

## **Injury Epidemiology in an Elite Ballet School: A Seven-Season Cohort Study of 2121 Medical Attention Injuries and 1656 Time-Loss Injuries**

Joseph W. Shaw<sup>1,2,3</sup>, Niall MacSweeney<sup>2,3</sup>, Karen Sheriff<sup>3,4</sup>, Wayne Kitchener<sup>3</sup>, Charles R. Pedlar<sup>2,5</sup>

<sup>1</sup> Ballet Healthcare, Royal Opera House, London, UK

<sup>2</sup> Faculty of Sport, Technology and Health Sciences, St Mary's University, Twickenham, UK

<sup>3</sup> Healthcare, The Royal Ballet School, London, UK

<sup>4</sup> Project RED-D, UK

<sup>5</sup> Institute of Sport, Exercise and Health, Division of Surgery and Interventional Science, University College London, UK

Twitter:

Joseph W. Shaw - @JosephShaw\_

Niall MacSweeney - @NiallMacSweeney

Charles R. Pedlar - @pedlarcr

## Abstract

**Objectives:** To describe the epidemiology of injuries in an elite vocational ballet school over seven academic years.

**Methods:** Injury records pertaining to 569 students (267 boys and 302 girls) were prospectively collected by Chartered Physiotherapists using a cloud-based athlete management system over seven academic years (2016/17 to 2022/23) at an elite ballet school.

**Results:** 1548 student-academic-years, encompassing 266,468 student-days, were completed, during which 2121 medical attention injuries were prospectively recorded, 1656 of which resulted in time-loss. Injury incidence was comparable between sexes but was greater at the upper school (ages 16–19; 9.0 injuries per 1,000 exposure days, 95% CI 8.4 to 9.7) than the lower school (ages 11–16; 6.5 injuries per 1,000 exposure days, 95% CI 6.0 to 6.9). By severity scale, 282 injuries (13.3%) were classified as *mild* (1–7 days), 582 (27.4%) were classified as *moderate* (8–28 days), and 792 (37.3%) were classified as *severe* (> 28 days). The injury burden was 236 and 416 days lost per 1000 exposure days at the lower school and the upper school, respectively. The most common injury mechanism was *repetitive – gradual onset* (54.8%), and 25% of injuries were recurrences. The most common movements associated with injury were *jumping and landing* (boys 30.8%; girls 21.4%) and *other dancing movements* (boys 23.2%; girls 27.9%); 16.4% of injuries affecting girls were associated with *pointe work*. During term time, the mean percentage of students fully available without injury was 78.8% at the lower school and 66.2% at the upper school.

**Conclusion:** A large injury burden was observed across the seven years in elite ballet students. Ballet schools must balance the training stimulus with appropriate recovery, and ensure appropriate medical support is in place to manage injuries and implement prevention programs.

### **What is already known on this topic**

Injury incidence in vocational ballet schools is comparable to sport and professional ballet; however, existing research is based on self-reported data and lacks detail and robustness.

### **What this study adds**

A large injury burden was observed, characterised by extended periods during which students trained whilst managing an injury.

This study adds detailed incidence, severity, and injury burden estimates for sexes, year groups, and injury diagnoses. Incidence, severity, and burden were all greatest at the upper school, with the lower limb most affected.

### **How this study might affect research, practice or policy**

This study should be used to direct injury prevention strategies in ballet schools.

Bone injuries, and injuries affecting the lower leg, foot and ankle should be targets of injury prevention strategies.

Based on these results, ballet schools should consider the balance of training load and recovery, and ensure nutrition, sleep, and monitoring strategies are in place to maximise student training availability and optimise development.

## Introduction

Ballet schools aim to train, educate, and support young dancers through their development into adult professionals. Like all sports and athletic activities, ballet comes with a risk of injury; one professional ballet company, for example, reported a medical attention injury incidence rate of 3.5 injuries·1000 h<sup>-1</sup> (time-loss injury incidence: 1.2 injuries·1000 h<sup>-1</sup>), and a mean injury severity of 14 days.<sup>1</sup> Whilst some risk of injury is unavoidable, ballet schools have a duty of care towards their students, and should structure training and put in place appropriate healthcare support to mitigate injury risk.

Injury epidemiology provides the foundations for injury prevention pathways.<sup>2</sup> Although the epidemiology of injury in adult professional ballet dancers has been well-established, children and adolescent dancers are a distinct population, facing specific challenges and stressors associated with their growth, maturation, and development.<sup>3</sup> To date, epidemiological research in this population has been limited, using small sample sizes, a lack of injury detail, and non-standardised reporting methods.<sup>4</sup> Furthermore, the largest studies to date have used self-reported injury data, which may limit the detail and accuracy around diagnoses.<sup>5</sup> Subsequently, little data is available to guide the implementation of injury risk intervention strategies in ballet schools. The identification of the most frequent, severe, and burdensome injury types and mechanisms would enable healthcare practitioners to target key injuries.<sup>6</sup> Furthermore, details around the most affected sub-populations, and the movements and mechanisms associated with injuries, would facilitate the development of appropriate interventions.<sup>6</sup>

To guide injury prevention and management strategies, sports science and medicine teams require accurate and detailed epidemiological research to inform decision-making. The aim of this study was, therefore, to investigate the epidemiology of injuries in an elite ballet school over seven academic years, including the incidence, severity, and burden of injury, with reference to the anatomical location, injury mechanisms, and resulting impact on student availability.

## **Methods**

### ***Study design and setting***

A seven-year cohort study (2016/17 to 2022/23) was employed to investigate the epidemiology of medical attention and time-loss injuries at an elite ballet school. Students board and train full-time alongside academic studies, separated into:

- Lower school: UK academic year groups 7 to 11 (ages 11 to 16), hereon referred to as *lower school*.
- Upper school; UK academic year groups 12 to 14 (ages 16 to 19), hereon referred to as *upper school*.

In addition to academic work, students typically completed approximately 19 to 29 h of ballet training each week, scheduled between Monday and Saturday, 08:30 to 18:30. The STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS) was used to guide reporting of this study.<sup>6</sup>

### ***Participants***

All students enrolled at the school were eligible to take part. Each year, participant year group (7–14) and school section (*upper school/lower school*) was recorded. Written informed consent was obtained from participants and parents, and ethical approval was given by the institutional ethics committee in accordance with The Declaration of Helsinki (ref: SMU\_ETHICS\_2024-25\_1063).

### ***Data Collection***

#### ***Injury Data***

Injury data were prospectively collected by eight Chartered Physiotherapists, four sport and exercise medicine consultants doctors, and three nurses, each of who had a minimum of five years' experience working in high-performance sport or dance environments. Injury data were recorded using a cloud-based athlete management system (Teamworks Athlete Management System, Teamworks, USA); all clinicians were trained in the system prior to use, including standardised protocols for injury categorisation. Injuries were recorded using the Orchard Sports Injury and Illness Classification System (OSIICS) version 10. Physiotherapists were present in the school's healthcare department and available to treat students at all times during the school training day, though were not in attendance at every session. All injuries would

be expected to have been evaluated and recorded within 24 h of their onset. Injury records were audited termly by the Head of Healthcare and the Clinical Lead as part of formal reporting processes to the school's Board of Governors.

Injuries were defined in line with IOC consensus definitions.<sup>6</sup> Medical attention injuries were defined as 'any musculoskeletal complaint for which a student received medical attention'. Time-loss injuries were defined as 'any injury that results in a student being unable to complete the current or future session'. Injury recurrence was recorded by the treating physiotherapist when entering the injury note, based on existing notes, and the student's self-reported history. Injury mode of onset and contact classification were defined in line with IOC consensus recommendations: contact classification was defined as *contact* or *non-contact*, however, the type of contact was not defined; onset mechanism was defined as *acute* or *repetitive*, and onset presentation was defined as *sudden onset* or *gradual onset*. The location, activity, footwear, and movement associated with each injury was also recorded.

The training availability of each student was determined by the treating physiotherapist after each physiotherapy session. Availability was recorded as: 'Unavailable', 'Available with Activity Modification', 'Fully Available with Pathology', or 'Fully Available'. Injury severity was calculated as the total number of days a student was designated as *unavailable* or *available with activity modification* as a result of the injury. Injury severity was classified as: *no time-loss* (0 days), *minor* (1–7 days), *moderate* (8–28 days), or *severe* (>28 days).

### *Exposure Data*

Student-training-days and student-years were collected as measures of exposure. Historical term dates and school calendars were used to determine the dates when students attended the school, with Sundays and school holidays removed. For each student, a list of school dates between their date of joining and leaving the school was created. Days during which the student was classified as *unavailable* due to injury, or was absent from the school with illness, were removed from their record of exposure.

### **Data and Statistical Analysis**

At the conclusion of the data collection period, injury records were exported from the athlete management system for analysis. Injury proportions were calculated for time-loss/no time-loss, severity scale, mode of onset, tissue type, location, pathology type,

movement, activity, footwear, and occurrence. Mean and median injury severity were calculated based on time-loss injuries only, and treating recurrences as individual injuries. Raw injury incidence was calculated for medical attention and time-loss injuries, by dividing the injury count by the count of exposure days, expressed as injuries per 1000 days. Raw injury burden was calculated by dividing the sum of time-loss by the count of exposure days, expressed as days lost per 1000 days. Bootstrapped 95% confidence intervals (CI) were calculated, accounting for clustering within participant.<sup>7,8</sup> Injury risk matrices were calculated for i) body region and body part, and ii) tissue type and pathology type, each of which was broken down by sex and by school. The additional calculation of injury burden per student-year was conducted to facilitate comparisons across studies.

The incidence proportion of medical attention and time-loss injuries was calculated for the lower school and upper school during each academic year, by dividing the number of students who sustained a medical attention or time-loss injury during that year by the total number of students in each academic year.

Medical attention and time-loss incidence were modelled using negative binomial generalised linear mixed effects models fitted with the *glmmTMB* package, with the injury count as the dependent variable, and exposure time (days) included as an offset variable. For severity, a Gamma generalised linear mixed-effects model was fitted, with the total number of time-loss days as the dependent variable and the log of the number of time-loss injuries as an offset. For all models, sex, year group, and school section were included as fixed factors, and participant identity was included as a random factor. Injury burden was calculated as the product of time-loss injury incidence and time-loss injury severity. To calculate confidence intervals, bootstrap resampling ( $n = 1000$ ) was conducted,<sup>7,8</sup> and each model refitted to each bootstrap replicate. Estimated marginal mean values were extracted from each model, and back-transformed using the *emmeans* package. Comparisons of each parameter between sexes, sections, and sexes within sections, were assessed by evaluating the proportion of bootstrap replicates in which one group's estimate exceeded the other's. *P*-values from all pairwise comparisons were adjusted for multiple testing using the false discovery rate method. Significance was set at  $p < .050$ . All analyses were completed using R v.4.3.2 (R Foundation for Statistical Computing, Vienna, Austria).

### ***Equity, diversity and inclusion statement***

The research team contained four men and one woman, including two early career researchers and two clinicians. The study population included all students at the school, of which 53% were girls and 47% were boys. The school provides financial bursaries to students through the Equal Opportunities Fund.

### ***Patient and Public Involvement***

This research was completed without patient or public involvement.

## **Results**

All students training at the school during the study period took part in the study (267 boys: mean joining age =  $14.4 \pm 2.4$  y, mean leaving age =  $17.0 \pm 2.4$  y; 302 girls: mean joining age =  $14.2 \pm 2.3$  y, mean leaving age =  $16.5 \pm 2.3$  y). Across seven academic years, 266,468 student-days of exposure, and 1548 student-years of exposure were logged. A total of 2121 medical attention injuries were recorded, 1656 of which resulted in time-loss. Raw incidence, severity, and burden data are presented in Table 1, whilst the results of statistical models are presented in Table 2 and in the following text.

### ***Injury Incidence***

The medical attention injury incidence rate was greater ( $p < .001$ ) at the upper school (9.0 injuries per 1,000 exposure days, 95% CI 8.4 to 9.7) compared to the lower school (6.5 injuries per 1,000 exposure days, 95% CI 6.0 to 6.9), but did not differ between sexes ( $p = .537$ ). Furthermore, the time-loss injury incidence rate was greater ( $p < .001$ ) at the upper school (6.9 injuries per 1,000 exposure days, 95% CI 6.3 to 7.5) compared to the lower school 5.1 injuries per 1,000 exposure days, 95% CI 4.7 to 5.5), but did not differ between sexes ( $p = .880$ ). Raw and modelled incidence rates for each year group are presented in Tables 1 and 2, respectively.

### ***Incidence Proportion***

The incidence proportion for a single academic year at the lower school was 64.2% (95% CI 61.2 to 67.3%), and for a single academic year at the upper school was 78.7% (95% CI 75.3 to 82.1%). The single year incidence proportion for each year group is presented in Table 1.

**Table 1** Raw injury incidence, incidence proportion, mean and median severity, and injury burden for each sex, section, and year group.

Group	Injury Count		Injury Incidence (injuries per 1000 exposure days)		Injury Incidence Proportion (%)		Injury Severity (Days Time-Loss)		Injury Burden (day lost per 1000 exposure days)		
	Medical Attention	Time Loss	Medical Attention	Time Loss	Medical Attention	Time Loss	Mean	Median	Days Modified	Days Off	All Time-Loss
<b>Girls</b>											
<b>Lower</b>	<b>626</b>	<b>490</b>	<b>7.1 [6.2 to 7.7]</b>	<b>5.4 [4.8 to 6.1]</b>	<b>62.8 (58.6-67.1)</b>	<b>54.5 (50.3-58.7)</b>	<b>48.3 [42.8 to 54.6]</b>	<b>23.0 (21.0-28.0)</b>	<b>214.8 (178.8-253.0)</b>	<b>45.4 (34.8-56.6)</b>	<b>260.2 (224.8-306.2)</b>
7	97	72	5.8 [4.5 to 7.2]	4.3 [3.2 to 5.4]	54.8 (44.7-65.0)	48.4 (37.7-59.1)	27.1 [21.0 to 34.3]	18.0 (12.0-27.0)	98.6 (65.2-134.1)	19.0 (9.1-31.2)	117.6 [78.8 to 157.4]
8	124	97	7.3 [5.8 to 9.1]	5.7 [4.4 to 7.2]	64.6 (54.8-74.4)	55.2 (45.0-65.4)	38.9 [28.1 to 52.0]	18.0 (13.0-33.0)	185.2 (123.2-263.0)	38.3 (16.0-64.3)	223.5 [147.5 to 321.1]
9	121	103	6.3 [5.3 to 7.5]	5.4 [4.4 to 6.6]	68.2 (59.1-77.3)	60.9 (51.8-70.1)	51.8 [40.5 to 64.6]	28.0 (21.0-44.5)	245.7 (176.6-333.6)	32.9 (19.9-48.8)	278.6 [201.7 to 376.9]
10	137	106	7.8 [6.2 to 9.5]	6.1 [4.6 to 7.4]	66.3 (57.3-75.4)	57.4 (47.2-67.7)	54.8 [42.3 to 68.9]	21.0 (17.0-35.0)	265.5 (184.6-357.0)	67.3 (38.1-101.8)	332.8 [231.8 to 448.6]
11	147	112	7.4 [5.8 to 9.0]	5.6 [4.4 to 7.0]	59.6 (50.3-69.0)	50.0 (40.5-59.5)	60.3 [46.0 to 76.0]	30.5 (22.0-41.5)	272.9 (190.3-361.4)	65.8 (36.8-101.5)	338.7 [238.2 to 452.0]
<b>Upper</b>	<b>478</b>	<b>358</b>	<b>10.3 [9.2 to 11.5]</b>	<b>7.7 [6.8 to 8.6]</b>	<b>77.9 (72.8-83.0)</b>	<b>70.0 (64.4-75.7)</b>	<b>60.0 [53.3 to 67.6]</b>	<b>32.0 (27.0-42.5)</b>	<b>364.4 (305.3-429.8)</b>	<b>99.1 (74.6-127.2)</b>	<b>463.5 [396.2 to 538.8]</b>
12	177	136	10.5 [8.7 to 12.2]	8.1 [6.5 to 9.5]	78.8 (71.1-86.6)	70.2 (61.3-79.0)	65.6 [51.5 to 81.9]	33.0 (26.0-45.0)	422.7 (313.1-546.8)	106.0 (61.8-157.6)	528.6 [390.7 to 675.0]
13	166	120	9.8 [8.1 to 11.6]	7.1 [5.8 to 8.6]	74.2 (65.1-83.3)	68.0 (58.6-77.4)	57.9 [45.9 to 69.8]	27.5 (23.0-38.0)	300.9 (226.5-389.3)	110.5 (63.0-163.9)	411.4 [310.2 to 534.1]
14	135	102	10.7 [9.0 to 12.8]	8.1 [6.6 to 10.0]	81.8 (72.0-91.6)	72.7 (61.8-83.6)	54.9 [43.6 to 67.6]	44.5 (23.0-52.5)	371.4 (265.7-498.2)	74.7 (40.2-115.9)	446.1 [325.1 to 583.2]
<b>Boys</b>											
<b>Lower</b>	<b>529</b>	<b>428</b>	<b>6.9 [6.1 to 7.6]</b>	<b>5.6 [5.0 to 6.2]</b>	<b>66.2 (61.5-70.9)</b>	<b>58.9 (54.4-63.4)</b>	<b>52.8 [45.2 to 61.5]</b>	<b>26.0 (21.0-30.0)</b>	<b>239.1 (199.9-285.1)</b>	<b>54.2 (39.2-74.5)</b>	<b>293.3 [245.9 to 347.9]</b>
7	88	67	6.1 [4.9 to 7.6]	4.7 [3.5 to 6.1]	63.6 (52.8-74.4)	53.2 (42.0-64.5)	39.9 [21.0 to 69.8]	14.0 (9.0-20.0)	131.6 (78.8-204.7)	54.8 (5.2-146.9)	186.5 [89.5 to 345.9]
8	112	93	6.7 [5.5 to 7.9]	5.6 [4.6 to 6.6]	66.3 (56.0-76.6)	63.2 (53.5-72.8)	48.7 [35.5 to 66.5]	21.0 (14.0-30.0)	219.8 (148.7-303.6)	53.0 (26.2-81.9)	272.7 [187.8 to 367.5]
9	89	73	6.0 [4.8 to 7.2]	4.9 [3.8 to 6.1]	64.7 (54.1-75.3)	54.1 (43.3-65.0)	61.0 [45.4 to 79.7]	33.0 (25.0-49.0)	247.8 (164.3-344.0)	51.6 (32.9-75.4)	299.4 [203.0 to 413.6]
10	109	96	7.5 [5.7 to 9.3]	6.6 [5.0 to 8.2]	65.5 (55.4-75.6)	61.9 (51.5-72.3)	58.0 [44.3 to 80.5]	30.0 (23.5-44.0)	312.9 (218.2-426.8)	70.1 (44.9-100.4)	382.9 [272.3 to 513.2]
11	131	99	7.9 [6.5 to 9.3]	5.9 [4.8 to 7.1]	70.1 (60.6-79.6)	60.8 (51.0-70.6)	54.3 [40.6 to 70.8]	28.0 (22.5-42.0)	278.7 (190.3-379.5)	43.4 (23.9-66.0)	322.2 [226.3 to 431.6]
<b>Upper</b>	<b>488</b>	<b>380</b>	<b>9.2 [8.2 to 10.2]</b>	<b>7.1 [6.2 to 8.1]</b>	<b>80.0 (75.2-84.8)</b>	<b>70.8 (65.7-76.0)</b>	<b>63.2 [53.3 to 73.3]</b>	<b>28.5 (23.0-35.0)</b>	<b>343.2 (274.8-411.0)</b>	<b>107.0 (81.5-136.0)</b>	<b>450.2 [367.6 to 533.3]</b>
12	168	133	9.4 [7.8 to 10.9]	7.4 [6.1 to 8.6]	81.7 (74.2-89.3)	76.9 (68.8-85.1)	77.2 [58.3 to 100.0]	35.0 (27.0-50.0)	431.8 (313.2-570.9)	140.0 (86.9-200.4)	571.7 [420.9 to 744.6]
13	177	132	9.3 [7.7 to 10.9]	6.9 [5.5 to 8.3]	78.4 (70.5-86.2)	62.2 (53.0-71.4)	67.9 [51.0 to 85.5]	27.5 (19.0-41.0)	361.9 (251.7-484.2)	106.8 (67.9-149.8)	468.7 [336.6 to 605.5]
14	143	115	8.8 [7.5 to 10.0]	7.1 [5.9 to 8.2]	80.0 (71.0-89.0)	75.0 (65.2-84.8)	41.6 [34.1 to 50.8]	24.0 (18.0-30.0)	223.4 (168.2-282.5)	70.9 (42.6-105.8)	294.3 [227.1 to 371.2]

**Table 2** Modelled injury incidence, mean severity, and injury burden for each sex, section, and year group.

Sex	Year Group	Medical Attention Injury Incidence (injuries per 1000 exposure days)	Time-loss Injury Incidence (injuries per 1000 exposure days)	Injury Severity (Mean Days Time-Loss)	Injury Burden (day lost per 1000 exposure days)
-	Lower School	6.5 (6.0 to 6.9) *	5.1 (4.7 to 5.5) *	46.1 (42.6 to 49.6) *	235.7 (211.4 to 261.4) *
-	Upper School	9.0 (8.4 to 9.7) †	6.9 (6.3 to 7.5) †	60.4 (55.4 to 65.6) †	416.1 (370.9 to 465.3) †
Girls	-	7.8 (7.2 to 8.4)	6.0 (5.5 to 6.5)	51.9 (48.3 to 55.6)	309.7 (278.0 to 345.6)
Boys	-	7.5 (7.0 to 8.0)	5.9 (5.5 to 6.4)	53.6 (49.0 to 58.1)	316.6 (284.5 to 350.1)
<b>Girls</b>	<b>Lower School</b>	<b>6.4 (5.8 to 7.1) *</b>	<b>5.0 (4.5 to 5.6) *</b>	<b>44.1 (40.1 to 48.1) *</b>	<b>221.4 (190.5 to 254.8) *</b>
	7	5.4 (4.3 to 6.6)	4.0 (3.1 to 4.9)	26.9 (21.9 to 32.2)	108.2 (76.6 to 140.8)
	8	6.9 (5.6 to 8.2)	5.4 (4.3 to 6.5)	37.2 (28.1 to 46.8)	199.6 (139.2 to 268.2)
	9	6.2 (5.3 to 7.2)	5.2 (4.4 to 6.2)	48.1 (38.9 to 57.7)	252.4 (189.4 to 327.2)
	10	7.3 (6.1 to 8.5)	5.6 (4.5 to 6.6)	53.5 (43.3 to 63.6)	298.1 (224.7 to 378.9)
	11	6.7 (5.6 to 7.9)	5.1 (4.2 to 6.2)	66.7 (52.3 to 82.1)	340.8 (247.4 to 430.6)
	<b>Upper School</b>	<b>9.5 (8.6 to 10.4) †</b>	<b>7.1 (6.3 to 7.9) †</b>	<b>61.1 (54.7 to 67.6) †</b>	<b>434.3 (372.7 to 499.4) †</b>
	12	9.5 (8.2 to 10.7)	7.3 (6.0 to 8.4)	65.4 (52.8 to 78.4)	475.2 (359.9 to 598.7)
	13	8.9 (7.6 to 10.3)	6.5 (5.5 to 7.7)	58.4 (47.7 to 70.3)	382.4 (295.3 to 477.4)
	14	10.1 (8.6 to 11.8)	7.6 (6.2 to 9.1)	60.5 (49.3 to 71.5)	458.7 (347.4 to 574.1)
<b>Boys</b>	<b>Lower School</b>	<b>6.6 (5.9 to 7.1) *</b>	<b>5.2 (4.7 to 5.8) *</b>	<b>48.2 (42.1 to 54.2) *</b>	<b>251.5 (215.2 to 289.3) *</b>
	7	5.9 (4.7 to 7.0)	4.4 (3.4 to 5.4)	29.1 (20.9 to 37.4)	128.8 (81.4 to 177.4)
	8	6.5 (5.4 to 7.4)	5.4 (4.5 to 6.2)	44.7 (32.7 to 57.4)	240.0 (168.0 to 317.4)
	9	6.0 (4.9 to 7.1)	4.8 (3.8 to 5.7)	61.2 (45.9 to 76.8)	291.8 (206.0 to 380.4)
	10	7.2 (5.8 to 8.6)	6.2 (4.9 to 7.5)	62.2 (48.5 to 77.0)	385.8 (280.6 to 495.4)
	11	7.6 (6.4 to 8.8)	5.6 (4.7 to 6.6)	54.3 (41.5 to 67.3)	304.9 (220.2 to 394.9)
	<b>Upper School</b>	<b>8.6 (7.8 to 9.4) †</b>	<b>6.7 (6.0 to 7.4) †</b>	<b>59.7 (52.3 to 67.2) †</b>	<b>399.7 (339.2 to 466.6) †</b>
	12	9.1 (7.9 to 10.3)	7.1 (6.1 to 8.1)	78.2 (61.1 to 95.3)	555.2 (415.9 to 699.3)
	13	8.8 (7.5 to 10.0)	6.4 (5.4 to 7.5)	67.3 (52.8 to 81.5)	433.4 (327.0 to 554.2)
	14	8.1 (7.0 to 9.2)	6.6 (5.7 to 7.6)	40.9 (33.4 to 48.5)	269.5 (209.8 to 333.4)

\* Significantly different from the upper school ( $p < .050$ ). † Significantly different from the lower school ( $p < .050$ ). No significant differences observed between sexes. P-values adjusted for multiple comparisons using the false discovery rate method across all tests. Models were not adjusted for additional covariates.

### ***Injury Severity***

Of the 2121 injuries, 465 (21.9%) did not result in time-loss, whilst 282 (13.3%) were classified as *mild*, 582 (27.4%) were classified as *moderate*, and 792 (37.3%) were classified as *severe*. Regression models indicated that injury severity was significantly greater in the upper school than the lower school ( $p < .001$ , 46.1 vs 60.4 days), but did not differ between boys and girls ( $p = .709$ ). Raw mean and median, and modelled mean injury severity, by sex and year group, is presented in Tables 1 and 2.

### ***Injury Burden***

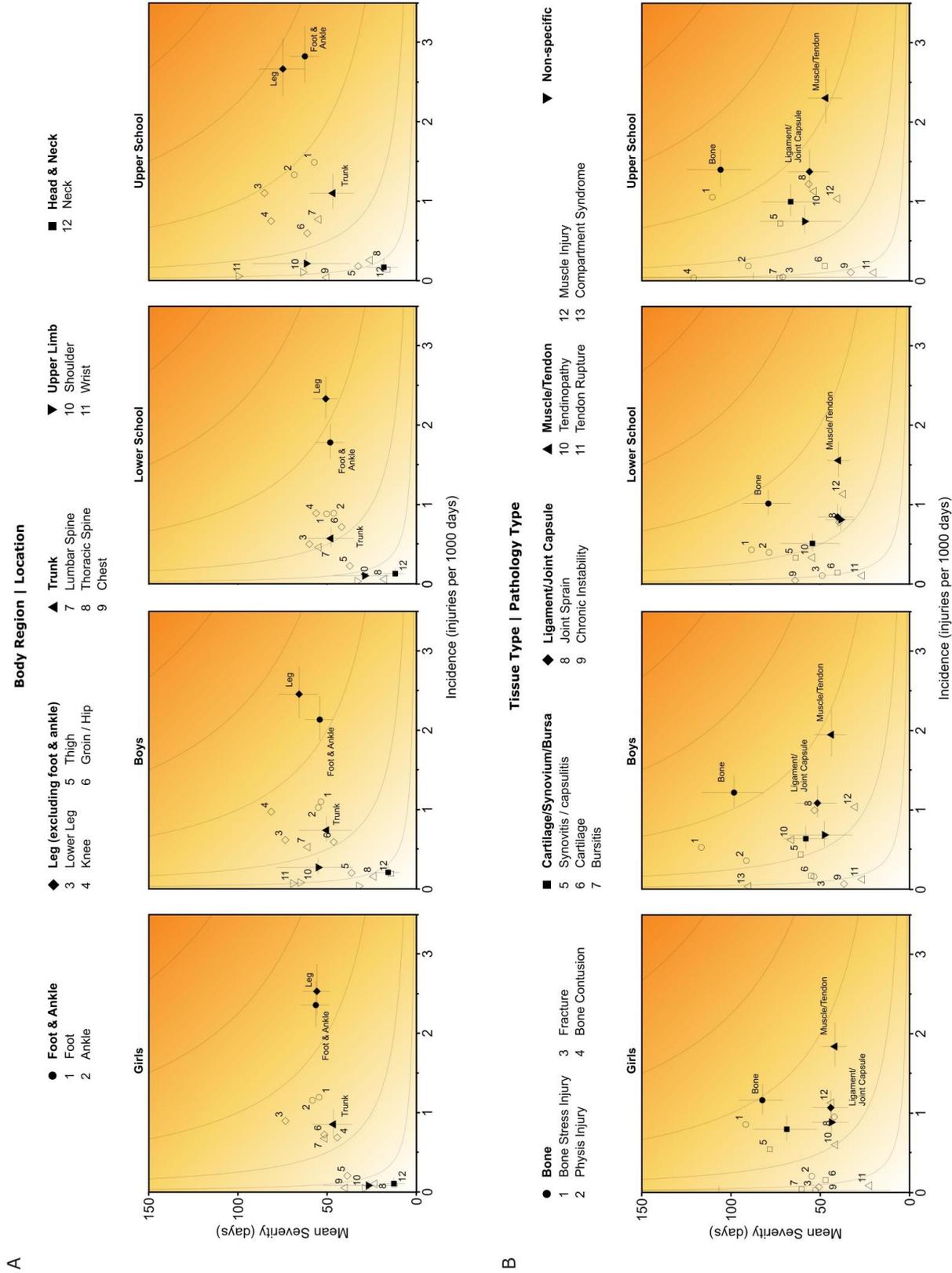
Injury burden was greater ( $p < .001$ ) in the upper school (416 days lost per 1,000 exposure days, 95% CI 371 to 465) than the lower school (236 days lost per 1,000 exposure days, 95% CI 211 to 261), but did not differ between sexes ( $p = .802$ ). Raw and modelled injury burden for each year group  $\times$  sex combination are presented in Tables 1 and 2. Injury risk matrices presenting injury burden by body region and location, and by tissue type and pathology, are presented in Figure 1. Per student-year, the raw injury burden was 48.6 days lost per student-year (95% CI 43.3 to 54.5) in the lower school, and 80.9 days lost per student-year (95% CI 71.3 to 90.7) in the upper school.

### ***Tissue Type, Pathology and Location***

Muscle/tendon was the most commonly injured tissue type (34.0%), followed by ligament and joint capsule injuries (17.3%), bone injuries (17.3%), non-specific injuries (16.1%), and cartilage/synovium/bursa injuries (12.6%). The most common pathologies were muscle injuries (19.7%), pain without a specified tissue (17.2%), ligament injuries (15.0%), tendinopathies (11.2%), and bone stress injuries (10.1%). The most commonly injured locations were the foot (18.3%) and ankle (18.1%), followed by the knee (14.1%), lower leg (12.1%), groin/hip (11.8%), and lumbar spine (10.7%). The incidence, severity, and burden of injuries by body part, pathology type, and diagnosis, are presented in Tables 3 and 4, for boys and girls, respectively. Supplementary Tables 1 and 2 present the incidence, severity, and burden of injuries by school section, sex, body region, and pathology type.

### ***Availability***

Student availability status across an average academic year is presented in Figure 2. The mean proportion of term time students spent *available*, *fully available with*



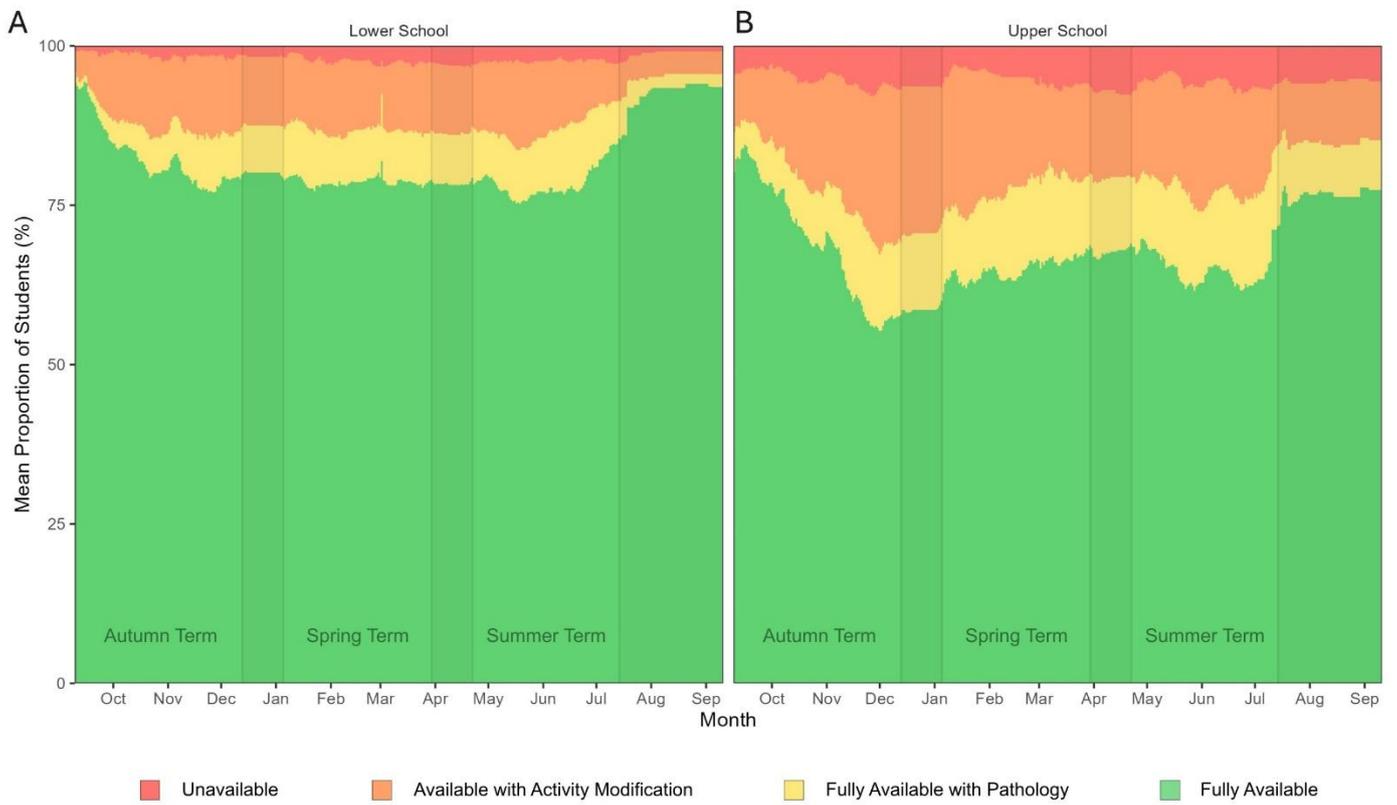
**Figure 1** Risk matrices presenting the time-loss injury burden (i.e., incidence × severity) grouped by A) Tissue type and pathology, and B) Anatomical region and body part.

**Table 3** Injury count, incidence, severity, and injury burden in boys, by body part, pathology type, and diagnosis, sorted by injury burden.

Body Part   Pathology Type   <i>Diagnosis</i>	n	Injury Incidence (injuries per 1000 exposure days)	Mean Injury Severity (days time-loss)	Time-loss Burden (day lost per 1000 exposure days)
<b>Knee</b>	<b>165</b>	<b>1.27 (1.09-1.47)</b>	<b>69.7 (52.3-88.9)</b>	<b>88.2 (65.4-112.1)</b>
Physis Injury	39	0.30 (0.22-0.41)	113.3 (78.1-153.4)	33.9 (19.8-49.7)
<i>Apophysitis/ avulsion fracture tibial tubercle (OGS)</i>	21	0.16 (0.11-0.25)	158.8 (107.3-218.4)	25.6 (13.5-40.5)
<i>Apophysitis/ avulsion fracture distal pole patella (SLJ)</i>	14	0.11 (0.06-0.18)	54.9 (32.4-79.2)	5.9 (2.3-10.3)
Tendinopathy	31	0.24 (0.17-0.34)	88.5 (38.9-155.2)	21.0 (7.8-39.4)
<i>Patellar tendinopathy (excl. Sinding Larsen Johannson syndrome see JTKP)</i>	12	0.09 (0.05-0.16)	101.8 (26.8-228.9)	9.4 (1.7-22.2)
Pain without tissue type specified	34	0.26 (0.19-0.37)	57.3 (19.4-110.0)	14.9 (5.1-28.8)
<i>Knee haemarthrosis cause undiagnosed</i>	1	0.01 (0.00-0.05)	660	5.1 (0.0-14.9)
Cartilage	22	0.17 (0.11-0.26)	58.5 (34.0-82.5)	9.9 (3.6-17.0)
<b>Foot</b>	<b>181</b>	<b>1.39 (1.20-1.61)</b>	<b>45.2 (36.2-55.6)</b>	<b>62.8 (47.6-82.5)</b>
Ligament	40	0.31 (0.23-0.42)	58.8 (32.4-94.2)	18.0 (8.9-30.0)
<i>Midfoot joint/ligament sprain</i>	16	0.12 (0.08-0.20)	90.4 (36.3-168.4)	11.1 (3.3-22.2)
Bone stress Injury	27	0.21 (0.14-0.30)	78.1 (51.7-106.2)	16.2 (9.0-24.8)
Fracture	15	0.12 (0.07-0.19)	65.3 (45.7-86.0)	7.5 (3.3-13.0)
Pain without tissue type specified	36	0.28 (0.20-0.38)	21.1 (11.1-33.5)	5.8 (2.3-10.8)
Tendinopathy	15	0.12 (0.07-0.19)	48.9 (20.3-83.7)	5.6 (1.5-11.7)
<b>Ankle</b>	<b>188</b>	<b>1.44 (1.25-1.66)</b>	<b>42.0 (33.1-50.5)</b>	<b>60.6 (44.7-77.6)</b>
Ligament	67	0.51 (0.40-0.65)	49.5 (33.7-68.4)	25.5 (14.9-38.6)
<i>Ankle lateral ligament sprain</i>	20	0.15 (0.10-0.24)	52.7 (31.4-77.0)	8.1 (4.0-13.0)
<i>Anterior talofibular ligament sprain</i>	26	0.20 (0.14-0.29)	35.1 (19.5-57.6)	7.0 (3.1-11.8)
<i>Lateral ligaments rupture (grade 3 injury)</i>	3	0.02 (0.01-0.07)	270.7 (119.0-427.0)	6.2 (0.7-13.8)
Synovitis / capsulitis	46	0.35 (0.26-0.47)	54.2 (35.9-73.0)	19.1 (10.4-32.1)
<i>Posterior impingement ankle</i>	18	0.14 (0.09-0.22)	52.3 (18.8-91.5)	7.2 (1.7-16.5)
Tendinopathy	33	0.25 (0.18-0.36)	31.4 (21.1-43.8)	8.0 (4.1-12.2)
<b>Lower Leg</b>	<b>89</b>	<b>0.68 (0.55-0.84)</b>	<b>68.0 (44.0-95.3)</b>	<b>46.4 (27.0-67.6)</b>
Bone stress Injury	40	0.31 (0.23-0.42)	113.9 (70.8-164.6)	35.0 (20.1-54.0)
<i>Posteromedial shin periostitis/stress syndrome/shin splints</i>	12	0.09 (0.05-0.16)	186.2 (84.7-304.6)	17.1 (6.6-32.0)
<i>Anterior shin periostitis/stress syndrome/shin splints</i>	16	0.12 (0.08-0.20)	73.1 (31.8-138.7)	9.0 (3.0-17.3)
<i>Tibial stress reaction</i>	6	0.05 (0.02-0.10)	132.3 (30.5-320.5)	6.1 (0.7-15.6)
<b>Hip and Groin</b>	<b>126</b>	<b>0.97 (0.81-1.15)</b>	<b>41.0 (31.9-51.0)</b>	<b>39.7 (27.5-58.7)</b>
Muscle Injury	45	0.35 (0.26-0.46)	26.9 (18.1-37.1)	9.3 (5.4-13.6)
Tendinopathy	23	0.18 (0.12-0.27)	52.0 (32.0-79.7)	9.2 (4.4-15.4)
Physis Injury	10	0.08 (0.04-0.14)	86.8 (59.1-113.1)	6.7 (2.6-11.3)
Pain without tissue type specified	29	0.22 (0.15-0.32)	26.2 (9.1-48.9)	5.8 (1.5-17.4)
<b>Lumbar Spine</b>	<b>83</b>	<b>0.64 (0.51-0.79)</b>	<b>36.7 (23.7-51.6)</b>	<b>23.3 (15.1-34.7)</b>
Bone stress Injury	7	0.05 (0.03-0.11)	160.6 (71.6-251.8)	8.6 (2.9-15.9)
Muscle Injury	36	0.28 (0.20-0.38)	29.6 (15.5-47.1)	8.2 (3.9-13.5)
<i>Lumbar Spine muscle and Tendon Strain/ Spasm/Trigger Points</i>	29	0.22 (0.15-0.32)	31.4 (16.7-49.3)	7.0 (3.2-11.8)
<b>Shoulder</b>	<b>25</b>	<b>0.19 (0.13-0.28)</b>	<b>49.5 (28.4-76.5)</b>	<b>9.5 (4.6-14.6)</b>
<b>Thigh</b>	<b>38</b>	<b>0.29 (0.21-0.40)</b>	<b>27.8 (15.6-43.9)</b>	<b>8.1 (4.3-13.1)</b>
Muscle Injury	29	0.22 (0.15-0.32)	23.7 (12.3-36.4)	5.3 (2.4-9.0)
<b>Wrist</b>	<b>17</b>	<b>0.13 (0.08-0.21)</b>	<b>40.4 (10.2-83.4)</b>	<b>5.3 (1.1-10.6)</b>
<b>Thoracic Spine</b>	<b>25</b>	<b>0.19 (0.13-0.28)</b>	<b>24.4 (13.6-39.7)</b>	<b>4.7 (2.1-7.9)</b>
<b>Cervical Spine</b>	<b>40</b>	<b>0.30 (0.22-0.41)</b>	<b>10.8 (6.1-16.9)</b>	<b>3.3 (1.6-5.6)</b>
<b>Unspecified</b>	<b>16</b>	<b>0.12 (0.08-0.20)</b>	<b>21.8 (0.8-58.9)</b>	<b>2.7 (0.1-8.4)</b>

**Table 4** Injury count, incidence, severity, and injury burden in girls, by body part, pathology type, and diagnosis, sorted by injury burden.

Body Part   Pathology Type   <i>Diagnosis</i>	n	Injury Incidence (injuries per 1000 exposure days)	Mean Injury Severity (days time- loss)	Time-loss Burden (day lost per 1000 exposure days)
<b>Foot</b>	<b>199</b>	<b>1.46 (1.27-1.68)</b>	<b>51.1 (42.6-61.1)</b>	<b>74.7 (55.4-98.4)</b>
Bone stress Injury	52	0.38 (0.29-0.50)	86.9 (66.6-108.1)	33.2 (20.4-47.6)
<i>Metatarsal stress reaction</i>	15	0.11 (0.07-0.18)	96.3 (52.8-143.7)	10.6 (4.1-19.7)
<i>Second metatarsal stress fracture</i>	7	0.05 (0.02-0.11)	154.9 (129.9-181.0)	8.0 (1.9-15.9)
Pain without tissue type specified	36	0.26 (0.19-0.37)	44.9 (25.7-69.2)	11.9 (5.1-20.8)
Synovitis / capsulitis	14	0.10 (0.06-0.17)	83.2 (24.8-162.5)	8.6 (2.7-19.9)
Tendinopathy	27	0.20 (0.14-0.29)	30.8 (20.2-42.9)	6.1 (3.6-9.0)
Ligament	33	0.24 (0.17-0.34)	23.8 (14.9-33.9)	5.8 (3.3-8.6)
<b>Lower Leg</b>	<b>133</b>	<b>0.98 (0.82-1.16)</b>	<b>67.7 (52.9-83.3)</b>	<b>66.1 (46.8-86.5)</b>
Bone stress Injury	65	0.48 (0.37-0.61)	82.7 (61.6-110.1)	39.5 (24.3-59.0)
<i>Anterior shin periostitis/ stress syndrome/shin     splints</i>	20	0.15 (0.09-0.23)	79.2 (47.7-116.7)	11.6 (5.9-19.0)
<i>Tibial stress reaction</i>	14	0.10 (0.06-0.17)	104.4 (48.0-197.1)	10.7 (2.8-26.3)
<i>Posteromedial shin periostitis/stress     syndrome/ shin splints</i>	22	0.16 (0.11-0.25)	57.6 (34.5-85.0)	9.3 (4.3-15.9)
<i>Fibula stress reaction</i>	7	0.05 (0.02-0.11)	100.6 (44.7-159.6)	5.2 (1.9-9.8)
Muscle Injury	47	0.35 (0.26-0.46)	51.7 (27.3-79.0)	17.8 (9.9-28.9)
<b>Ankle</b>	<b>243</b>	<b>1.79 (1.57-2.02)</b>	<b>36.8 (28.8-44.7)</b>	<b>65.8 (47.4-88.1)</b>
Synovitis/capsulitis	56	0.41 (0.32-0.53)	71.5 (46.4-105.7)	29.4 (17.0-45.0)
<i>Posterior impingement ankle</i>	26	0.19 (0.13-0.28)	44.3 (25.3-66.4)	8.5 (3.8-14.8)
<i>Ankle joint synovitis</i>	5	0.04 (0.02-0.09)	206.2 (10.6-420.8)	7.6 (1.7-17.2)
Ligament	71	0.52 (0.41-0.66)	32.2 (22.9-41.5)	16.8 (9.8-25.8)
<i>Anterior talofibular ligament sprain</i>	22	0.16 (0.11-0.25)	35.2 (18.3-53.4)	5.7 (2.0-10.4)
Tendinopathy	52	0.38 (0.29-0.50)	28.9 (17.0-44.0)	11.0 (5.1-18.2)
<b>Hip and Groin</b>	<b>154</b>	<b>1.13 (0.97-1.33)</b>	<b>40.6 (31.7-51.2)</b>	<b>45.9 (33.6-63.5)</b>
Muscle Injury	61	0.45 (0.35-0.58)	36.5 (23.5-52.1)	16.4 (10.1-24.1)
Pain without tissue type specified	33	0.24 (0.17-0.34)	35.7 (18.5-57.7)	8.6 (4.3-13.7)
Physis Injury	14	0.10 (0.06-0.17)	66.6 (41.3-92.4)	6.9 (2.4-12.5)
<b>Knee</b>	<b>137</b>	<b>1.00 (0.84-1.18)</b>	<b>32.2 (24.8-41.4)</b>	<b>32.4 (20.5-46.5)</b>
Ligament	10	0.07 (0.04-0.14)	140.1 (72.0-215.6)	10.3 (2.8-20.5)
<i>Patellar dislocation</i>	7	0.05 (0.02-0.11)	156.3 (79.7-249.3)	8.0 (2.3-15.3)
Pain without tissue type specified	38	0.27 (0.20-0.38)	20.3 (12.9-28.8)	5.7 (2.6-10.0)
Cartilage	25	0.18 (0.12-0.27)	27.4 (15.4-42.5)	5.0 (1.7-10.2)
<b>Lumbar Spine</b>	<b>110</b>	<b>0.81 (0.67-0.97)</b>	<b>39.0 (27.5-51.5)</b>	<b>31.5 (20.0-46.3)</b>
Pain without tissue type specified	34	0.25 (0.18-0.35)	44.1 (22.7-71.2)	11.0 (4.9-17.7)
<i>Lumbar Spine Facet Joint Pain/Stiffness</i>	20	0.15 (0.09-0.23)	57.3 (22.4-98.1)	8.4 (2.7-15.6)
Muscle Injury	45	0.33 (0.25-0.44)	24.1 (15.8-34.2)	8.0 (4.5-12.3)
<i>Lumbar Spine muscle and Tendon     Strain/Spasm/Trigger Points</i>	38	0.28 (0.20-0.38)	26.5 (16.1-37.8)	7.4 (4.1-11.7)
Bone stress Injury	11	0.08 (0.04-0.15)	73.4 (34.9-117.8)	5.9 (2.3-10.5)
<b>Thigh</b>	<b>31</b>	<b>0.23 (0.16-0.32)</b>	<b>26.2 (16.5-38.0)</b>	<b>6.0 (3.4-9.1)</b>
<b>Thoracic Spine</b>	<b>33</b>	<b>0.24 (0.17-0.34)</b>	<b>12.5 (5.8-20.6)</b>	<b>3.0 (0.8-6.1)</b>
<b>Shoulder</b>	<b>15</b>	<b>0.11 (0.07-0.18)</b>	<b>17.9 (2.7-42.9)</b>	<b>2.0 (0.5-3.9)</b>
<b>Wrist</b>	<b>6</b>	<b>0.04 (0.02-0.10)</b>	<b>27.8 (8.2-49.2)</b>	<b>1.2 (0.1-2.8)</b>
<b>Cervical Spine</b>	<b>17</b>	<b>0.12 (0.08-0.20)</b>	<b>5.4 (2.6-8.8)</b>	<b>0.7 (0.3-1.2)</b>
<b>Unspecified</b>	<b>9</b>	<b>0.07 (0.03-0.13)</b>	<b>9.6 (0.0-21.6)</b>	<b>0.6 (0.0-4.3)</b>



**Figure 2** Plots presenting average student training availability across the seven years for A) the lower school, and B) the upper school. Each bar represents availability for a single calendar day. Holiday periods are denoted by the shaded area.

*pathology, available with activity modification, and unavailable* at the lower school was 78.8%, 7.2%, 11.7%, and 2.4%, respectively, whilst at the upper school was 66.2%, 10.8%, 16.7%, and 6.2%.

### ***Occurrence, Movement, Activity, and Footwear***

The most common injury mechanism was *repetitive – gradual onset* (54.8%), followed by *acute – sudden onset* (23.0%), and *repetitive – sudden onset* (17.4%), whilst 4.8% of injuries did not have a recorded mode of onset. The majority of injuries were classified as first episodes (74.9%), whilst 25.1% were recurrences. The most common movements associated with injury were *jumping and landing* (boys: 30.8%; girls: 21.4%) and *other dancing movements* (boys: 23.2%; girls: 27.9%), whilst 16.4% of injuries affecting girls were associated with *pointe work*. The proportion of injuries by occurrence and mode of onset is presented in Supplementary Table 3. The proportion of injuries associated with movement, activity, and footwear types is presented in Supplementary Table 4

### **Discussion**

Across seven academic years at an elite vocational ballet school, we observed 2121 medical attention injuries — 1656 of which were time-loss injuries — resulting in an injury burden ranging from 111 (year 7 girls) to 583 (year 12 boys) days lost per 1000 days of exposure. The mean proportion of students whose availability was affected by injury on any given day during term-time was 21% at the lower school and 34% at the upper school. The results of this study demonstrate the importance of comprehensive science and medicine departments in vocational ballet schools to manage the injury burden, and implement injury prevention strategies.

### ***Injury Burden in Context***

A major finding of this study is the high injury burden, particularly at the upper school (416 day lost per 1,000 exposure days; 81 days lost per student-year) – characterised by students spending large periods of the year training whilst carrying an injury. This injury burden, for example, exceeds the values reported in elite academy football (23 days lost per athlete-season).<sup>9</sup> Speculatively, the greater injury burden in the upper school compared with the lower school may be explained by several factors. As students progress toward the end of their training and prepare for professional careers, increasing training volume and intensity place greater mechanical stress on the body,

potentially leading to acute spikes in load or cumulative overuse if recovery is insufficient.<sup>10,11</sup> Periods of rapid physical development, for example, peak height and weight velocities, have been associated with injury risk in several youth sport cohorts, affecting factors such as relative strength and coordination.<sup>12</sup> Previous injury is frequently identified as a leading risk factor for subsequent injury; as students progress through their training, the accumulation of prior injuries may further elevate their susceptibility to future injury.<sup>11</sup> Within school sections, we observed the highest injury burdens in year groups 10 and 12. These are points in the syllabus characterised by increased training demands, and coincide with the intake of new students from around the world, many of whom may not yet be fully adapted to the school's training demands.<sup>13</sup> As a result, these year groups may be primary targets for injury prevention interventions.

### ***Dancing through Injury***

As a consequence of the high injury burden, the average term-time proportion of students free from injury was 79% (lower school) and 66% (upper school), with the steepest decline in available students evident in the autumn term. This may reflect a spike in training load following the summer holiday, or availability reaching a state of equilibrium, wherein the balance of new injuries and injury rehabilitation is met. Notably, the proportion of students classified as *unavailable* stays relatively stable throughout the school year, whilst the number of students managing an injury whilst still taking some part in training increases dramatically. Although short term, managing training around an injury is desirable, we suggest that the extent to which that is seen in the present results reflects inadequate time for healing, rather than ongoing management. Training whilst managing an injury may not facilitate optimal technical and physical development, and is unlikely to prepare students for a healthy career. Professional ballet careers are short, and beginning a career with a significant injury history is likely to impact a dancers longevity, and subsequently, their career success.<sup>14</sup> Ballet schools must carefully reconsider the balance between stimulus and recovery (and ultimately, what is an acceptable degree of injury burden) to optimise students' development.

### ***Activity Modification Augments Severity***

Mean injury severity in the present study was higher than typical values reported in sports medicine literature.<sup>15,16</sup> To this end, a previous study in professional ballet noted

that the 35% of time-loss injuries classified as 'severe' was unusually high<sup>1</sup>; our results suggest that this same proportion was 48% in the current cohort. Looking closely at the injury burden during which the athlete was restricted rather than fully absent from training (Table 1), however, further supports a picture of extended periods during which students manage injuries, rather than long periods of complete absence. Whilst continuing to train whilst injured is sometimes intentional, and this may be the cultural norm across ballet, school managers should question whether this approach is optimal, and if allowing students to fully rehabilitate before returning to training might be preferable.<sup>17</sup>

### ***Body Part and Pathology Type***

In line with previous research in professional ballet, the lower limb was the most burdensome region of injury.<sup>1,18</sup> The specific body part most affected differed between sexes, however; injuries to the knee in boys, and the foot in girls, resulted in the greatest time-loss. In previous ballet epidemiology research, injuries to muscles and tendons, joints and ligaments, and bones have shown similar injury burdens.<sup>1</sup> In contrast, our findings indicate that bone injuries were associated with a substantially greater burden than any other injury type. We speculate that this may stem from a combination of high training loads,<sup>11,19</sup> growth-related injury risk,<sup>20</sup> and a risk of under-fuelling due to a perceived pressure to maintain a certain body type.<sup>21</sup> Given the large injury burden caused by bone injuries, the relatively well-understood etymology,<sup>22,23</sup> and the potential for longer-term issues as a result,<sup>24,25</sup> we suggest ballet schools address these injuries as a priority.

A large proportion of injuries were categorised as pain without a specified tissue type. These findings are consistent with previous research in ballet dancers demonstrating the prevalence of low-level, non-debilitating pain, particularly in the lower back and foot,<sup>26,27</sup> and align with studies suggesting chronic musculoskeletal pain is prevalent in ballet.<sup>26,28</sup> Angoules et al.,<sup>27</sup> for example, reported that in a cohort of 46 pre-professional dance students, 67.4% of had experienced non-specific lower back pain in the preceding 12 months. Whilst such injuries may be transient, and present challenges when identifying the specific structural causes, appropriate management is fundamental to ensure the likelihood of chronic issues is minimised.<sup>29</sup>

In girls, injuries relating to synovitis/capsulitis at the foot and ankle were amongst the most burdensome, and highlight the need for caution around student's pointe load, and capacity to tolerate that load.<sup>30</sup> Our results also demonstrate the importance of managing students around periods of growth, with physal injuries to the leg in lower school boys resulting in a greater injury burden than any other injury type. Monitoring of growth and maturation status,<sup>31</sup> load management, and appropriate implementation of training interventions may be viable interventions for managing the risk of the most burdensome injuries observed in ballet schools.

### ***Mechanism***

In line with previous research, the majority of injuries with a clearly associated movement were related to jumping and landing, followed by *pointe* work.<sup>1</sup> This is likely related to the high volume of jumping and landing observed in ballet classes and rehearsals.<sup>32</sup> Open-source methods for quantifying jump load in ballet dancers are available,<sup>33</sup> whilst management strategies such as no-jump or no-*pointe* days may provide an opportunity for students to recover. Most injuries were gradual onset in nature, typical to ballet, wherein students complete high volumes of repetitive movement to hone ballet vocabulary, and learn choreography. Given the high degree of repetition, it is logical that a quarter of injuries recorded were recurrences. It is important that artistic and medical staff ensure that students are physically robust to manage the demands of ballet training, and that students returning from injury are fully ready before restarting ballet.

### ***Clinical Implications and Further Research***

The high injury burden observed clearly demonstrates the demand for comprehensive healthcare services in vocational ballet schools, and the need for preventative measures to reduce injury incidence and preserve long-term dancer health (e.g. load management and periodisation strategies, bone health screening, physical development programs, psychological and nutritional support, etc). Such interventions require effective collaboration between healthcare, artistic, and administrative staff to minimise injury risk whilst maximising balletic performance.

The large number of injuries recorded in this study, compared with research into other ballet schools,<sup>5</sup> may be a result of greater medical staff availability. In the present study, for example, participants had immediate access to healthcare professionals,

which may have increased the number of injuries recorded, and improved return-to-dance times. In many ballet schools and youth sport settings, this level of healthcare access is not available; such differences are important to consider when comparing the burden of injuries.

Our results identified a clear pattern of dancers training whilst managing injuries for extended periods in the year. Whilst this may be the norm in elite-level ballet,<sup>17</sup> senior members of ballet schools must judge whether the balance of stimulus and recovery is appropriate.<sup>34</sup> The high injury burden resulting from lower limb injuries and bone injuries provide clear targets for injury prevention strategies. In boys, growth-related injuries should also be a target, whilst in girls the greater burden of foot and ankle cartilage/synovium/bursa injuries may be indicative of the need for *pointe*-specific strategies. Previously identified risk factors associated with elite-level ballet, such as training load<sup>19,35</sup> and nutrition<sup>36,37</sup>, may be effective areas from which to target these injuries.

Future research should build on this study to develop and implement interventions targeting the most burdensome injuries observed in this cohort. In addition, we suggest further research is warranted aiming to better understand other related domains of health (e.g., mental health, female health, nutritional health), which will facilitate a comprehensive understanding of the healthcare need of student-dancers.

### ***Strengths and Limitations***

This is the largest injury epidemiology study in student-dancers using prospectively collected injury data recorded by Chartered Physiotherapists, recorded using a recognised classification system. We also report considerable additional detail around contextual factors such as movement, activity, and footwear, and most notably, availability status throughout a year. We acknowledge, however, that the use of clinician-recorded data, and the injury definitions used, may underestimate the burden of injury in his population.<sup>38</sup> It was not possible to record exposure hours in the present study, and as such, we were unable to report incidence rates per 1000 h; instead, each student's unique day-to-day exposure was calculated to facilitate the reporting of incidence. Subsequently, we acknowledge that comparisons with other cohorts are limited, and readers should consider these methodological differences when making such assessments. Though the cohort was large, it was taken from a single school,

and so generalising to other schools should be done with caution. This may be particularly important given the lack of governance across dance schools (compared to the uniform governance across football academies in the UK, for example), meaning data collection practices may be inconsistent.

A strength of the current study is the use of a seven-year follow-up period, facilitating the collection of a large volume of data, and as a result, robust granular analysis of specific injury types. However, given the extended follow-up period, readers should also consider that factors such as institutional policy, changes in staffing, and approaches to training and injury management, will have changed across the data collection period. Furthermore, the COVID-19 global pandemic also took place during this study, most significantly affecting the 2019-20 and 2020-21 academic years. Readers should consider the extent to which these factors affect the generalisability of the results to other cohorts.

## **Conclusion**

A large injury burden was observed across the school, typically characterised by periods of modification, as students managed injuries whilst continuing to train, with 34% of the upper school, and 21% of the lower school managing an injury on the average in-term day. Injuries affecting the lower limb, most notably bone stress injuries and growth-related injuries, should be targets for injury risk mitigation strategies. Injury incidence was greatest at the upper school (9.0 vs 6.5 injuries per 1,000 exposure days), but was comparable between boys and girls. To ensure the appropriate development of their students, ballet schools must carefully consider the balance between training stimulus and recovery to optimise both performance and health, and ensure comprehensive sports medicine departments are in place to manage and mitigate the injury burden. This study provides the foundation for the implementation of targeted injury prevention strategies in vocational ballet schools.

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## References

1. Mattiussi AM, Shaw JW, Williams S, et al. Injury epidemiology in professional ballet: a five-season prospective study of 1596 medical attention injuries and 543 time-loss injuries. *Br J Sports Med.* 2021;55(15):843-850. doi:10.1136/BJSPORTS-2020-103817
2. van Mechelen W, Hlobil H, Kemper HCG. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. *Sports Med.* 1992;14(2):82-99. doi:10.2165/00007256-199214020-00002
3. Swain M, Kamper SJ, Maher CG, Broderick C, McKay D, Henschke N. Relationship between growth, maturation and musculoskeletal conditions in adolescents: a systematic review. *Br J Sports Med.* 2018;52(19):1246-1252. doi:10.1136/BJSPORTS-2017-098418
4. Caine D, Goodwin BJ, Caine CG, Bergeron G. Epidemiological Review of Injury in Pre-Professional Ballet Dancers. *Journal of Dance Medicine and Science.* 2015;19(4):140-148. doi:10.12678/1089-313X.19.4.140
5. Critchley ML, Ferber R, Pasanen K, Kenny SJ. Injury epidemiology in pre-professional ballet dancers: A 5-year prospective cohort study \*. Published online 2022. doi:10.1016/j.ptsp.2022.10.001
6. Bahr R, Clarsen B, Derman W, et al. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). *Orthop J Sports Med.* 2020;54:372-389. doi:10.1136/bjsports-2019-101969
7. Shrier I, Steele RJ, Hanley J, Rich B. Analyses of injury count data: some do's and don'ts. *Am J Epidemiol.* 2009;170(10):1307-1315. doi:10.1093/AJE/KWP265
8. Williams S, Shaw JW, Emery C, Stokes KA. Adding confidence to our injury burden estimates: is bootstrapping the solution? *Br J Sports Med Month.* 2023;0(0). doi:10.1136/bjsports-2023-107496

9. Materne O, Chamari K, Farooq A, et al. Injury incidence and burden in a youth elite football academy: a four-season prospective study of 551 players aged from under 9 to under 19 years. *Br J Sports Med.* 2021;55(9):493-500. doi:10.1136/BJSPORTS-2020-102859
10. Windt J, Gabbett TJ. The workload—injury aetiology model. *Br J Sports Med.* 2017;51(21):1559-1559. doi:10.1136/BJSPORTS-2016-096653
11. Hoenig T, Hollander K, Popp KL, et al. International Delphi consensus on bone stress injuries in athletes. *Br J Sports Med.* 2025;59(2):78-90. doi:10.1136/BJSPORTS-2024-108616
12. Parry GN, Williams S, McKay CD, Johnson DJ, Bergeron MF, Cumming SP. Associations between growth, maturation and injury in youth athletes engaged in elite pathways: a scoping review. *Br J Sports Med.* 2024;58(17):1001-1010. doi:10.1136/BJSPORTS-2024-108233
13. Gabbett TJ. The training—injury prevention paradox: should athletes be training smarter and harder? *Br J Sports Med.* 2016;50(5):273-280. doi:10.1136/BJSPORTS-2015-095788
14. Lewis RL, T Dickerson JW, Davies Rebecca L Lewis BA J W T Dickerson GJ, Jill Davies BEd HG, Lewis R. Lifestyle and injuries of professional ballet dancers: reflections in retirement.
15. Sprouse B, Alty J, Kemp S, et al. The Football Association Injury and Illness Surveillance Study: The Incidence, Burden and Severity of Injuries and Illness in Men's and Women's International Football. *Sports Medicine.* 2024;54(1):213-232. doi:10.1007/S40279-020-01411-8/TABLES/7
16. Lathlean TJH, Gastin PB, Newstead S V, Finch CF. The incidence, prevalence, severity, mechanism and body region of injury in elite junior Australian football players: A prospective cohort study over one season. *J Sci Med Sport.* 2018;21:1013-1018. doi:10.1016/j.jsams.2018.03.002
17. Bolling C, van Rijn RM, Pasma HR, van Mechelen W, Stubbe JH. In your shoes: A qualitative study on the perspectives of professional dancers and staff

- regarding dance injury and its prevention. *Transl Sports Med.* 2021;4(3):386-394. doi:10.1002/TSM2.226
18. Allen N, Nevill A, Brooks J, Koutedakis Y, Wyon M. Ballet injuries: injury incidence and severity over 1 year. *J Orthop Sports Phys Ther.* 2012;42(9):781-790. doi:10.2519/JOSPT.2012.3893
  19. Shaw JW, Mattiussi AM, Brown DD, et al. Rehearsal and Performance Volume in Professional Ballet: A Five-Season Cohort Study. *Journal of Dance Medicine and Science.* 2023;27(1):3-12. doi:10.1177/1089313X231174684
  20. Johnson DM, Cumming SP, Bradley B, Williams S. The influence of exposure, growth and maturation on injury risk in male academy football players. *J Sports Sci.* 2022;40(10):1127-1136. doi:10.1080/02640414.2022.2051380,
  21. Toro J, Guerrero M, Sentis J, Castro J, Puértolas C. Eating disorders in ballet dancing students: Problems and risk factors. *European Eating Disorders Review.* 2009;17(1):40-49. doi:10.1002/ERV.888
  22. Warden SJ, Davis IS, Fredericson M. Management and prevention of bone stress injuries in long-distance runners. *Journal of Orthopaedic and Sports Physical Therapy.* 2014;44(10):749-765. doi:10.2519/JOSPT.2014.5334
  23. Hoenig T, Ackerman KE, Beck BR, et al. Bone stress injuries. doi:10.1038/s41572-022-00352-y
  24. Popp KL, Ackerman KE, Rudolph SE, et al. Changes in Volumetric Bone Mineral Density Over 12 Months After a Tibial Bone Stress Injury Diagnosis: Implications for Return to Sports and Military Duty. *American Journal of Sports Medicine.* 2021;49(1):226-235. doi:10.1177/0363546520971782/ASSET/IMAGES/LARGE/10.1177\_0363546520971782-FIG4.JPEG
  25. Weaver CM, Gordon CM, Janz KF, et al. The National Osteoporosis Foundation's position statement on peak bone mass development and lifestyle factors: a systematic review and implementation recommendations. *Osteoporos Int.* 2016;27(4):1281-1386. doi:10.1007/S00198-015-3440-3

26. Ramel E, Moritz U. Self-reported musculoskeletal pain and discomfort in professional ballet dancers in Sweden. *Scand J Rehabil Med.* 1994;26(1):11-16. doi:10.2340/16501977941116
27. Angoules AG, Dionyssiotis Y, Angoules GA, Balakatounis KC, Panou A, Papathanasiou J. An Epidemiological Study of Non-specific Low Back Pain in Non-professional Female Greek Classic Ballet Dancers. *Folia Medica I 2018 I.* 60(2). doi:10.1515/folmed-2017-0087
28. Albán-Reyes AP, Tamayo-Montoya PA, Giraldo-Jiménez CF, Ordoñez-Mora LT. Coping strategies for combating chronic pain among professional ballet dancers in Cali, Colombia. Qualitative study. *J Bodyw Mov Ther.* 2024;40:2082-2090. doi:10.1016/j.jbmt.2024.10.062
29. de Souza BL, de Souza PC, Ribeiro AP. Effect of low back pain on clinical-functional factors and its associated potential risk of chronicity in adolescent dancers of classical ballet: cross-sectional study. *BMC Sports Sci Med Rehabil.* 2022;14(1):1-9. doi:10.1186/S13102-022-00474-6/TABLES/4
30. Lai JC, Kruse DW. Assessing readiness for En Pointe in young ballet dancers. *Pediatr Ann.* 2016;45(1):e21-e25. doi:10.3928/00904481-20151215-01
31. Parry GN, Williams S, McKay CD, Johnson DJ, Bergeron MF, Cumming SP. Associations between growth, maturation and injury in youth athletes engaged in elite pathways: a scoping review Systematic review. *Br J Sports Med.* 2024;58:1001-1010. doi:10.1136/bjsports-2024-108233
32. Maloney BM, Mattiussi AM, Cleather DJ, Price P, Shaw JW. Jumping demands during classical ballet class. *Scand J Med Sci Sports.* 2024;34(1):e14502. doi:10.1111/SMS.14502
33. Shaw JW, Maloney B, Mattiussi AM, et al. The development and validation of an open-source accelerometry algorithm for measuring jump height and frequency in ballet. *J Sports Sci.* 2023;41(5):463-469. doi:10.1080/02640414.2023.2223048
34. Murray A. Managing the Training Load in Adolescent Athletes. *Int J Sports Physiol Perform.* 2017;12(s2):S2-42. doi:10.1123/IJSPP.2016-0334

35. Shaw JW, Mattiussi AM, Brown DD, et al. Dance Exposure, Individual Characteristics, and Injury Risk over Five Seasons in a Professional Ballet Company. *Med Sci Sports Exerc.* 2021;53(11):2290-2297. doi:10.1249/MSS.0000000000002725
36. Frusztajer NT, Dhuper S, Warren MP, Brooks-Gunn J, Fox RP. Nutrition and the incidence of stress fractures in ballet dancers. *Am J Clin Nutr.* 1990;51(5):779-783. doi:10.1093/AJCN/51.5.779
37. Shaw JW, Mattiussi AM, Brown DD, Springham M, Pedlar CR, Tallent J. The activity demands and physiological responses observed in professional ballet: A systematic review. *The Journal of Sport and Exercise Science.* 2021;5(4). doi:10.36905/JSES.2021.04.04
38. Kenny SJ, Palacios-Derflingher L, Whittaker JL, Emery CA. The influence of injury definition on injury burden in preprofessional ballet and contemporary dancers. *Journal of Orthopaedic and Sports Physical Therapy.* 2018;48(3):185-193. doi:10.2519/JOSPT.2018.7542,

## Tables

**Table 1** Raw injury incidence, incidence proportion, mean and median severity, and injury burden for each sex, section, and year group.

**Table 2** Modelled injury incidence, mean severity, and injury burden for each sex, section, and year group.

**Table 3** Injury count, incidence, severity, and injury burden in boys, by body part, pathology type, and diagnosis, sorted by injury burden.

**Table 4** Injury count, incidence, severity, and injury burden in girls, by body part, pathology type, and diagnosis, sorted by injury burden.

**Supplementary Table 1** Upper school injury incidence, severity, and injury burden by injured region and pathology type.

**Supplementary Table 2** Lower school injury incidence, severity, and injury burden by injured region and pathology type.

**Supplementary Table 3** Proportion (95% CI) of medical attention and time-loss injuries by occurrence and mode of onset.

**Supplementary Table 4** Proportion (95% CI) of medical attention and time-loss injuries by injury movement, activity, and footwear.

## Figures

**Figure 1** Risk matrices presenting the time-loss injury burden (i.e., incidence × severity) grouped by A) Tissue type and pathology, and B) Anatomical region and body part.

**Figure 2** Plots presenting average student training availability across the seven years for A) the lower school, and B) the upper school. Each bar represents availability for a single calendar day. Holiday periods are denoted by the shaded areas.

**Supplementary Table 1** Upper school injury incidence, severity, and injury burden by injured region and pathology type.

Region	Pathology	Time-Loss Injury Count		Injury Incidence (injuries per 1000 exposure days)		Mean Injury Severity (days time-loss)		Injury Burden (days lost per 1000 exposure days)		
		Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	
Lower Limb	Bone stress Injury	57	21	1.19 (0.92-1.54)	0.38 (0.25-0.59)	95.1 (70.9-125.7)	81.4 (42.6-144.5)	112.9 (82.9-147.3)	31.2 (12.4-61.0)	
	Tendinopathy	66	48	1.37 (1.08-1.75)	0.87 (0.66-1.16)	26.5 (18.4-35.6)	63.7 (31.8-107.4)	36.5 (23.8-53.8)	55.7 (30.5-84.6)	
	Synovitis / capsulitis	42	36	0.87 (0.65-1.18)	0.62 (0.44-0.87)	59.7 (34.9-89.9)	37.0 (20.3-56.3)	52.2 (30.5-79.9)	24.3 (12.0-44.0)	
	Ligament	31	45	0.65 (0.45-0.92)	0.82 (0.61-1.10)	56.6 (34.3-86.7)	39.9 (24.8-59.2)	36.6 (22.2-52.6)	32.7 (19.7-47.9)	
	Muscle Injury	37	25	0.77 (0.56-1.06)	0.44 (0.29-0.65)	33.3 (15.4-60.6)	20.4 (7.5-41.1)	25.6 (14.9-38.8)	9.3 (3.1-17.4)	
	Unspecified tissue type	31	21	0.65 (0.45-0.92)	0.36 (0.24-0.56)	35.8 (20.6-56.5)	12.0 (4.1-20.4)	23.1 (12.2-40.3)	4.6 (1.5-7.1)	
	Cartilage	6	13	0.12 (0.06-0.28)	0.24 (0.14-0.41)	69.0 (6.3-170.0)	61.7 (34.7-93.1)	8.6 (0.7-25.6)	14.6 (7.2-22.7)	
	Physis Injury	9	3	0.19 (0.10-0.36)	0.05 (0.02-0.17)	92.6 (58.0-128.8)	68.3 (0.0-105.0)	17.3 (8.7-27.7)	3.7 (0.9-7.5)	
	Muscle compartment syndrome	-	5	-	0.09 (0.04-0.22)	-	116.8 (28.2-262.8)	-	-	10.6 (2.4-20.9)
	Fracture	-	3	-	0.05 (0.02-0.17)	-	112.0 (52.0-147.0)	-	-	6.1 (2.2-10.8)
	Bursitis	4	1	0.08 (0.03-0.22)	0.02 (0.00-0.13)	45.0 (8.5-96.8)	19	3.7 (0.5-13.1)	0.3 (0.0-1.0)	
	Chronic instability	2	1	0.04 (0.01-0.17)	0.02 (0.00-0.13)	48.5 (43.0-54.0)	63	2.0 (0.3-4.7)	1.1 (0.0-2.8)	
Trunk	Unspecified tissue type	25	14	0.52 (0.35-0.77)	0.26 (0.16-0.44)	40.7 (17.5-68.5)	21.1 (4.9-47.1)	21.3 (6.6-45.0)	5.6 (0.5-13.1)	
	Muscle Injury	29	18	0.61 (0.42-0.87)	0.34 (0.21-0.54)	19.2 (11.0-29.4)	23.1 (12.3-35.2)	11.6 (5.4-19.9)	7.8 (2.8-14.6)	
	Ligament	9	8	0.19 (0.10-0.36)	0.15 (0.08-0.30)	54.7 (20.0-107.5)	19.2 (9.4-29.2)	10.3 (1.8-22.7)	2.9 (0.9-5.2)	
	Bone stress Injury	2	4	0.04 (0.01-0.17)	0.08 (0.03-0.20)	55.5 (6.0-105.0)	121.5 (31.5-211.5)	2.3 (0.0-6.6)	9.1 (0.7-21.7)	
	Nerve Injury	3	1	0.06 (0.02-0.19)	0.02 (0.00-0.13)	113.3 (0.0-340.0)	0	7.1 (0.0-32.2)	-	
Upper Limb	Bone Contusion	0	4	-	0.08 (0.03-0.20)	-	85.5 (0.0-251.2)	-	6.4 (0.0-15.3)	
	Muscle Injury	0	3	-	0.06 (0.02-0.17)	-	40.0 (0.0-117.0)	-	2.3 (0.0-6.5)	
Medical	Unspecified tissue type	1	1	0.02 (0.00-0.15)	0.02 (0.00-0.13)	15	466	0.3 (0.0-0.9)	8.8 (0.0-27.6)	

**Supplementary Table 2** Lower school injury incidence, severity, and injury burden by injured region and pathology type.

Region	Pathology	Time-Loss Injury Count		Injury Incidence (injuries per 1000 exposure days)		Mean Injury Severity (days time-loss)		Injury Burden (day lost per 1000 exposure days)	
		Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
Lower Limb	Bone stress Injury	63	50	0.72 (0.56-0.92)	0.65 (0.49-0.86)	72.9 (57.8-89.8)	99.0 (65.5-134.1)	52.2 (34.0-73.5)	65.6 (35.0-91.3)
	Ligament	92	72	1.04 (0.85-1.28)	0.94 (0.75-1.19)	33.2 (24.3-43.8)	61.6 (42.6-84.1)	34.7 (20.9-54.2)	58.8 (35.2-88.4)
	Physis Injury	20	64	0.23 (0.15-0.35)	0.82 (0.64-1.05)	37.0 (21.6-54.3)	86.1 (62.5-112.8)	8.4 (4.6-13.7)	73.0 (46.0-89.3)
	Muscle Injury	112	89	1.27 (1.06-1.53)	1.14 (0.92-1.41)	40.0 (28.2-53.6)	23.8 (17.7-31.1)	50.9 (32.6-73.5)	28.1 (18.7-38.5)
	Unspecified tissue type	107	96	1.20 (0.99-1.46)	1.26 (1.03-1.54)	28.3 (19.8-38.7)	32.6 (19.3-48.9)	34.4 (22.7-47.5)	41.5 (22.3-85.7)
	Synovitis / capsulitis	58	43	0.66 (0.51-0.85)	0.57 (0.42-0.77)	55.3 (31.3-84.5)	51.2 (35.4-70.7)	36.4 (20.8-55.6)	29.1 (17.5-42.2)
	Tendinopathy	53	59	0.60 (0.46-0.79)	0.77 (0.59-0.99)	37.8 (25.1-52.5)	52.5 (37.8-71.1)	22.8 (14.2-32.6)	41.1 (25.3-57.3)
	Cartilage	21	12	0.24 (0.16-0.37)	0.16 (0.09-0.28)	31.0 (16.5-48.1)	46.8 (18.6-78.2)	7.4 (2.9-13.3)	7.4 (1.8-15.4)
	Fracture	5	14	0.06 (0.02-0.14)	0.19 (0.11-0.31)	54.8 (27.4-77.0)	46.7 (29.6-66.2)	3.1 (1.1-5.7)	8.7 (3.5-15.8)
	Tendon rupture	17	18	0.19 (0.12-0.31)	0.24 (0.15-0.38)	12.6 (4.0-23.8)	20.2 (10.6-31.3)	2.4 (0.7-4.7)	4.8 (2.1-7.9)
	Chronic instability	11	3	0.12 (0.07-0.23)	0.04 (0.01-0.12)	38.8 (3.5-95.5)	57.7 (7.0-110.0)	4.8 (0.8-10.8)	2.3 (0.5-4.7)
	Contusion/vascular	13	18	0.15 (0.09-0.25)	0.24 (0.15-0.38)	14.2 (4.0-32.1)	12.1 (6.7-18.5)	2.1 (0.5-4.2)	2.9 (1.2-5.9)
	Bursitis	3	-	0.03 (0.01-0.11)	-	61.0 (7.0-164.0)	-	2.1 (0.0-6.9)	-
Trunk	Bone stress Injury	9	7	0.10 (0.05-0.20)	0.09 (0.04-0.19)	77.3 (32.8-126.7)	194.0 (100.3-283.6)	7.9 (2.4-14.9)	17.6 (4.5-36.7)
	Muscle Injury	32	34	0.36 (0.26-0.51)	0.44 (0.31-0.62)	23.2 (12.4-36.0)	35.9 (17.5-59.0)	8.4 (3.4-16.0)	15.8 (7.1-28.1)
	Unspecified tissue type	29	18	0.33 (0.23-0.47)	0.23 (0.15-0.37)	26.6 (10.5-47.9)	29.1 (5.9-60.0)	8.7 (2.8-17.8)	6.8 (0.5-26.6)
	Ligament	18	17	0.20 (0.13-0.32)	0.22 (0.14-0.35)	25.9 (10.5-46.1)	33.4 (13.5-59.3)	5.3 (1.2-12.9)	7.4 (1.7-17.0)
Upper Limb	Ligament	5	7	0.06 (0.02-0.14)	0.09 (0.04-0.19)	15.4 (2.8-26.6)	47.3 (16.4-85.4)	0.9 (0.0-2.0)	4.3 (0.4-9.2)
	Fracture	2	10	0.02 (0.01-0.09)	0.13 (0.07-0.24)	3.0 (0.0-6.0)	23.8 (8.2-42.4)	0.1 (0.0-0.2)	3.1 (0.4-7.8)
	Bone stress Injury	-	1	-	0.01 (0.00-0.09)	-	238	-	3.1 (0.0-8.2)
	Bone Contusion	-	2	-	0.03 (0.01-0.10)	-	97.5 (52.0-143.0)	-	2.5 (0.0-9.8)
Medical	Unspecified tissue type	6	1	0.07 (0.03-0.15)	0.01 (0.00-0.09)	69.0 (15.0-145.0)	12	4.7 (0.6-10.8)	0.2 (0.0-0.4)

**Supplementary Table 3** Proportion (95% CI) of medical attention and time-loss injuries by occurrence and mode of onset.

		Medical Attention Injuries			Time-Loss Injuries		
		All	Boys	Girls	All	Boys	Girls
Mode of Onset	Repetitive - Gradual Onset	54.8 (52.7-56.9)	51.3 (48.3-54.3)	57.9 (55.0-60.8)	52.1 (49.7-54.5)	48.8 (45.2-52.3)	55.3 (51.8-58.8)
	Acute - Sudden Onset	23.0 (21.2-24.7)	27.1 (24.2-29.9)	19.2 (16.9-21.6)	25.8 (23.6-28.0)	30.0 (26.6-33.3)	21.8 (19.1-24.6)
	Repetitive - Sudden Onset	17.4 (15.8-19.1)	16.2 (13.9-18.5)	18.6 (16.3-20.9)	18.8 (16.8-20.7)	17.3 (14.7-20.0)	20.2 (17.5-22.9)
	Not Recorded	4.8 (3.9-5.7)	5.4 (4.0-6.9)	4.3 (3.0-5.5)	3.3 (2.5-4.2)	4.0 (2.6-5.4)	2.7 (1.6-3.8)
Occurrence	First Episode	74.9 (73.1-76.8)	77.5 (74.9-80.0)	72.6 (69.9-75.3)	76.2 (74.2-78.3)	77.4 (74.4-80.3)	75.2 (72.4-78.1)
	Recurrence	25.1 (23.3-26.9)	22.5 (19.9-25.2)	27.4 (24.8-30.0)	23.8 (21.7-25.9)	22.6 (19.7-25.6)	24.8 (21.8-27.8)

**Supplementary Table 4** Proportion (95% CI) of medical attention and time-loss injuries by injury movement, activity, and footwear.

		Medical Attention Injuries			Time-Loss Injuries		
		All	Boys	Girls	All	Boys	Girls
Activity	Class	65.4 (63.3-67.5)	63.6 (60.5-66.6)	67.1 (64.4-69.8)	66.2 (63.9-68.6)	64.2 (60.9-67.6)	68.2 (65.1-71.4)
	Other	18.0 (16.3-19.6)	18.6 (16.1-21.1)	17.3 (15.1-19.6)	18.9 (17.0-20.8)	19.6 (16.9-22.3)	18.2 (15.5-20.8)
	Rehearsal	9.1 (7.8-10.4)	9.3 (7.4-11.1)	9.0 (7.3-10.7)	8.6 (7.2-9.9)	9.2 (7.1-11.2)	8.0 (6.2-9.9)
	No associated activity	4.0 (3.2-4.8)	4.2 (3.0-5.5)	3.8 (2.7-5.0)	2.5 (1.8-3.3)	2.5 (1.4-3.5)	2.6 (1.5-3.7)
	Performance	1.8 (1.2-2.4)	2.0 (1.1-2.8)	1.6 (0.8-2.4)	1.9 (1.3-2.6)	2.1 (1.1-3.1)	1.8 (0.9-2.7)
	Gym	1.4 (0.9-1.9)	1.7 (0.9-2.5)	1.1 (0.5-1.7)	1.4 (0.9-2.0)	1.9 (0.9-2.8)	1.1 (0.4-1.7)
	Pilates	0.2 (0.0-0.4)	0.5 (0.1-0.9)	0.0 (0.0-0.0)	0.2 (0.0-0.4)	0.4 (-0.1-0.8)	0.0 (0.0-0.0)
	Rehab	0.1 (0.0-0.3)	0.2 (-0.1-0.5)	0.1 (-0.1-0.3)	0.2 (0.0-0.4)	0.2 (-0.1-0.6)	0.1 (-0.1-0.3)
Footwear	Ballet Flats	56.2 (54.2-58.3)	71.9 (69.0-74.7)	41.8 (38.8-44.8)	57.8 (55.4-60.1)	72.9 (69.8-76.0)	43.4 (40.1-46.8)
	Pointe Shoes	14.4 (12.9-16.0)	0.3 (-0.1-0.7)	27.5 (24.8-30.2)	14.0 (12.4-15.6)	0.2 (-0.1-0.6)	27.2 (24.2-30.2)
	No associated footwear	10.3 (9.0-11.6)	10.0 (8.0-12.1)	10.5 (8.6-12.5)	8.5 (7.1-9.8)	8.0 (6.1-10.0)	8.9 (6.8-10.9)
	Trainers	6.5 (5.5-7.5)	8.0 (6.3-9.7)	5.2 (3.8-6.5)	7.2 (6.0-8.5)	8.7 (6.7-10.7)	5.9 (4.3-7.5)
	Barefoot	5.2 (4.2-6.2)	4.4 (3.1-5.7)	6.0 (4.6-7.4)	5.4 (4.3-6.6)	5.1 (3.5-6.7)	5.8 (4.2-7.3)
	Other	4.3 (3.5-5.2)	4.1 (2.9-5.4)	4.4 (3.2-5.7)	4.6 (3.5-5.6)	4.1 (2.7-5.5)	5.0 (3.4-6.5)
	Soft Blocks	1.8 (1.2-2.4)	0.0 (0.0-0.0)	3.4 (2.3-4.6)	1.5 (0.9-2.1)	0.0 (0.0-0.0)	3.0 (1.7-4.2)
	Character Shoes	1.0 (0.6-1.5)	1.2 (0.5-1.8)	0.9 (0.3-1.5)	0.9 (0.4-1.4)	0.9 (0.2-1.5)	0.9 (0.3-1.6)
Jazz	0.1 (0.0-0.3)	0.1 (-0.1-0.3)	0.2 (-0.1-0.4)	0.1 (-0.1-0.2)	0.1 (-0.1-0.4)	0.0 (0.0-0.0)	
Movement	Jumping/Landing	25.9 (23.9-27.9)	30.8 (27.9-33.7)	21.4 (18.9-23.9)	28.0 (25.9-30.2)	33.3 (30.1-36.5)	23.0 (20.3-25.7)
	Other	25.7 (23.7-27.6)	23.2 (20.7-25.8)	27.9 (25.3-30.6)	24.7 (22.5-26.9)	22.8 (19.9-25.7)	26.4 (23.3-29.6)
	Non-dance related	10.3 (9.0-11.6)	11.7 (9.7-13.8)	9.0 (7.2-10.7)	10.5 (9.0-12.0)	11.4 (9.1-13.6)	9.7 (7.6-11.7)
	Plie/releve	9.7 (8.4-11.0)	12.0 (9.9-14.1)	7.6 (6.0-9.2)	9.4 (8.0-10.8)	11.3 (9.1-13.5)	7.6 (5.8-9.3)
	Pointe work	9.0 (7.8-10.2)	1.0 (0.4-1.6)	16.4 (14.2-18.7)	8.9 (7.5-10.4)	1.0 (0.3-1.7)	16.5 (14.0-19.1)
	No associated movement	5.7 (4.7-6.7)	5.4 (3.9-6.9)	5.7 (4.3-7.1)	4.4 (3.4-5.4)	4.0 (2.6-5.3)	4.8 (3.3-6.3)
	Cannot recall	4.9 (4.0-5.8)	3.8 (2.6-5.1)	5.9 (4.5-7.3)	5.0 (3.9-6.0)	3.8 (2.5-5.2)	6.0 (4.4-7.6)
	Arabesque	4.0 (3.2-4.9)	3.9 (2.7-5.2)	4.1 (2.9-5.3)	4.0 (3.0-5.0)	4.1 (2.7-5.4)	3.9 (2.6-5.2)
	Lifting/Lifted	3.6 (2.8-4.4)	6.4 (4.9-7.9)	1.0 (0.4-1.6)	3.7 (2.7-4.6)	6.6 (4.8-8.3)	0.9 (0.3-1.6)
	Pirouette	1.3 (0.8-1.7)	1.7 (0.9-2.5)	0.9 (0.3-1.5)	1.4 (0.9-2.0)	1.9 (0.9-2.8)	1.1 (0.3-1.8)