

TITLE

Injury Epidemiology in Professional Ballet: A Five-Season Prospective Study of 1596 Medical Attention Injuries and 543 Time-Loss Injuries

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4

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6

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35 **ABSTRACT**

36 **Objectives** To describe the incidence rate, severity, burden, and aetiology of medical attention
37 and time-loss injuries across five consecutive seasons at a professional ballet company.

38 **Methods** Medical attention injuries, time-loss injuries, and dance exposure hours of 123
39 professional ballet dancers (female: $n = 66$, age: 28.0 ± 8.3 y; male: $n = 57$, age: 27.9 ± 8.5 y)
40 were prospectively recorded between the 2015/16 and 2019/20 seasons.

41 **Results** The incidence rate (per 1000 h) of medical attention injury was 3.9 (95% CI: 3.3–4.4)
42 for females and 3.1 (95% CI: 2.6–3.5) for males. The incidence rate (per 1000 h) of time-loss
43 injury was 1.2 (95% CI: 1.0–1.5) for females and 1.1 (95% CI: 0.9–1.3) for males. First Soloists
44 and Principals experienced between 2.0–2.2 additional medical attention injuries per 1000
45 hours and 0.9–1.1 additional time-loss injuries per 1000 hours compared to Apprentices ($p \leq$
46 .025). Further, intra-season differences were observed in medical attention, but not time-loss,
47 injury incidence rates with the highest incidence rates in early (August and September) and
48 late (June) season months. Thirty-five percent of time-loss injuries resulted in over 28 days of
49 modified dance training. A greater percentage of time-loss injuries were classified as overuse
50 (female: 50%; male: 51%) compared to traumatic (female: 40%; male: 41%).

51 **Conclusion** This is the first study to report the incidence rate of medical attention and time-
52 loss injuries in professional ballet dancers. Incidence rates differed across company ranks and
53 months, which may inform targeted injury prevention strategies.

54

55 **Key Words:** Aetiology, Dance Medicine, Injury Surveillance

56 **What are the new findings?**

- 57 • This is the first study to document medical attention incidence rate in professional
58 ballet and identify the burden placed on dance medicine and science teams through
59 non-time-loss musculoskeletal complaints.
- 60 • Time-loss and medical attention incidence rates are highest in First Soloists and
61 Principal dancers of a professional ballet company.
- 62 • Medical attention injury incidence rates are greater during the start and the end of the
63 season compared to mid-season.
- 64 • The severity of time-loss injuries is high, with 35% of all injuries resulting in more
65 than 28 days of modified dance.

66

67 **How might it impact on clinical practice in the future?**

- 68 • Company rank and month of the season offer opportunity to target context-specific
69 risk factors in professional ballet.
- 70 • Lower extremity injuries may be addressed by injury-specific prevention strategies.
71 These strategies may include targeting the ankle in females, and stress fractures of
72 the foot and tibia in males.
- 73 • A high proportion of injuries were overuse in nature. Improved management of the
74 rehearsal and performance schedule may mitigate the burden of these injuries.
- 75 • A common mechanism of injury was jumping and landing activities, which may
76 warrant further attention from dance science and medicine practitioners.

77 **INTRODUCTION**

78 The probability of sustaining a musculoskeletal injury in professional ballet is high, with one
79 article reporting an incidence proportion of 6.8 injuries per dancer over a season.¹ However,
80 differences in time-loss injury are observed across professional ballet companies, with
81 incidence proportions ranging from 1.8–6.8 injuries per dancer.^{1–7} Similarly, differences in
82 incidence rates are observed across studies, with values ranging from 0.6–4.4 injuries per
83 1000 hours of dance exposure.^{1–3,5} The variation in incidence rates may reflect the use of
84 contractual hours when calculating dance exposure (as opposed to individualised class,
85 rehearsal, and performance schedules) or inconsistent injury definitions across studies.^{3–7}

86 No research has described the incidence rate of medical attention injuries in professional
87 ballet. The inclusion of medical attention injuries in epidemiology research has been
88 recommended by Clarsen and Bahr,⁸ and various consensus statements in sport,^{9,10} as it
89 provides a more comprehensive understanding of the medical burden within an organisation.
90 Medical attention injuries, for example, impact performance outcomes in professional cricket.¹¹
91 Although performance outcomes in professional ballet are less tangible than sport, medical
92 attention injury incidence rates may affect casting. Quantifying the incidence rate of medical
93 attention injuries alongside time-loss injuries is therefore an important step towards effective
94 medical management within professional ballet.¹²

95 Most injury epidemiology research in professional ballet is not reported in line with current
96 methodological standards and lacks comprehensive contextual detail.¹³ For example, atypical
97 or no severity scales have been applied, there is inconsistent reporting of injury definitions,
98 diagnoses, and tissue types, and few studies have reported differences in injury incidence
99 rates and aetiology across contextual risk factors.^{1–7} Specific injury risk factors, such as sex,
100 company rank, and intra- and inter-season variation, have been identified in professional
101 ballet.^{14,15} However, only one study has reported statistical differences in injury incidence rates
102 across sex and rank,¹ and although several studies have reported longitudinal injury incidence
103 rates in professional ballet dancers,^{2,3,5–7} none of these conduct statistical analyses.

104 This study aimed to investigate the sex, company rank, and intra- and inter-season differences
105 in medical attention and time-loss injury incidence rates across five consecutive seasons at a
106 professional ballet company. We also aimed to describe the severity, burden, and aetiology of
107 medical attention and time-loss injuries.

108

109 **METHODS**

110 **Study Design and Setting**

111 A prospective cohort study design was employed to investigate medical attention and time-
112 loss injuries in professional ballet dancers. Data were collected across five consecutive
113 seasons at The Royal Ballet, commencing August 8th 2015 and ending March 15th 2020. The
114 2019/20 season ended prematurely due to the COVID-19 global pandemic. All scheduled
115 dance events were completed within the Royal Opera House, London. All dance exposure
116 and medical data were entered into standardised electronic forms (Smartabase version
117 6.5.11, Fusion Sport, Brisbane, Australia). Medical attention and time-loss injuries were
118 evaluated and recorded by in-house Chartered Physiotherapists, typically within 24 hours of
119 the onset. Dance exposure data were prospectively entered by the company Artistic
120 Scheduling Manager. Injury diagnoses were categorised using version 10 of the Orchard
121 Sports Injury Classification System (OSICS).¹⁶ Data entered outside of each season were
122 excluded from the analysis (e.g., tour, summer break). There was no patient or public
123 involvement in the design, conduct, or reporting of this study.

124

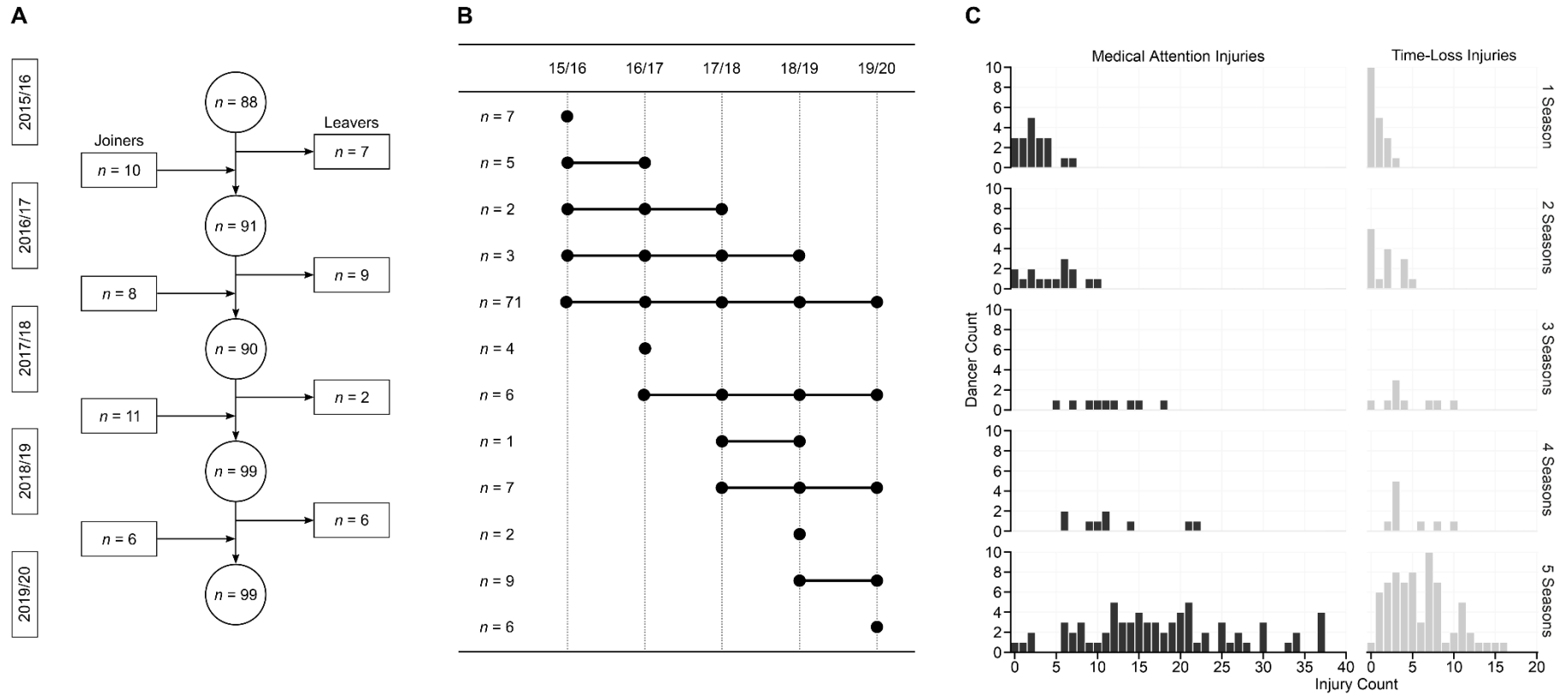
125 **Participants**

126 Of 124 eligible elite professional dancers across the ranks of Apprentice, Artist, First Artist,
127 Soloist, First Soloist, Principal, and Principal Character Artist, 123 were included in this
128 analysis (female: 66, age: 28.0 ± 8.3 y; male: 57, age: 27.9 ± 8.5 y; Figure 1). Dancers who
129 joined or left the company during the study period were included for the duration of their time

130 in the company. Written informed consent was provided by 108 dancers. The remaining 16
131 were contacted, one of which declined consent, and 15 did not respond. A legitimate interest
132 assessment to use the anonymised data for the present analysis was approved by the Data
133 Controller of the Royal Opera House, in line with GDPR (2016) and the UK Data Protection
134 Act (2018). Written support was provided by the Clinical Director of The Royal Ballet. Ethical
135 approval was granted by St Mary's University Ethics Committee in accordance with the
136 Declaration of Helsinki.

ACCEPTED

137



138

139 **Figure 1** A) The number of participants joining, leaving, and present each season. B) The number of participants who were present across

140 specific seasons. C) The count of injuries across participants who were involved in one, two, three, four, or five seasons.

141

142 **Injury Definitions**

143 Medical attention injuries were defined as “any musculoskeletal complaint that required
144 medical attention from a physiotherapist”.⁸ Time-loss injuries were defined as “any injury that
145 prevented a dancer from taking a full part in all dance-related activities that would normally be
146 required of them for a period equal to or greater than 24 hours after the injury was sustained”.¹
147 Time-loss injuries were closed on the date of their final appointment when no follow-up
148 appointment occurred within 28 days. Prevalence was defined as the count of injured dancers
149 divided by the count of included dancers each season. Incidence proportion was defined as
150 the count of injuries divided by the count of included dancers each season. Severity was
151 classified as either minor (1–7 days), moderate (8–28 days), or severe (>28 days).¹⁷ Recurrent
152 injury was defined as “any injury of the same location and type as the index injury, which
153 occurred following a full return to all dance-related activities”.¹⁸ Overuse injuries were defined
154 as “any medical incident that did not have a sudden onset from a discrete event”.¹⁹ The nature
155 of injuries were categorised based on the physiotherapist's interpretation of the primary risk
156 factor, where intrinsic was related to the characteristics of the individual and extrinsic was
157 related to environmental factors.² The term “not classified” was applied when a physiotherapist
158 was unable to distinguish the mechanism, activity, footwear, classification, occurrence, or
159 nature of the injury.

160

161 **Data Analysis**

162 *Dance Exposure*

163 Individualised exposure hours for class, rehearsal, and performance were extracted from the
164 online data management system and calculated for each dancer. Performance casts for each
165 show were inspected manually and cross-referenced with updated casting sheets to account
166 for cast changes. Following a new time-loss injury, prospectively scheduled dance events
167 were removed to accurately calculate dance exposure. Individualised rehearsal and
168 performance exposure hours were grouped by production length (i.e., stand-alone full-length

169 ballets (≥ 90 minutes) or shorter productions that were staged together (< 90 minutes)), and
170 by production type (i.e., new creations or existing works).

171

172 *Medical Attention and Time-Loss Injury*

173 The total medical attention injuries, time-loss injuries, and exposure hours were calculated for
174 each unique dancer and grouped by sex, rank, month, season. The incidence rate (per 1000
175 h) of medical attention and time-loss injuries by production length, production type, anatomical
176 region, and tissue type was calculated by dividing grouped injury count by grouped exposure
177 time. Mean prevalence and incidence proportion of medical attention and time-loss injuries
178 were calculated across the four complete seasons (2015/16–2018/19). Time-loss injury
179 severity was calculated as median days lost, as severity data were not normally distributed.
180 Time-loss injury severity was also calculated as the percentage of injuries classed as minor,
181 moderate, and severe. Injury burden (days lost per 1000 h) and risk matrices (incidence rate
182 \times median severity) were calculated by anatomical region and tissue type. The number and
183 percentage of medical attention and time-loss injuries by activity, mechanism, footwear,
184 occurrence, classification, nature were calculated. For all values, 95% confidence intervals
185 (CI) were calculated. Mechanism of injury fields were concatenated based on movement
186 similarities (e.g., 'Plié' and 'Relevé' became 'Plié/relevé'). The anatomical region and tissue
187 type of injuries were classified using the OSICS diagnosis code.^{13,16} There were five open
188 injury records at the onset of the study. Three dancers were partaking in restricted rehearsals,
189 and were therefore included in the study from the onset. Two were fully removed from normal
190 rehearsal, but returned to rehearsal after 34 and 55 days; these dancers were included in the
191 study following their return.

192

193 **Statistical Analysis**

194 A Poisson generalized linear mixed model was used to calculate incidence rates for all medical
195 attention and time-loss injuries using the *lme4* package.²⁰ The output variable was the number
196 of recorded medical attention and time-loss injuries offset by the log of dance exposure hours
197 for each individual. Sex, rank, sex × rank interaction, month, and season were included as
198 fixed factors. Dancer identity was included as a random factor to account for repeated
199 observations over time. Main effects of the generalized linear mixed model were compared by
200 applying an analysis of variance using the *car* package.²¹ The estimated marginal means
201 (EMM) for each fixed factor were extracted from the model, with 95% CI, and back-
202 transformed to calculate incidence rate per 1000 hours using the *emmeans* package.²² Post-
203 hoc pairwise comparisons, with false discovery rate adjustment, were used to investigate
204 statistically significant main effects.²² Significance was set at $p \leq .025$ to account for two
205 primary outcome measures. All data and statistical analysis were conducted using *R* (version
206 4.0.3, R Foundation for Statistical Computing, Vienna, Austria).

207

208 **RESULTS**

209 **Dance Exposure**

210 There were 20,762 unique scheduled dance events over 5 consecutive seasons. This resulted
211 in 283,453 individual dancer events (class: 99,733; rehearsal: 152,588; performance: 31,132).
212 Scheduled dance events represented a total of 417,693 hours of individual dance exposure
213 (class: 115,772; rehearsal: 209,529; performance: 92,392).

214

215 **Injuries**

216 Table 1 outlines the number of dancers, medical attention injuries, and time-loss injuries over
217 the five seasons. The count of injuries by dancer and number of seasons in the company is
218 presented in Figure 1

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219 **Table 1** Number of dancers, medical attention injuries, and time-loss injuries across five consecutive seasons.

	2015/16			2016/17			2017/18			2018/19			2019/20		
	<i>n</i>	MA	TL	<i>n</i>	MA	TL	<i>n</i>	MA	TL	<i>n</i>	MA	TL	<i>n</i>	MA	TL
All	88	384	88	91	305	112	90	338	138	99	286	130	99	283	75
Female	48	228	53	50	180	60	49	183	75	52	171	70	53	163	42
App.	2	8	1	4	10	4	3	4	2	4	5	1	4	12	2
Artist	11	46	8	11	46	11	10	53	21	14	53	17	12	33	7
F. Artist	9	35	12	10	31	11	11	43	26	10	28	10	12	48	16
Soloist	11	62	21	9	27	10	8	30	7	4	11	3	5	15	3
F. Soloist	7	39	5	7	33	12	6	18	4	9	37	21	9	31	3
Principal	6	36	6	8	31	10	8	30	12	8	29	13	8	16	8
PCA	2	2	0	1	2	2	3	5	3	3	8	5	3	8	3
Male	40	156	35	41	125	52	41	155	63	47	115	60	46	120	33
App.	3	6	0	4	9	2	4	18	9	4	4	1	2	4	0
Artist	7	30	5	7	26	9	7	23	11	10	30	15	11	36	11
F. Artist	5	21	5	6	20	4	6	22	5	7	14	8	7	24	5
Soloist	8	27	7	7	21	13	7	39	14	7	26	15	8	15	4
F. Soloist	7	29	6	5	20	9	4	20	11	5	14	9	5	14	4
Principal	7	42	12	9	27	13	8	23	8	9	20	8	8	23	6
PCA	3	1	0	3	2	2	5	10	5	5	7	4	5	4	3

220 App., Apprentice; F. Artist, First Artist; F. Soloist, First Soloist; PCA, Principal Character Artist; MA, Medical Attention Injury; TL Time-Loss Injury

221

222 **Incidence Rates by Sex and Company Rank**

223 The incidence rates of medical attention and time-loss injuries can be found in Table 2. A
224 significant main effect of company rank was observed on medical attention injury incidence
225 rate ($F_7 = 2209.1$; $p < .001$). Post-hoc pairwise comparisons revealed that medical attention
226 incidence rates were lower in Apprentices (2.5 per 1000 h; 95% CI: 1.9–3.2) than First Soloists
227 (4.5 per 1000 h; 95% CI: 3.7–5.5; $p = .003$), and Principals (4.7 per 1000 h; 95% CI: 3.9–5.8;
228 $p = .002$). No significant main effects of sex ($p = .031$) or sex \times rank ($p = .659$) were observed
229 on medical attention incidence rate.

230 A significant main effect of company rank was observed on time-loss injury incidence rate (F_7
231 $= 1216.2$; $p < .001$). Post-hoc pairwise comparisons revealed that Apprentices (0.6 per 1000
232 h; 95% CI: 0.4–1.0) demonstrated lower time-loss injury incidence rates than First Soloists
233 (1.5 per 1000 h; 95% CI: 1.1–2.1; $p = .015$) and Principals (1.7 per 1000 h; 95% CI: 1.3–2.4;
234 $p = .006$). No significant main effects of sex ($p = .496$) or sex \times rank ($p = .205$) were observed
235 on time-loss injury incidence rate.

237 **Table 2** Estimated marginal mean incidence rate (per 1000 h), prevalence (% injured dancers), incidence proportion (injuries per dancer) of medical attention
 238 and time-loss injuries across five consecutive seasons (95% confidence intervals).

	Medical Attention Injury						Time-Loss Injury					
	Incidence Rate		Prevalence*		Incidence Proportion*		Incidence Rate		Prevalence*		Incidence Proportion*	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
All Ranks	3.9 (3.3–4.4)	3.1 (2.6–3.5)	91.5 (82.0–100.0)	88.4 (78.5–98.2)	3.8 (3.7–4.0)	3.3 (3.0–3.6)	1.2 (1.0–1.5)	1.1 (0.9–1.3)	70.3 (60.8–79.9)	61.4 (51.6–71.3)	1.3 (1.1–1.5)	1.2 (1–1.5)
App.	2.7 (1.9–3.8)	2.3 (1.6–3.3)	79.2 (57.6–100.0)	87.5 (56.7–100.0)	2.3 (2.0–2.6)	2.4 (1.4–3.4)	0.6 (0.3–1.3)	0.6 (0.3–1.1)	45.8 (24.2–67.4)	31.2 (0.4–62.1)	0.6 (0.3–0.9)	0.8 (0.0–1.8)
Artist	3.4 (2.8–4.2)	3.1 (2.5–3.9)	94.2 (79.2–100.0)	93.9 (70.7–100.0)	4.4 (3.8–4.9)	3.6 (3.2–4.0)	0.9 (0.6–1.3)	1.0 (0.7–1.5)	68.1 (53.2–83.1)	73.6 (50.3–96.8)	1.3 (0.7–1.8)	1.3 (0.9–1.6)
F. Artist	4.2 (3.4–5.3)	2.8 (2.1–3.7)	92.2 (73.9–100.0)	88.7 (77.0–100.0)	3.4 (2.8–4.0)	3.3 (3.1–3.5)	1.5 (1.1–2.2)	0.7 (0.4–1.1)	76.4 (58.1–94.7)	50.1 (38.4–61.8)	1.4 (0.8–2.1)	0.9 (0.7–1.1)
Soloist	4.1 (3.2–5.2)	3.2 (2.5–4.2)	85.1 (66.8–100.0)	90.2 (70.1–100.0)	3.8 (3.3–4.3)	3.9 (3.4–4.5)	1.4 (0.9–2.1)	1.3 (0.9–1.9)	68.7 (50.4–87.0)	66.5 (46.4–86.6)	1.2 (0.7–1.7)	1.7 (1.2–2.3)
F. Soloist	5.3 (4.1–6.9)	3.8 (2.8–5.2)	93.7 (72.9–100.0)	100.0 (88.1–100.0)	4.3 (3.6–5.1)	4.0 (3.2–4.7)	1.5 (0.9–2.2)	1.6 (1.0–2.6)	71.0 (50.3–91.8)	82.9 (71.0–94.7)	1.4 (0.6–2.2)	1.8 (1.0–2.6)
Principal	4.8 (3.5–6.4)	4.7 (3.6–6.3)	100.0 (91.6–100.0)	96.9 (87.3–100.0)	4.3 (4.0–4.6)	3.5 (3.1–3.9)	1.7 (1.1–2.6)	1.8 (1.2–2.8)	76.0 (67.6–84.5)	66.8 (57.2–76.4)	1.3 (1.1–1.6)	1.3 (0.9–1.6)
PCA	3.2 (1.8–5.5)	2.1 (1.3–3.5)	87.5 (46.4–100.0)	45.0 (18.1–71.9)	1.8 (1.0–2.7)	1.1 (0.7–1.5)	1.6 (0.7–3.6)	1.1 (0.5–2.1)	58.3 (17.2–99.4)	36.7 (9.7–63.6)	1.2 (0.3–2.0)	0.6 (0.2–1.0)

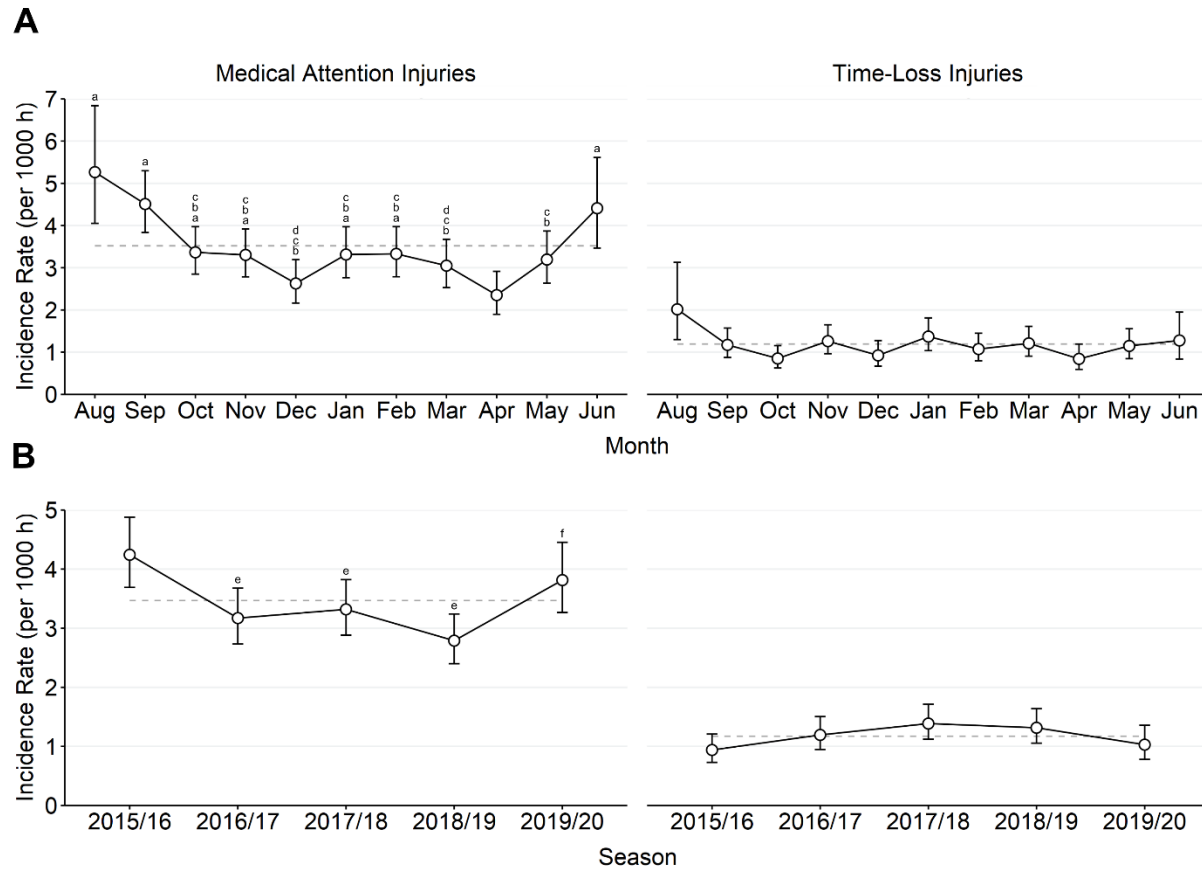
239 App., Apprentice; F. Artist, First Artist; F. Soloist, First Soloist; PCA, Principal Character Artist; MA, Medical Attention Injury; TL, Time-Loss Injury; * calculated based on four seasons of data due to the premature end of
 240 the 2019/20 season.

242 **Intra- and Inter-Season Incidence Rates**

243 A significant main effect of month ($F_{10} = 59.7$; $p < .001$) and season ($F_4 = 31.9$; $p < .001$) was
244 observed on medical attention injury incidence rate (per 1000 h); post-hoc pairwise
245 comparisons are illustrated in Figure 2. No main effects of month ($p = .029$) or season ($p =$
246 $.042$) were observed on time-loss injury incidence rate.

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248 **Figure 2** A) Intra-season medical attention and time-loss injury incidence rate with 95% CI. ^aSignificantly different to April ($p < .025$); ^bSignificantly
 249 different to August ($p < 0.025$); ^cSignificantly different to September ($p < .025$); ^dSignificantly different to June ($p < .025$). B) Inter-season medical
 250 attention and time-loss injury incidence rate with 95% CI. ^eSignificantly different to the 2015/16 season ($p < .025$); ^fSignificantly different to the
 251 2018/19 season ($p < .025$).

252 **Incidence Rates by Production Type**

253 Medical attention and time-loss injury incidence rates were 6.0 (95% CI: 5.5–6.6) and 2.0 (95%
254 CI: 1.7–2.3) per 1000 hours for mixed bills and 3.7 (95% CI: 3.4–4.0) and 1.2 (95% CI: 1.1–
255 1.4) per 1000 hours for full-length productions, respectively. Medical attention and time-loss
256 injury incidence rates were 4.2 (95% CI: 3.6–4.8) and 1.5 (95% CI: 1.2–1.9) per 1000 hours
257 for new creations and 4.3 (95% CI: 4.0–4.6) and 1.4 (95% CI: 1.3–1.6) per 1000 hours for
258 existing productions, respectively.

259

260 **Prevalence and Incidence Proportion**

261 Table 2 outlines the mean prevalence and incidence proportion of medical attention and time-
262 loss injuries across the four complete seasons (2015/16–2018/19).

263

264 **Severity, Burden, and Aetiology of Time-loss Injuries**

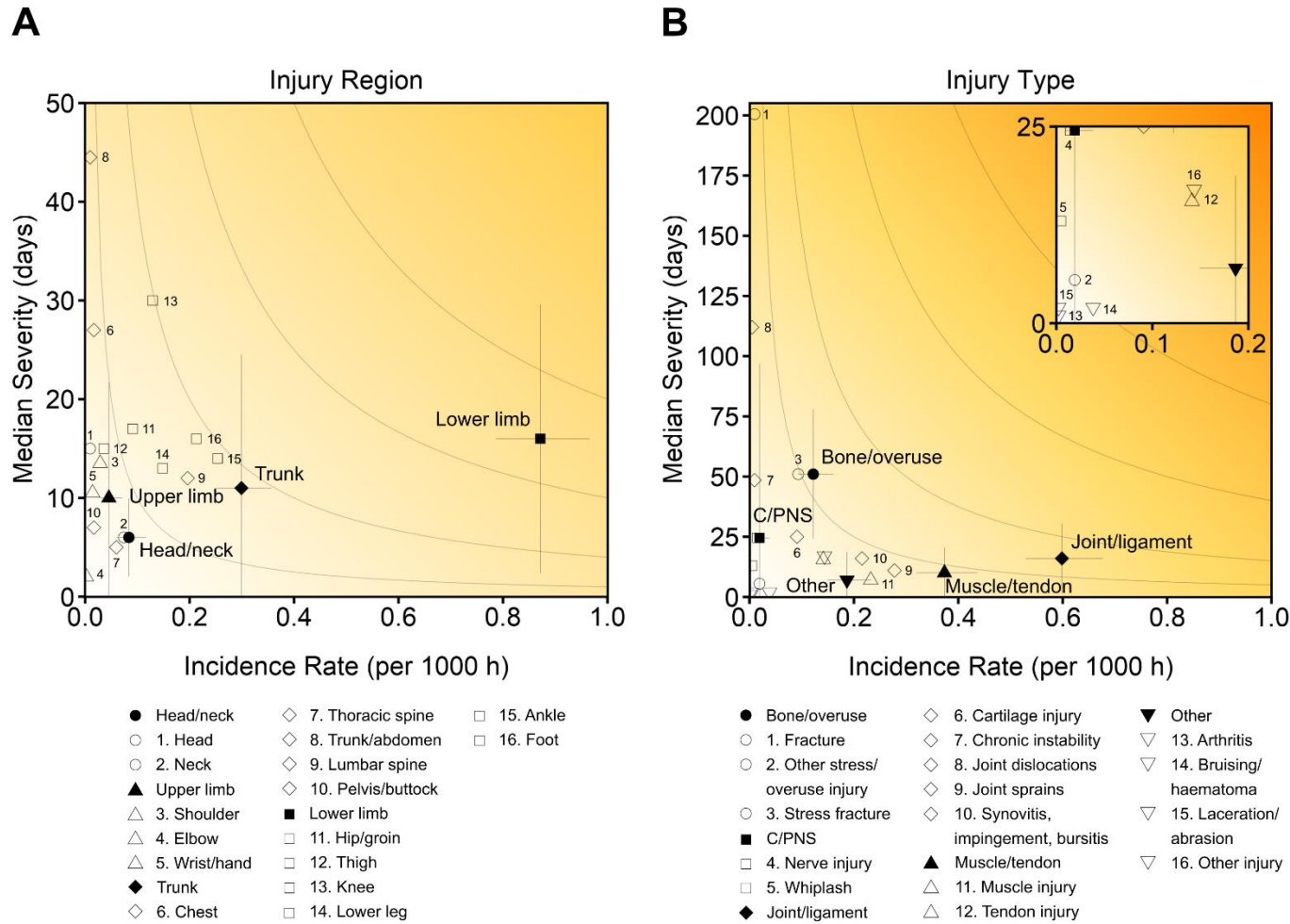
265 Table 3 presents the median severity and percentage of time-loss injuries by severity scale.
266 Figure 3 illustrates the time-loss injury burden by anatomical region and tissue type. The
267 incidence rate, severity, and burden of time-loss injuries by anatomical region and tissue type
268 are presented in Supplementary Table 1. Supplementary Table 2 outlines the percentage of
269 medical attention and time-loss injuries by classification, occurrence, and nature. The
270 percentage of medical attention and time-loss injuries by mechanism, activity, and footwear is
271 provided in Supplementary Table 3.

272 **Table 3** Median severity of time-loss injuries and percentage of time-loss injuries by severity
 273 scale (95% confidence intervals)

	Female	Male
Median Severity (days)		
All Ranks	14 (10–16)	14 (7–16)
App.	17 (2–123)	22 (10–39)
Artist	10 (3–16)	12 (6–31)
F. Artist	24 (11–30)	14 (3–18)
Soloist	9 (3–33)	12 (3–18)
F. Soloist	18 (8–25)	21 (8–41)
Principal	9 (4–16)	6 (2–27)
PCA	10 (1–14)	14 (6–25)
Severity Scale (%)		
Mild (1–7 days)	39.9 (24.7–55.1)	41.5 (26.5–56.5)
Moderate (8–28)	25.2 (8.2–42.1)	23.7 (6.5–40.8)
Severe (>28)	34.9 (19.1–50.7)	34.9 (19.0–50.7)

274 App., Apprentice; F. Artist, First Artist; F. Soloist, First Soloist; PCA, Principal Character Artist

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275

276 **Figure 3** A) Time-loss injury burden (incidence rate x median severity) by anatomical region with 95% CI. B) Time-loss injury burden (incidence
 277 rate x median severity) by tissue type with 95% CI. The top right corner of plot B depicts a zoomed-in subsection of the main plot identifiable by
 278 the axis. It should be noted that the y-axis scale across plot A and B are not equal.

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279 **Supplementary Table 1** Number of injuries, incidence rate (injuries per 1000 h), severity
 280 (median days lost), and burden (days lost per 1000 h) of time-loss injuries by injury region
 281 and tissue type (95% confidence intervals).

	<i>n</i> injuries		Incidence Rates		Severity		Burden	
	Female	Male	Female	Male	Female	Male	Female	Male
Head	2	2	0.01 (0.00–0.04)	0.01 (0.00–0.04)	15 (0–33)	15 (0–40)	0 (0–1)	0 (0–1)
Neck	17	14	0.08 (0.05–0.12)	0.07 (0.04–0.12)	4 (0–9)	6 (0–13)	1 (0–1)	1 (0–1)
Shoulder	3	9	0.01 (0.00–0.04)	0.05 (0.02–0.09)	7 (0–48)	17 (2–32)	0 (0–1)	1 (1–2)
Elbow	1	-	0.00 (0.00–0.03)	-	2 (0–0)	-	0 (0–0)	-
Wrist/hand	1	5	0.00 (0.00–0.03)	0.03 (0.01–0.06)	14 (0–0)	7 (0–33)	0 (0–0)	0 (0–1)
Chest	4	3	0.02 (0.01–0.05)	0.02 (0.00–0.05)	18 (0–106)	27 (0–76)	1 (0–2)	1 (0–2)
Thoracic spine	10	15	0.04 (0.02–0.08)	0.08 (0.05–0.13)	10 (0–24)	4 (0–32)	1 (0–2)	2 (1–3)
Trunk/abdomen	4	-	0.02 (0.01–0.05)	-	44 (0–101)	-	1 (0–3)	-
Lumbar spine	48	34	0.22 (0.16–0.29)	0.17 (0.12–0.24)	16 (2–31)	5 (0–37)	6 (5–9)	6 (4–9)
Joint sprains	5	5	0.02 (0.01–0.05)	0.03 (0.01–0.06)	39 (0–100)	6 (0–39)	1 (1–4)	1 (0–1)
Cartilage injury	11	5	0.05 (0.03–0.09)	0.03 (0.01–0.06)	20 (0–51)	27 (8–46)	2 (1–3)	1 (0–1)
Synovitis, impingement, bursitis	14	11	0.06 (0.04–0.11)	0.06 (0.03–0.10)	12 (3–21)	2 (0–32)	1 (1–2)	1 (1–2)
Muscle injury	10	8	0.04 (0.02–0.08)	0.04 (0.02–0.08)	12 (0–34)	2 (0–21)	1 (1–2)	1 (0–1)
Pelvis/buttock	6	1	0.03 (0.01–0.06)	0.01 (0.00–0.04)	9 (0–59)	1 (0–0)	1 (0–2)	0 (0–0)
Hip/groin	26	12	0.12 (0.08–0.17)	0.06 (0.03–0.11)	23 (0–56)	10 (0–24)	6 (4–8)	1 (1–2)
Synovitis, impingement, bursitis	8	4	0.04 (0.02–0.07)	0.02 (0.01–0.05)	27 (0–114)	15 (2–28)	2 (1–5)	0 (0–1)
Other injury	7	3	0.03 (0.01–0.07)	0.02 (0.00–0.05)	33 (0–92)	52 (21–83)	2 (1–4)	1 (0–2)
Thigh	5	10	0.02 (0.01–0.05)	0.05 (0.03–0.10)	6 (0–19)	16 (0–38)	0 (0–1)	1 (1–2)
Knee	25	29	0.11 (0.08–0.17)	0.15 (0.10–0.21)	21 (0–64)	32 (0–72)	7 (5–11)	9 (6–13)
Joint sprains	5	3	0.02 (0.01–0.05)	0.02 (0.00–0.05)	119 (0–256)	17 (0–308)	3 (1–6)	2 (1–8)
Tendon injury	2	12	0.01 (0.00–0.04)	0.06 (0.03–0.11)	80 (55–105)	25 (0–64)	1 (0–3)	3 (1–5)
Lower leg	32	30	0.14 (0.10–0.20)	0.15 (0.11–0.22)	7 (0–25)	18 (0–48)	4 (3–5)	7 (5–10)
Stress fracture	8	7	0.04 (0.02–0.07)	0.04 (0.02–0.08)	60 (23–96)	71 (0–143)	2 (1–4)	3 (2–7)
Muscle injury	16	19	0.07 (0.04–0.12)	0.10 (0.06–0.15)	7 (0–32)	14 (6–22)	2 (1–2)	2 (1–2)
Ankle	66	40	0.30 (0.23–0.38)	0.21 (0.15–0.28)	14 (0–42)	12 (0–35)	13 (10–17)	8 (6–11)
Joint sprains	21	6	0.09 (0.06–0.14)	0.03 (0.01–0.07)	14 (0–38)	14 (0–58)	3 (2–5)	1 (1–3)
Synovitis, impingement, bursitis	20	14	0.09 (0.06–0.14)	0.07 (0.04–0.12)	22 (0–85)	10 (0–46)	5 (3–8)	3 (2–4)
Tendon injury	19	14	0.09 (0.05–0.13)	0.07 (0.04–0.12)	7 (0–43)	11 (0–36)	3 (2–5)	2 (1–3)
Foot	50	39	0.22 (0.17–0.30)	0.20 (0.15–0.27)	16 (0–34)	16 (0–45)	8 (6–11)	9 (7–13)
Stress fracture	13	9	0.06 (0.03–0.10)	0.05 (0.02–0.09)	46 (16–76)	46 (0–110)	3 (2–5)	3 (2–7)
Joint sprains	19	8	0.09 (0.05–0.13)	0.04 (0.02–0.08)	14 (1–27)	27 (5–49)	2 (1–3)	1 (1–3)

282

283 **Supplementary Table 2** Number and percentage of medical attention and time-loss injuries by classification, occurrence, and nature (95%
 284 confidence intervals).

	Medical Attention Injury				Time-Loss Injury			
	<i>n</i> injuries		Percentage		<i>n</i> injuries		Percentage	
	Female	Male	Female	Male	Female	Male	Female	Male
Classification								
Overuse	637	434	68.9 (65.9–71.8)	64.7 (61.1–68.3)	151	125	50.3 (44.7–56.0)	51.4 (45.2–57.7)
Traumatic	223	185	24.1 (21.4–26.9)	27.6 (24.2–31.0)	121	99	40.3 (34.8–45.9)	40.7 (34.6–46.9)
Not classified	65	52	7.0 (5.4–8.7)	7.7 (5.7–9.8)	28	19	9.3 (6.0–12.6)	7.8 (4.4–11.2)
Occurrence								
First episode	597	427	64.5 (61.5–67.6)	63.6 (60.0–67.3)	213	162	71.0 (65.9–76.1)	66.7 (60.7–72.6)
Recurrence	321	237	34.7 (31.6–37.8)	35.3 (31.7–38.9)	85	79	28.3 (23.2–33.4)	32.5 (26.6–38.4)
Not classified	7	7	0.8 (0.2–1.3)	1.0 (0.3–1.8)	2	2	0.7 (0.0–1.6)	0.8 (0.0–2.0)
Nature								
Extrinsic	249	174	26.9 (24.1–29.8)	25.9 (22.6–29.2)	99	80	33.0 (27.7–38.3)	32.9 (27.0–38.8)
Intrinsic	670	493	72.4 (69.6–75.3)	73.5 (70.1–76.8)	199	162	66.3 (61.0–71.7)	66.7 (60.7–72.6)
Not classified	6	4	0.6 (0.1–1.2)	0.6 (0.0–1.2)	2	1	0.7 (0.0–1.6)	0.4 (0.0–1.2)

285

286 **Supplementary Table 3** Number and percentage of medical attention and time-loss injuries by injury mechanism, activity, and footwear (95%
287 confidence intervals).

	Medical Attention Injury				Time-Loss Injuries				288
	<i>n</i> injuries		Percentage		<i>n</i> injuries		Percentage		
	Female	Male	Female	Male	Female	Male	Female	Male	
Mechanism									
Jumping/landing	200	206	21.6 (19.0–24.3)	30.7 (27.2–34.2)	81	92	27.0 (22.0–32.0)	37.9 (31.8–44.0)	
<i>Pointe</i>	132	3	14.3 (12.0–16.5)	0.4 (0.0–1.0)	37	0	12.3 (8.6–16.1)	0.0 (0.0–0.0)	
<i>Plié/relevé</i>	66	64	7.1 (5.5–8.8)	9.5 (7.3–11.8)	21	21	7.0 (4.1–9.9)	8.6 (5.1–12.2)	
Lifting/lifted	31	98	3.4 (2.2–4.5)	14.6 (11.9–17.3)	11	29	3.7 (1.5–5.8)	11.9 (7.9–16.0)	
<i>Arabesque</i>	65	20	7.0 (5.4–8.7)	3.0 (1.7–4.3)	15	7	5.0 (2.5–7.5)	2.9 (0.8–5.0)	
<i>Pirouette</i>	11	20	1.2 (0.5–1.9)	3.0 (1.7–4.3)	2	8	0.7 (0.0–1.6)	3.3 (1.0–5.5)	
Non-dance related	60	36	6.5 (4.9–8.1)	5.4 (3.7–7.1)	25	14	8.3 (5.2–11.5)	5.8 (2.8–8.7)	
Cannot recall	89	60	9.6 (7.7–11.5)	8.9 (6.8–11.1)	33	18	11.0 (7.5–14.5)	7.4 (4.1–10.7)	
Not classified	271	164	29.3 (26.4–32.2)	24.4 (21.2–27.7)	75	54	25.0 (20.1–29.9)	22.2 (17.0–27.4)	
Activity									
Rehearsal	478	307	51.7 (48.5–54.9)	45.8 (42.0–49.5)	149	100	49.7 (44.0–55.3)	41.2 (35.0–47.3)	
Performance	206	110	22.3 (19.6–25.0)	16.4 (13.6–19.2)	66	45	22.0 (17.3–26.7)	18.5 (13.6–23.4)	
Class	104	140	11.2 (9.2–13.3)	20.9 (17.8–23.9)	34	49	11.3 (7.7–14.9)	20.2 (15.1–25.2)	
Gym	8	21	0.9 (0.3–1.5)	3.1 (1.8–4.4)	1	7	0.3 (0.0–1.0)	2.9 (0.8–5.0)	
Pilates/Gyrotonics®	3	1	0.3 (0.0–0.7)	0.1 (0.0–0.4)	1	0	0.3 (0.0–1.0)	0.0 (0.0–0.0)	
Rehab	-	3	-	0.4 (0.0–1.0)	-	2	-	0.8 (0.0–2.0)	
Non-dance related	56	39	6.1 (4.5–7.6)	5.8 (4.0–7.6)	25	20	8.3 (5.2–11.5)	8.2 (4.8–11.7)	
Not classified	70	50	7.6 (5.9–9.3)	7.5 (5.5–9.4)	24	20	8.0 (4.9–11.1)	8.2 (4.8–11.7)	
Footwear									
Ballet Flats	106	533	11.5 (9.4–13.5)	79.4 (76.4–82.5)	34	187	11.3 (7.7–14.9)	77.0 (71.7–82.2)	
<i>Pointe</i> Shoes	658	7	71.1 (68.2–74.1)	1.0 (0.3–1.8)	210	2	70.0 (64.8–75.2)	0.8 (0.0–2.0)	
Character Shoes	30	22	3.2 (2.1–4.4)	3.3 (1.9–4.6)	9	10	3.0 (1.1–4.9)	4.1 (1.6–6.6)	
Barefoot	8	9	0.9 (0.3–1.5)	1.3 (0.5–2.2)	3	5	1.0 (0.0–2.1)	2.1 (0.3–3.8)	
Trainers	20	22	2.2 (1.2–3.1)	3.3 (1.9–4.6)	6	7	2.0 (0.4–3.6)	2.9 (0.8–5.0)	
Not classified	103	78	11.1 (9.1–13.2)	11.6 (9.2–14.0)	38	32	12.7 (8.9–16.4)	13.2 (8.9–17.4)	

289 **DISCUSSION**

290 This is the first study to report longitudinal medical attention incidence rates in professional
291 ballet. Differences in medical attention incidence rates were observed across company rank,
292 with First Soloists and Principals demonstrating an almost two-fold greater incidence rate
293 compared to Apprentices. The time-loss injury incidence rate observed in this study is in line
294 with published literature,¹⁻⁵ however, the severity of time-loss injuries was greater, with 35% of
295 injuries resulting in more than 28 days of modified dance activity.^{1,4} Consistent with previous
296 research in professional ballet, most time-loss injuries were classified as overuse.¹⁻³ The most
297 common mechanism of time-loss injury was jumping and landing activities, however, a similar
298 number of injuries did not have a clear mechanism of injury.

299

300 **Incidence Rate**

301 No studies in professional ballet have previously reported medical attention injury incidence
302 rates, however, the values observed in the present study are similar to those seen in
303 professional contemporary dance.²³ The incidence rate of time-loss injuries in this study falls
304 within ranges that are reported in professional ballet,^{1-3,5} is comparable to cricket²⁴ and
305 contemporary dance,²³ greater than that of modern dance,^{25,26} but lower than rugby union or
306 ice hockey.^{27,28} In the absence of a direct comparison of activity profiles across dance genres,
307 it is speculative to discuss differences in incidence rates between them. While time-motion
308 analysis has revealed reduced activity demands in contemporary dance compared to ballet,²⁹
309 no such comparisons have been made between modern dance and ballet. Compared to
310 invasion sports, however, the lower incidence rates observed in the present study may be due
311 to fewer traumatic contact events during dance performance versus match play; incidence
312 rates during rugby training, for example, are similar to those observed in the present study.³⁰

313 First Soloists and Principals sustained between 2.0–2.2 additional medical attention injuries
314 per 1000 hours and 0.9–1.1 additional time-loss injuries per 1000 hours compared to

315 Apprentices. The transition period from pre-professional training into a professional ballet
316 company has been previously identified as a potential risk factor for injury.³¹ Our findings,
317 however, demonstrate that Apprentices are at the lowest risk of injury compared to other
318 company members. It is plausible that Apprentices may avoid disclosing injuries when trying
319 to establish themselves within a new company. However, injury incidence rates are likely
320 higher in senior ranking dancers due to the casting of more technically and physically
321 demanding roles within these ranks compared to junior dancers.^{14,32} The casting of roles and
322 distribution of workload across company ranks is, however, at the discretion of the Artistic
323 Director, and the utilisation of junior dancers may differ across ballet companies.

324 Between 2.0–2.8 additional medical attention injuries per 1000 hours were observed at the
325 start (August and September) and end (June) of the season compared to mid-season. Higher
326 medical attention injury incidence rates at the start of a season may suggest strategies are
327 warranted for returning dancers, such as pre-season training or a more gradual reintroduction
328 to ballet. The higher incidence rates observed at the end of the season may be influenced by
329 dancers who have been managing medical issues during the season.¹⁵ However, it should be
330 noted that mixed bill productions, which demonstrate an additional 2.3 medical attention
331 injuries and 0.8 and time-loss injuries per 1000 hours compared to full-length stand-alone
332 productions, are more common later in the season. While inter-season differences in medical
333 attention injury incidence rates were seen, no clear pattern was observed across the five
334 seasons, potentially due to inter-season variation in repertoire. Understanding the incidence
335 rates associated with production types may be beneficial to Artistic Directors and medical staff
336 when planning and periodising a season.

337

338 **Severity**

339 The severity of time-loss injuries within the present study is almost two-fold greater than the
340 severity previously published in professional ballet,¹ similar to football,³³ and lower than rugby
341 union,^{28,30} and volleyball.³⁴ Professional ballet has previously been described as a culture that

342 normalises pain,^{15,35,36} which may result in dancers not reporting medical issues and dancing
343 through discomfort. We observed that 56% of all days lost to time-loss injury were classified
344 as 'restricted' as opposed to 'off', suggesting that dancers may still have been participating in
345 some form of dance activity while injured.

346

347 **Time-Loss Injury Aetiology**

348 Between 65–69% of medical attention and 50–51% of time-loss injuries were insidious and a
349 consequence of overuse. The greater proportion of overuse injuries observed under the
350 medical attention definition suggests that overuse injuries may be underestimated using a
351 time-loss injury definition alone.³⁷ Previous studies in professional ballet have reported that a
352 high proportion of time-loss injuries were overuse;^{1,3} our results align with this, although it
353 should be noted that inter-season variation was observed. The high frequency of overuse
354 injuries observed may also be associated with the large exposure times; the scheduled
355 exposure hours in professional dance is greater than that reported in sport.^{14,25,34} The primary
356 mechanism of time-loss injury was jumping and landing, in line with previous research.¹ We
357 also observed a greater percentage of time-loss injuries associated with jumping and landing
358 in male dancers compared to females, however, the absolute number of injuries attributed to
359 this mechanism was similar across sexes. In contrast to sport, where injuries principally occur
360 in competition,^{27,28,33} more than two-thirds of all time-loss injuries observed in the present study
361 were attributed to training as opposed to performance. The higher proportion of training-
362 related injuries is likely due to the 3.5 fold greater exposure hours observed during class and
363 rehearsal compared to performance. Most injuries were classified as first episodes rather than
364 recurrences, suggesting that time-loss injury rehabilitation is largely successful. The majority
365 of injuries were classified as intrinsic, and may therefore provide an opportunity for training
366 interventions or appropriate load management.^{38–41}

367

368 **Anatomical Region and Tissue Type**

369 Previous research in professional ballet has reported injury region and tissue type
370 inconsistently, making comparison with these studies challenging.^{1,3-5} Generally, injuries to
371 the distal lower extremity and joint/ligament tissue types demonstrated the greatest burden
372 across all dancers. Ankle injuries pertaining to synovitis, impingement, and bursitis exhibited
373 the greatest burden in female dancers, however, tendon and joint pathologies of the ankle
374 were similar. *Pointe* positions, typically adopted by female dancers, require extreme range of
375 motion of the ankle and may have negative consequences for musculoskeletal joint health. In
376 male dancers, stress fractures to the foot and lower leg demonstrated the greatest burden.
377 Nineteen of the twenty-one stress fractures recorded in males were attributed to jumping and
378 landing activities and eighteen were non-traumatic. Medical management strategies
379 addressing the joint and ligament injuries to the ankle in females and stress fractures to the
380 foot and lower leg in males are warranted in this population.⁴³

381

382 **Strengths and Limitations**

383 The strengths of this study include the prospective data entry from Chartered Physiotherapists,
384 use of individualised prospectively entered dance exposure data, reporting of data through
385 standardised entry forms, duration of data collection, consistency of the observed cohort, and
386 the elite performance standard of the observed cohort.

387 Several limitations should be noted. Performance exposure was potentially inflated where
388 individuals were allotted the total duration of a performance rather than on-stage time. Further,
389 no register of attendance was taken for class or rehearsal, with attendance assumed but not
390 verified. The authors, however, believe that it would be unusual for dancers to not attend
391 scheduled dance events.

392 Multiple Chartered Physiotherapists were employed over the study period which may affect
393 the uniformity of how injury data were gathered. It should be emphasised, however, that all

394 physiotherapists used the same standardised entry forms and classification tools. The high
395 frequency of overuse injuries may result in the misclassification of injury mechanism due to
396 no traumatic inciting event.¹³ Data describing injury region and tissue type were only presented
397 for time-loss injuries, which may not represent all medical attention injuries. Four injuries were
398 rehabilitating at the point of analysis and were subsequently removed from severity
399 calculations. Finally, one ballet company was investigated and, thus, caution should be taken
400 when generalising findings to other companies based on the season structure, hierarchy of
401 company ranks, and casting of featured roles across company ranks.

402

403 **Conclusion**

404 This is the first prospective cohort study to investigate the longitudinal medical attention and
405 time-loss injury incidence rates in a professional ballet company. First Soloists and Principals
406 experienced medical attention and time-loss injury incidence rates roughly two-fold that of
407 Apprentices. Although no differences in intra-season time-loss injury incidence rates were
408 observed, 2.0–2.8 additional medical attentional injuries per 1000 hours were recorded at the
409 beginning and end of the season compared to mid-season. The majority of injuries were
410 overuse in nature and ~60% of all injuries occurred during training (rehearsal and class)
411 compared to performance. The most common mechanism of time-loss injury was jumping and
412 landing actions, however, many injuries were unclassified. Lower extremity injuries and
413 injuries pertaining to joint and ligament tissue types caused the greatest burden. The results
414 of this study may inform the design of targeted injury prevention interventions focusing on
415 senior company ranks, intra-season variation, and jumping and landing activities in
416 professional ballet dancers.

417 **DISCLOSURE**

418

419 **Competing Interests** None of the authors has any conflicts of interest to declare.

420 **Contributorship** GR implemented the electronic data management system. All authors
421 contributed to the conception and design of the work. AM, JS, and SW completed the data
422 analysis. AM wrote the first draft and prepared all revisions. All authors reviewed and edited
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435 **Data Sharing** No data are available

436 **Patient Involvement** There was no patient or public involvement in this study

437

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