCUSSION

The most important finding of this study is that among the foot and ankle injuries in professional ballet companies, ankle joint synovitis and impingement demonstrated the greatest medical attention incidence rate, whereas ankle joint sprains demonstrated the greatest time-loss injury incidence rate and burden. In addition, *pointe* and jumping actions were identified as the most common mechanisms of foot and ankle injuries, but the main mechanism differed

TABLE 2
Number and Incidence Rate of Medical Attention Injuries for Female and Male Dancers by Injury Type[a]

| Body part / Pathology type / Diagnosis | Female Dancers | | Male Dancers | |
|---|---|---|---|---|
| | MA, n | IR per Dancer-Season (95% CI) | MA, n | IR per Dancer-Season (95% CI) |
| Ankle | 199 | 0.84 (0.72-0.97) | 133 | 0.61 (0.49-0.72) |
| Synovitis, impingement | 63 | 0.27 (0.23-0.30) | 55 | 0.25 (0.00-0.50) |
| Posterior impingement | 37 | 0.16 (0.06-0.25) | 16 | 0.07 (0.02-0.13) |
| Anterior impingement | 13 | 0.06 (0.02-0.09) | 16 | 0.07 (0.00-0.17) |
| Synovitis | 6 | 0.03 (0.02-0.03) | 16 | 0.07 (0.00-0.15) |
| Tendon injuries | 58 | 0.25 (0.00-0.50) | 31 | 0.14 (0.08-0.20) |
| Achilles tendon | 19 | 0.08 (0.04-0.12) | 15 | 0.07 (0.00-0.20) |
| FHL tendon | 14 | 0.06 (0.01-0.11) | 8 | 0.04 (0.00-0.08) |
| TP tendon | 12 | 0.05 (0.00-0.12) | 4 | 0.02 (0.00-0.04) |
| Peroneal tendon | 9 | 0.04 (0.00-0.18) | 3 | 0.01 (0.00-0.05) |
| Joint sprains | 51 | 0.22 (0.16-0.27) | 26 | 0.12 (0.04-0.20) |
| Lateral ligament sprain | 42 | 0.18 (0.10-0.26) | 15 | 0.07 (0.00-0.16) |
| Chronic instability | 6 | 0.03 (0.00-0.06) | 3 | 0.01 (0.00-0.07) |
| Foot | 168 | 0.71 (0.60-0.82) | 88 | 0.40 (0.30-0.51) |
| Joint sprains | 40 | 0.17 (0.10-0.24) | 32 | 0.15 (0.10-0.19) |
| Midfoot sprain | 24 | 0.10 (0.01-0.20) | 8 | 0.04 (0.00-0.07) |
| Great toe sprain | 8 | 0.03 (0.02-0.05) | 13 | 0.06 (0.05-0.07) |
| Forefoot sprain | 4 | 0.02 (0.00-0.05) | 9 | 0.04 (0.04-0.05) |
| Stress fracture/reaction | 28 | 0.12 (0.05-0.19) | 7 | 0.03 (0.00-0.10) |
| Metatarsal fracture | 15 | 0.06 (0.03-0.09) | 1 | 0.005 (0.00-0.02) |
| Synovitis, impingement | 21 | 0.09 (0.00-0.17) | 10 | 0.05 (0.03-0.06) |
| MTP joint synovitis | 12 | 0.05 (0.05-0.05) | 3 | 0.01 (0.00-0.05) |
| Muscle injury | 18 | 0.08 (0.04-0.11) | 3 | 0.01 (0.01-0.02) |
| Tendon injuries | 13 | 0.05 (0.00-0.18) | 13 | 0.06 (0.00-0.21) |
| Extensor tendon | 6 | 0.03 (0.00-0.06) | 4 | 0.02 (0.00-0.10) |
| Bruising | 9 | 0.04 (0.01-0.07) | 6 | 0.03 (0.00-0.09) |
| Arthritis | 8 | 0.03 (0.00-0.10) | 3 | 0.01 (0.00-0.05) |
| Great toe arthritis | 8 | 0.03 (0.00-0.10) | 3 | 0.01 (0.00-0.05) |

[a]Injuries with >6 cases in either women or men are shown in the table. FHL, flexor hallucis longus; IR, incidence rate; MA, medical attention injuries; MTP, metatarsophalangeal joint; TP, tibialis posterior.

between the type of injuries. This study also revealed that women had a higher incidence rate of MA-FAIs and TL-FAIs than men. This is the first study to focus on the epidemiological patterns of foot and ankle injuries in professional ballet dancers in isolation.

## Incidence Rate

The incidence rate of TL-FAIs in this study was in line with previous research reporting foot and ankle injury incidence rates in professional ballet dancers.[21] Direct comparison with previous research in ballet is difficult due to differences in injury definition and the calculation of incidence rate.[1,25,28] This is the first study to report MA-FAI incidence rates across specific diagnoses.

In the present study, female dancers sustained an additional 0.4 MA-FAIs per dancer-season and 0.2 TL-FAIs per dancer-season compared with their male counterparts. Conversely, previous research in professional ballet dancers has not found any sex differences in medical attention and time-loss injury incidence rates across the whole body.[1,25] We speculate that the sex difference observed across MA-FAI and TL-FAI incidence rates is an effect of the different movements completed by men and women in classical ballet. Female ballet dancers often dance *en pointe*, during which they are required to balance, locomote, and jump while in maximum ankle and foot plantarflexion.[36] Dancing *en pointe* requires an extreme range of motion in the foot and ankle and results in changes to the joint congruency of the ankle over time,[28,36,37] potentially contributing to the higher incidence rate of foot and ankle injuries in women. Considering the higher risk of foot and ankle injuries in women, better understanding of the biomechanics of *pointe* activities and controlling load on the foot and ankle may contribute to reduce foot and ankle injuries, especially in women.

## Anatomic Location and Tissue Type

Ankle sprains have been reported as the most common type of foot and ankle injury among professional ballet dancers.[28,32] This finding is consistent with findings in the present study; however, to our knowledge, no previous literature has described the burden of foot and ankle injuries by diagnosis. Previous research has reported burden by injury type, where synovitis, impingement, bursitis, and tendon and joint sprains around the foot and ankle exhibited the greatest burden in female dancers.[25] We report similar findings in the present study; however, we provide additional insights. The burden of

TABLE 3
Number, Incidence Rate, Severity, and Burden of Time-Loss Injuries for Female and Male Dancers by Injury Type[a]

| Body part / Pathology type / Diagnosis | Female Dancers | | | | Male Dancers | | | |
|---|---|---|---|---|---|---|---|---|
| | TL, n | IR per Dancer-Season | Severity, Days | Burden, Days per Dancer-Season | TL, n | IR per Dancer-Season | Severity, Days | Burden, Days per Dancer-Season |
| Ankle | 91 | 0.39 (0.22-0.56) | 23 (11-46) | 22.9 (9.2-36.7) | 52 | 0.24 (0.13-0.34) | 41 (17-56) | 17.6 (1.8-33.3) |
| Synovitis, impingement | 26 | 0.11 (0.04-0.18) | 20 (4-42) | 7.1 (0.0-18.2) | 15 | 0.07 (0.00-0.17) | 17 (2-54) | 3.0 (0.0-9.9) |
| Posterior impingement | 19 | 0.08 (0.00-0.18) | 18 (4-98) | 5.9 (0.0-17.8) | 5 | 0.02 (0.00-0.06) | 90 (NA) | 2.2 (0.0-7.8) |
| Anterior impingement | 3 | 0.01 (0.00-0.04) | 42 (NA) | 0.5 (0.0-2.4) | 3 | 0.01 (0.00-0.05) | 17 (NA) | 0.3 (0.0 -1.3) |
| Synovitis | 0 | 0.00 (0.00-0.00) | 0 (0.0) | 0.0 (0.0-0.0) | 5 | 0.02 (0.00-0.04) | 8 (NA) | 0.4 (0.0 -1.2) |
| Tendon injuries | 20 | 0.09 (0.00-0.30) | 18 (4-64) | 5.7 (0.0-22.9) | 13 | 0.06 (0.01-0.10) | 52 (7-127) | 5.2 (0.0-16.1) |
| Achilles tendon | 9 | 0.04 (0.00-0.09) | 10 (1-219) | 2.2 (0.0-6.9) | 7 | 0.03 (0.00-0.07) | 70 (1-462) | 4.2 (0.0-17.2) |
| FHL tendon | 2 | 0.01 (0.00-0.05) | 27 (NA) | 0.24 (0.0 -1.2) | 3 | 0.01 (0.00-0.05) | 32 (NA) | 0.7 (0.0-3.3) |
| TP tendon | 5 | 0.02 (0.00-0.09) | 49 (NA) | 2.3 (0.0-10.8) | 1 | 0.00 (0.00-0.02) | 1 (NA) | 0.0 (0.0-0.0) |
| Peroneal tendon | 3 | 0.01 (0.00-0.07) | 64 (NA) | 1.0 (0.0-5.1) | 1 | 0.00 (0.00-0.02) | 44 (NA) | 0.2 (0.0 -1.0) |
| Joint sprains | 35 | 0.15 (0.11-0.18) | 24 (11-77) | 7.6 (1.4-13.9) | 17 | 0.08 (0.03-0.12) | 34 (6-147) | 6.9 (2.5-11.3) |
| Lateral ligament sprains | 28 | 0.12 (0.07-0.17) | 27 (11-91) | 6.8 (2.8-10.7) | 9 | 0.04 (0.00-0.13) | 34 (6-150) | 3.1 (0.0-9.9) |
| Cartilage lesion | 0 | 0.00 (0.00-0.00) | 0 (NA) | 0.0 (0.0-0.0) | 3 | 0.01 (0.00-0.05) | 80 (NA) | 1.5 (0.0-5.8) |
| Foot | 70 | 0.30 (0.22-0.38) | 24 (10-35) | 14.7 (6.4-22.9) | 42 | 0.19 (0.00-0.41) | 22 (7-53) | 12.1 (0.0-24.2) |
| Joint sprains | 22 | 0.09 (0.03-0.16) | 21 (4-35) | 2.3 (0.0-5.0) | 16 | 0.07 (0.04-0.11) | 31 (4-70) | 5.3 (0.0-11.5) |
| Midfoot sprain | 15 | 0.06 (0.01-0.12) | 29 (17-55) | 2.2 (0.0-4.9) | 5 | 0.02 (0.00-0.07) | 10 (NA) | 0.8 (0.0-3.7) |
| Great toe sprain | 4 | 0.02 (0.00-0.03) | 5 (NA) | 0.1 (0.0-0.2) | 7 | 0.03 (0.01-0.05) | 41 (4-250) | 2.8 (0.0-7.6) |
| Forefoot sprain | 2 | 0.01 (0.00-0.03) | 4 (NA) | 0.03 (0.0-0.1) | 4 | 0.02 (0.00-0.04) | 46 (NA) | 1.7 (0.0-6.5) |
| Stress fracture/reaction | 13 | 0.06 (0.00-0.12) | 24 (8-61) | 1.9 (0.0-6.0) | 6 | 0.03 (0.00-0.09) | 24 (1-251) | 2.1 (0.0-9.9) |
| Metatarsal fracture | 8 | 0.03 (0.02-0.05) | 14 (1-46) | 0.8 (0.0-2.4) | 3 | 0.01 (0.00-0.05) | 3 (NA) | 1.1 (0.0-5.8) |
| Synovitis, impingement | 6 | 0.03 (0.02-0.03) | 25 (1-142) | 1.4 (0.0-5.7) | 4 | 0.02 (0.00-0.04) | 17 (NA) | 0.5 (0.0 -1.7) |
| MTP joint synovitis | 5 | 0.02 (0.00-0.04) | 37 (NA) | 1.3 (0.0-5.7) | 2 | 0.01 (0.00-0.03) | 15 (NA) | 0.1 (0.0-0.7) |
| Muscle injury | 5 | 0.02 (0.00-0.06) | 32 (NA) | 1.7 (0.0-8.4) | 0 | 0.00 (0.00-0.00) | 0 (NA) | 0.0 (0.0-0.0) |
| Tendon injuries | 8 | 0.03 (0.00-0.12) | 24 (2-41) | 1.1 (0.0-5.1) | 7 | 0.03 (0.00-0.15) | 16 (1-221) | 2.0 (0.0-9.1) |
| Extensor tendon | 4 | 0.02 (0.00-0.03) | 15 (NA) | 0.3 (0.0 -1.0) | 4 | 0.02 (0.00-0.10) | 12 (NA) | 0.6 (0.0-3.4) |
| Bruising | 4 | 0.02 (0.00-0.05) | 64 (NA) | 1.2 (0.0-3.8) | 3 | 0.01 (0.00-0.05) | 2 (NA) | 0.0 (0.0-0.2) |

[a]Data in parentheses are 95% CIs. All diagnoses with >3 cases in either women or men are shown. FHL, flexor hallucis longus; MTP, metatarsophalangeal joint; NA, not applicable; TL, time-loss injuries; TP, tibialis posterior.

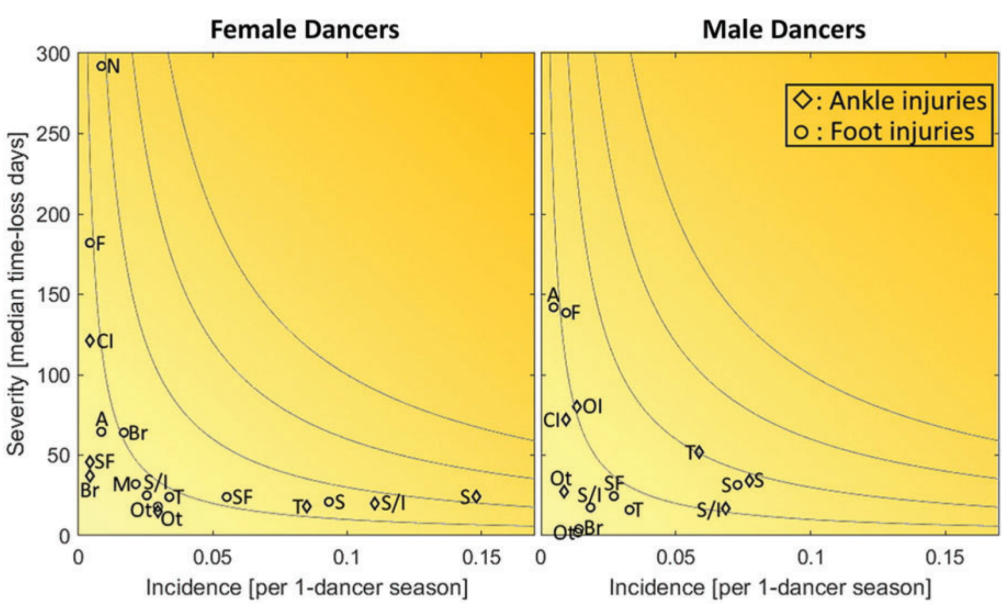


**Figure 1.** Risk matrix illustrating the incidence rates and severity of time-loss injuries in female and male dancers per tissue type. A, arthritis; Br, bruising; CI, chronic instability; F, fracture; M, muscle injury; N, nerve injury/neuroma; OI, osteochondral injury; Ot, others; S, joint sprain; SF, bone stress fracture/reaction; S/I, joint synovitis/impingement; T, tendon injury.

TABLE 4
Medical-Attention and Time-Loss Injuries in Female and Male Dancers by Classification, Injury Mechanism, and Footwear[a]

| | Medical Attention Injuries | | Time-Loss Injuries | |
|---|---|---|---|---|
| | Female | Male | Female | Male |
| Injury type | | | | |
| Overuse | 243 (66.2) | 131 (59.3) | 82 (50.9) | 45 (47.9) |
| Traumatic | 108 (29.4) | 80 (36.2) | 70 (43.5) | 44 (46.8) |
| Not classified | 16 (4.4) | 10 (4.5) | 9 (5.6) | 5 (5.3) |
| Injury mechanism | | | | |
| Plié/relevé | 59 (16.1) | 55 (24.9) | 23 (14.3) | 19 (20.2) |
| Jumping/landing | 98 (26.7) | 88 (39.8) | 51 (31.7) | 43 (45.7) |
| Pointe work | 115 (31.3) | 1 (0.5) | 51 (31.7) | 0 (0) |
| Lifting/lifted | 2 (0.5) | 0 (0) | 0 (0) | 0 (0) |
| Pirouette | 4 (1.1) | 11 (5) | 2 (1.2) | 3 (3.2) |
| Other/not classified | 89 (24.3) | 66 (29.9) | 34 (21.1) | 29 (30.9) |
| Footwear | | | | |
| Ballet flats | 36 (9.8) | 164 (74.2) | 14 (8.7) | 63 (67) |
| Pointe shoes | 276 (75.2) | 4 (1.8) | 118 (73.3) | 2 (2.1) |
| Character shoes | 12 (3.3) | 23 (10.4) | 5 (3.1) | 14 (14.9) |
| Barefoot | 3 (0.8) | 8 (3.6) | 2 (1.2) | 4 (4.3) |
| Trainers | 8 (2.2) | 8 (3.6) | 3 (1.9) | 6 (6.4) |
| Other/not classified | 32 (8.7) | 14 (6.3) | 19 (11.8) | 5 (5.3) |

[a]Data are reported as n (%).

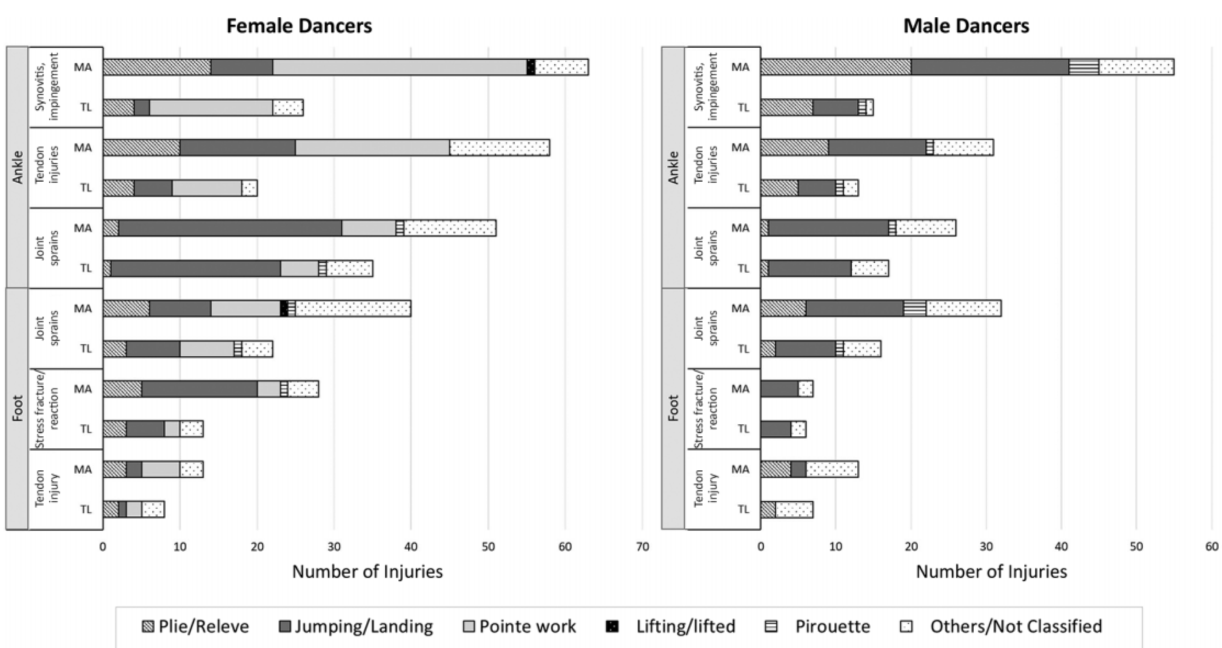


**Figure 2.** Mechanisms of medical-attention (MA) and time-loss (TL) injuries in female and male dancers by injury type. The 5 most common types of injuries are shown.

ankle sprains was primarily due to lateral ankle sprains, whereas synovitis and impingement-type injuries were primarily due to posterior impingement. Although the burden of tendon injuries was comparable, the diagnoses were distributed across the Achilles and tibialis posterior tendons. Previous work has identified that stress fractures to the foot and lower leg have exhibited the greatest burden in male dancers.[25] However, in the present study, foot and ankle joint sprains and ankle tendon injuries generated the greatest burden in men. The burden of joint sprains consisted of lateral ligament sprains and great toe sprains, whereas the burden of tendon issues was predominantly Achilles-related.

Lateral ankle sprains are reported frequently as one of the most common injuries in sports, whereas posterior ankle impingement syndrome has been reported to occur only in specific sports, such as ballet and football.[9,34] Whereas lateral ankle sprains can lead to notable time loss across sports, ankle impingement syndromes are infrequently time-loss injuries outside of ballet, constituting only 3% of all ankle time-loss injuries in football, for example.[42] Therefore, the high incidence rate and burden of medical attention and time-loss ankle impingement in these professional dancers appear to be features of the unique demands of classical ballet.

Because lateral ankle sprain and posterior ankle impingement are the 2 most burdensome injuries in professional ballet, the possible relationship between them should be considered. Ankle joint laxity, as a result of ankle joint sprain, can cause the talus to rotate anteriorly under the plafond during plantarflexion, which could lead to osseous impingement between the tibia and calcaneus.[16,34] Further, the risk for os trigonum syndrome surgery has been shown to be 10 times higher in professional athletes with chronic lateral ligament injuries than in those with acute lateral ankle ligament injury.[13] Prevention of ankle joint sprain and appropriate recovery from such a sprain may lead to a decrease in subsequent posterior ankle impingement syndrome. Further research investigating the relationship between ankle instability and posterior ankle impingement in dancers is warranted.

### Cause of Injuries

Poor technique while dancing has been described as a risk factor for injury,[12,27,40] and jumping and landing have been reported as the primary mechanisms of time-loss injury for all body regions among professional ballet dancers.[1,25] Whereas similar findings were observed for foot and ankle injuries in the present study, *pointe* work was also a common mechanism of foot and ankle injuries in women. In addition, assessing the mechanism of injury by injury pathology type revealed that the primary mechanism of injury of ankle sprains was jumping activities but the primary mechanisms of ankle synovitis and impingement in women were related to dancing *en pointe*. Previous biomechanical research studies have shown that pointe shoes, overuse of the lower extremity, and the biomechanics and function of the foot are risk factors associated with foot and ankle injuries in ballet dancers.[23]

Biomechanical research targeting *pointe* and jumping actions with their relationship to specific injuries may contribute to improve injury-prevention strategies. Several research studies have been conducted on the biomechanics of jumping and landing in ballet dancers,[24] and dancers have been reported to have different jumping and landing strategies compared with other athletes.[3,18] Additionally ground reaction forces have been reported to be different between different jump conditions.[26] As regards standing *en pointe*, this movement is unique to ballet, and the condition of pointe shoes may be associated with injury.[2,7] The uniqueness of those movements and the effect of shoe conditions should be taken into consideration in future biomechanical studies.

### Strengths and Limitations

One strength of this study is that we report medical-attention and time-loss injuries.[4] The inclusion of medical-attention injuries is important to the current population, as dancers have previously been observed to continue dancing through injury,[10,29] which may lead to an underestimation of the impact of injuries. A previous study investigating injuries across all body regions in a professional ballet company reported that approximately 66% of medical attention injuries did not require any modification of dance activity.[25] Foot and ankle injuries in this study had comparable results, where 57% of MA-FAIs did not require any modification of dance activity. Considering both medical attention injuries and time-loss injuries may help provide more comprehensive understanding of injuries.

The inclusion of 2 ballet companies in this study is a key strength. Previous research has called for multicenter studies to address epidemiological questions in dance,[19] facilitating greater sample sizes and better representation of the target population. However, the injury data reported here were therefore collected by different teams of physical therapists, a limitation that was alleviated by the use of standardized entry forms across the 2 companies. Furthermore, chartered physical therapists recorded all medical data using OSICS, as recommended in the International Olympic Committee (IOC) consensus statement.[4,10] No significant difference in injury incidence rate was observed between the 2 companies. The recording of exposure time was different across the 2 companies, and we were unable to provide injury incidence rates per 1000 hours. Incidence rate per dancer-season was used instead, as recommended by the IOC.[4]

## CONCLUSION

In this 3-season cohort study of 2 elite professional ballet companies, women had a higher incidence rate of foot and ankle medical attention and time-loss injuries than men. High incidence rates and injury burdens of ankle impingement syndromes and ankle sprains were observed. Jumping actions and *pointe* work were common mechanisms of injury; however, mechanisms of injury differed among pathologies. The results of this study highlight the importance of further investigation into the biomechanics of *pointe* work and jumping activities as well as injury prevention and treatment strategies for ankle impingement syndromes and ankle sprains in ballet dancers.

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