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**The risk of injuries in Paralympic Athletics  
differs by impairment and event discipline:  
A prospective cohort study at the London 2012 Paralympic Games**

25 **ABSTRACT:**

26 **Background:** The injury incidence rates and factors associated with injury in the sport of  
27 Paralympic athletics (track and field) have not been comprehensively and prospectively studied.

28 **Purpose:** To determine injury incidence rates, characteristics of injury, and associated factors in  
29 the sport of athletics at the London 2012 Paralympic Games.

30 **Study Design:** Prospective, cohort study

31 **Methods:** Nine hundred seventy-seven athletes competing in the sport of athletics were followed  
32 over a total 10-day competition period of the Games. Daily injury data was obtained via two  
33 databases: 1) a custom built, web-based injury and illness surveillance system (WEB-IISS),  
34 populated by team medical personnel, and 2) the organizing committee database, populated by  
35 medical providers in the medical stations operated by the Organizing Committee. Athlete  
36 impairment category and event discipline were obtained via the International Paralympic  
37 Committee athlete database. Injury incidence rates (injuries per 1000 athlete-days) by  
38 impairment type, event discipline, sex, and age were examined.

39 **Results:** The overall injury incidence rate was 22.1 injuries per 1000 athlete-days (95% CI;19.5 -  
40 24.7). In track disciplines, ambulant athletes with cerebral palsy experienced a lower incidence  
41 of injury (IR=10.2, 95% CI; 4.2 - 16.2) when compared to ambulant athletes from other  
42 impairment categories. Athletes in seated throws experienced a higher incidence of injury  
43 (IR=23.7, 95% CI; 17.5 – 30.0), when compared to athletes in wheelchair racing (IR=10.6, 95%  
44 CI; 5.5 - 15.6). In both track and field disciplines, the majority of injuries did not result in time-  
45 loss from competition or training. Ambulant athletes experienced the greatest incidence of  
46 injuries to the thigh (16.4% of all injuries, IR=4.0), observed predominantly in track athletes.

47 Wheelchair or seated athletes experienced the greatest incidence of injuries to the  
48 shoulder/clavicle (19.3% of all injuries, IR=3.4), observed predominantly in field athletes.

49 **Conclusion:** This is the first prospective cohort study examining injury incidence rate and  
50 associated factors in the sport of athletics at the Paralympic Games. Injury patterns are specific to  
51 the event discipline and athlete impairment type. The majority of injuries occur to the thigh  
52 (ambulant athletes) or shoulder/clavicle (wheelchair or seated athletes), and are not time-loss.

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65 **What is known about the subject:**

- 66 • There have been few prior publications detailing the types and rates of injuries in the  
67 sport of Paralympic athletics. Athletics is the largest sport on the Paralympic program,  
68 and was shown to have the 6<sup>th</sup> highest injury incidence rate of all Paralympic sports at the  
69 London 2012 Paralympic Games.<sup>21</sup>

70 **What this study adds to existing knowledge:**

- 71 • Injury incidence rates in the London 2012 Paralympic Games were similar when  
72 comparing track versus field disciplines in Paralympic athletics. Ambulant athletes with  
73 cerebral palsy experienced a lower incidence of injury in track disciplines when  
74 compared to other ambulant athletes. Wheelchair/seated athletes competing in seated  
75 throws (field) experienced a higher incidence of injury than those competing in  
76 wheelchair racing (track). For both ambulant and wheelchair/seated athletes, the majority  
77 of injuries occurred in competition and did not result in time-loss from competition or  
78 training.
- 79 • Sport medicine clinicians caring for athletes in Paralympic athletics should anticipate an  
80 injury pattern that is impairment and discipline specific, with wheelchair/seated athletes  
81 experiencing predominantly injuries to the shoulder/clavicle, and ambulatory athletes  
82 experiencing injuries to the thigh and lower extremity.
- 83 • This data can be utilized to form the basis for planning prevention strategies to reduce the  
84 risk of injury, which will vary amongst different profiles of Paralympic athletes.

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87 **INTRODUCTION:**

88 In recent years, injury surveillance in the sport of athletics (track and field) has grown to become  
89 an important area of research in sports medicine and injury prevention<sup>6,9,19,22</sup>. The reason for this  
90 is twofold. First, physicians responsible for the care of athletes at major international  
91 competitions benefit from an increased awareness of the incidence and types of injuries that their  
92 athletes might sustain. Second, through the identification of risk factors associated with common  
93 injuries, prevention strategies may be developed and monitored for effectiveness over time<sup>23</sup>.

94 The sport of athletics involves the largest and most diverse number of athletes participating at the  
95 Paralympic Games. At the London 2012 Paralympic Games, 26% of the total 4302 athletes  
96 competed in athletics. As defined by International Paralympic Committee (IPC) rules<sup>11</sup>,  
97 Paralympic athletics is inclusive of both track and field events, catering to a number of different  
98 impairment categories. This includes athletes with amputation, spinal cord injury, cerebral palsy,  
99 visual impairment, and intellectual impairment, among others.

100 Several large injury surveillance studies with focus on the sport of athletics have been carried out  
101 in major international and national competitions<sup>1,2,3,10,12,22</sup> with increasing focus on the benefits  
102 of injury prevention programs. In studies carried out at the International Association of Athletics  
103 Federations (IAAF) World Athletics Championships in 2007, 2009, and 2011, the injury  
104 incidence proportion ranged from 97.0 to 153.4 injuries per 1000 registered athletes<sup>1,2,3</sup>. At the  
105 London 2012 Paralympic Games, the first comprehensive injury and illness surveillance study  
106 was conducted with a focus on athletes in Paralympic summer sports<sup>8</sup>. When taking into account  
107 all sports, this revealed an overall injury incidence rate (IR) of 12.7 injuries per 1000 athlete-  
108 days. Athletics (track and field) was shown to have the 6<sup>th</sup> highest injury IR<sup>21</sup>. Prior studies  
109 focused on injury in the sport of Paralympic athletics have been limited by small sample sizes,

110 limited athlete exposure data, and the predominant use of retrospective or cross-sectional surveys  
111 with data reflecting athletes' self-report of injury, thus being subject to recall bias<sup>5,7,15,16,18,20</sup>.

112 The aim of the study therefore was to report further detail regarding the injury incidence rate and  
113 characteristics of injury in the sport of athletics at the London 2012 Paralympic Games.

114 Additionally, we sought to determine if potential risk factors such as sex, age, discipline (for  
115 example track versus field, sprint versus distance) and impairment category were associated with  
116 increased rates of injury within this cohort.

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## 118 **MATERIALS AND METHODS:**

119 This cohort study was completed as a sub-analysis of a comprehensive injury and illness  
120 surveillance study carried out at the London 2012 Paralympic Games. The general methodology  
121 used to carry out the comprehensive injury and illness surveillance study has been previously  
122 described<sup>8</sup>. This will be summarized here, with inclusion of additional detail regarding the  
123 methodology utilized for the athletics-specific sub-analysis.

### 124 **Procedures**

125 The Paralympic Injury and Illness Surveillance System was approved by the International  
126 Paralympic Committee (IPC). Prior to initiation of the study, ethics board approval was obtained  
127 through [REDACTED] Athlete consent  
128 to utilize their de-identified medical data for research purposes was obtained at the time of their  
129 registration for the Games.

130 A total of 3565 athletes from 160 delegations participated in the comprehensive injury and  
131 illness surveillance study (four delegations declined participation for undisclosed reasons). A

132 comprehensive database of athlete demographic information was obtained from the IPC,  
133 containing the following de-identified information: age, gender, sport code, country code, and  
134 accreditation number.

135 Data regarding injuries was gathered via two sources. First, a database was populated from the  
136 electronic medical data capture system (EMDCS) (ATOS, France) utilized at all athlete medical  
137 stations operated by the London Organizing Committee for the Olympic and Paralympic Games  
138 (LOCOG). LOCOG medical staff entered all injury encounters when an athlete presented to a  
139 medical station with a complaint consistent with the pre-determined definition of injury (see  
140 below). A second database was populated by medical staff providing care for their own teams  
141 utilizing a novel web-based injury and illness surveillance system (WEB-IISS) that was  
142 developed specifically for the purposes of this study and is described in greater detail elsewhere<sup>8</sup>.  
143 Utilization of the WEB-IISS allowed for the gathering of greater clinical detail regarding injury.

144 The injury incidence rate (IR) was defined as the number of injuries per 1000 athlete-days.  
145 Further detail regarding the calculation of athlete-days has been described<sup>8</sup>. The injury incidence  
146 proportion (IP) was defined as the percentage of athletes reporting an injury, calculated as the  
147 number of injuries per 100 athletes (%).

148 For the purposes of the comprehensive study, our definition of injury, previously described by  
149 Derman et al.<sup>8</sup>, was ‘any newly acquired injury as well as exacerbations of preexisting injury that  
150 occurred during training and/or competition of the 14 day pre-competition and competition  
151 period of the London 2012 Paralympic Games.’ An acute traumatic injury was considered ‘an  
152 injury that was caused by an acute precipitating traumatic event.’ An acute on chronic injury was  
153 considered ‘an acute injury in an athlete with symptoms of a chronic injury in the same

154 anatomical area.’ Finally, a chronic (overuse) injury was considered ‘an injury that developed  
155 over days, weeks or months and was not associated with any acute precipitating event.’

### 156 **Athletics-specific sub-analysis**

157 Data regarding injuries in athletics was gathered concurrently with data for the larger study, as  
158 outlined above. For the athletics-specific sub-analysis, injury data was extracted for the total 10-  
159 day athletics competition period of the Games, therefore accounting for a total of 9,770 athlete-  
160 days.

161 Additionally, for both ambulant and wheelchair athletes competing in track disciplines, “sprint”  
162 versus “distance” events were defined as previously described in the literature<sup>2</sup>, with 100 m, 200  
163 m, and 400 m events considered as “sprints,” and 800 m, 1500 m, 5000 m, and marathon (42.2  
164 km) events considered as “distance.” Previously utilized definitions of “middle” and “long”  
165 distance<sup>2</sup> were combined to simply “distance” for the purpose of this analysis, given that: a) a  
166 low total number of Paralympic athletes compete in the long distance events (5000 m and  
167 marathon), and b) many Paralympic athletes cross-over to compete in many or all “distance”  
168 events from 800 m to marathon, particularly in the sport of wheelchair racing.

169 To enable the reporting of meaningful, sport-specific data regarding the injury IR and injury IP  
170 in athletics, further data was extracted from the IPC athlete database regarding athlete  
171 classification and event type. This allowed for the characterization of injuries per impairment  
172 category (derived from classification data) as well as for the comparison of track versus field  
173 disciplines.

### 174 **Statistical Analysis**



175 Data were available in the form of counts indicating the number of injuries experienced by each  
176 athlete. An athlete could report more than one injury over the 10-day athletics competition period  
177 of the Games, and athletes could compete in more than one event. Standard descriptive statistical  
178 analysis were conducted, including numbers, proportions (including 95% confidence interval  
179 [CI]) and incidences (including 95% CI) in the total sample as well as for sub-groups divided out  
180 by event discipline, impairment type, sex, and age. The 95% CI was used to determine  
181 significant differences in the incidence data. Incidence rate ratios (IRRs with 95% CI) were  
182 additionally used to compare data by sex and age as well as to compare ambulant track versus  
183 wheelchair racing disciplines.

184

## 185 **RESULTS:**

### 186 **Overall incidence of injuries (track and field)**

187 Of the total 3565 athlete participating in the larger comprehensive injury and illness surveillance  
188 study, 977 athletes from 138 countries participated in the sport of athletics. This accounted for  
189 86.4% of the total 1130 athletes competing in athletics at the 2012 London Paralympic Games.

#### 190 *Incidence proportion (IP)*

191 A total of 216 injuries were reported (IP=18.4 injuries/100 athletes, 95% CI; 16.0 – 20.9) during  
192 the total 10-day period. Of these, 95 injuries in 497 athletes occurred in track disciplines  
193 (IP=17.1 injuries/100 athletes, 95% CI; 13.8 – 20.4) and 121 injuries in 480 athletes occurred in  
194 field disciplines (IP=19.8 injuries/100 athletes, 95% CI; 16.2 – 23.4).

#### 195 *Incidence rate (IR)*

196 The injury incidence rate (IR: injuries per 1000 athlete-days) in athletics for the total period was  
197 22.1 (95% CI 19.5 - 24.7). There was no significant difference in the IR in track (19.1, 95% CI;  
198 15.7 - 22.6) compared to field disciplines (25.2, 95% CI; 21.3 - 29.1).

199

## 200 **Injury Incidence Rate (IR) in track disciplines**

### 201 *IR by impairment category*

202 In track disciplines, a total of 36 injuries occurred in 121 ambulant amputee athletes (IR=29.8,  
203 95% CI; 21.6 - 37.9), 37 injuries occurred in 160 ambulant visually impaired athletes (IR=23.1,  
204 95% CI; 16.6 - 29.7), and 10 injuries occurred in 98 ambulant cerebral palsy (CP) athletes  
205 (IR=10.2, 95% CI; 4.2 - 16.2). Ambulant track athletes with visual impairment and amputation  
206 experienced a significantly higher incidence of injury than track athletes with CP [IRR=2.27  
207 (95% CI; 1.1 - 5.11) and IRR=2.92 (95% CI; 1.42 – 6.59) respectively] (Table 1). The lowest  
208 injury IR was seen in athletes participating in wheelchair racing, who experienced total of 15  
209 injuries (IR=10.6, 95% CI; 5.5 - 15.6). The risk of injury in ambulant track events was two-fold  
210 that in wheelchair racing (IRR=2.07, 95% CI; 1.19 – 3.86).

### 211 *IR by sex and age category*

212 A total of 78 injuries occurred in 355 male athletes (IR=22.0, 95% CI; 17.7 - 26.3) and 17  
213 injuries occurred in 142 female athletes (IR=12.0, 95% CI; 6.6 - 17.3), indicating that male  
214 athletes in track disciplines experience a significantly higher incidence of injury when compared  
215 to females (IRR=1.84, 95% CI; 1.08 – 3.31) (Table 1). There was no statistically significant  
216 difference in injury IR amongst athletes aged 26-34 (IR=22.3, 95% CI; 16.3 - 28.3), athletes aged  
217 13-25 (IR=17.6, 95% CI; 12.5 - 22.8), and athletes aged 35+ (IR=16.5, 95% CI; 9.3 - 23.7).

218

## 219 **Injury Incidence Rate (IR) in field disciplines**

### 220 *IR by impairment category*

221 In field disciplines, a total of 54 injuries occurred in 343 ambulant throws athletes (IR=15.7,  
222 95% CI; 11.9 - 19.6). In comparing ambulant throws impairment categories, the injury IR was  
223 significantly higher for athletes in short stature throws when compared to the overall group  
224 (Table 2). A total of 42 injuries occurred in 177 athletes participating in seated throws (IR=23.7,  
225 95% CI; 17.5 – 30.0), indicating that seated throws athletes experienced a significantly higher IR  
226 of injury when compared to wheelchair racing athletes. In jumping disciplines, a total of 45  
227 injuries occurred in 137 athletes (IR=32.8, 95% CI; 25.0 - 40.7). Overall, athletes competing in  
228 ambulant jumps experienced a significantly higher injury IR compared to athletes competing in  
229 ambulant throws.

### 230 *IR by sex and age category*

231 A total of 81 injuries occurred in 315 male athletes (IR=25.7, 95% CI; 20.9 - 30.5) and 40  
232 injuries occurred in 165 female athletes (IR=24.2, 95% CI; 17.7 - 30.8), indicating no sex-related  
233 difference in injury incidence in field disciplines (Table 2). There was no statistically significant  
234 difference in injury IR amongst athletes aged 26-34 (IR=29.5, 95% CI; 22.7 - 36.3), athletes aged  
235 13-25 (IR=23.9, 95% CI; 17.2 – 30.6), and athletes aged 35+ (IR=21.7, 95% CI; 15.2 – 28.3).

236

## 237 **Characteristics of injuries**

### 238 *Ambulant athletes (track or field discipline)*

239 Overall, a total of 159 injuries occurred in 658 ambulant athletes (IR=24.2, 95% CI; 20.9 – 27.4)  
240 (Table 3). There was no statistically significant difference in injury IR amongst athletes in  
241 jumping disciplines (IR=32.8), sprinters (IR=24.0), distance runners (IR=19.7), and throws

242 (IR=20.5). For the total ambulant group, significantly more injuries occurred in competition  
243 (IR=10.2, 95% CI; 7.9 - 12.5) than in training (IR=3.2, 95% CI; 1.8 - 4.5). In competition,  
244 ambulant athletes experienced a total of 67 injuries, with significantly higher IR during the event  
245 (IR=6.2, 95% CI; 4.4 – 8.1) as opposed to warm-up (IR=3.6) or cool-down (IR=0.3). Of the total  
246 159 injuries, 80 were classified as acute traumatic resulting in a significantly higher IR (IR=12.2,  
247 95% CI; 9.7 – 14.7) compared to 33 acute on chronic (IR=5.0, 95% CI; 3.3 – 6.7) and 46 chronic  
248 overuse (IR=7.0, 95% CI; 5.0 – 8.9). Additionally, there was a significantly higher IR of non-  
249 time loss injuries (0-1 days missed) (IR=17.3, 95% CI; 14.4 – 20.2) when compared to time loss  
250 injuries (IR=6.7, 95% CI; 4.8 – 8.6).

#### 251 *Wheelchair/seated athletes*

252 Overall, a total of 57 injuries occurred in 319 wheelchair or seated athletes (IR=17.9, 95% CI;  
253 13.7 – 22.1) (Table 3). Athletes in seated throwing disciplines experienced a higher IR of injury  
254 (IR=23.7, 95% CI; 17.5 – 30.0) when compared to wheelchair racing (IR=10.6, 95% CI; 5.5 -  
255 15.6). There was a significantly higher IR in competition (IR=7.5, 95% CI; 4.6 – 10.4) than in  
256 training (IR=2.2, 95% CI; 0.6 - 3.8). In competition, wheelchair or seated athletes experienced a  
257 total of 24 injuries, with a similar IR during the event (IR=4.4, 95% CI; 2.1 - 6.6) and warm-up  
258 (IR=2.2, 95% CI; 0.6 - 3.8), but lower IR during cool-down (IR=0.9, 95% CI; -0.1 - 2.0)  
259 compared to the IR during an event. Of the total 57 injuries, 28 were classified as acute traumatic  
260 (IR=8.8) compared to 12 acute on chronic (IR=3.8) and 17 overuse (IR=5.3), and the IR for these  
261 showed no statistically significant difference. The IR of non-time loss injuries (0-1 days missed)  
262 (IR=13.8, 95% CI; 10.0 – 17.6) was significantly greater than time loss injuries (IR=4.1, 95% CI;  
263 1.9 – 6.2).

264

265 **Location of injury**

266 *Ambulant athletes (track or field discipline)*

267 Ambulant athletes experienced the greatest proportion (% of injuries) of injuries to the thigh  
268 (16.4% of total injuries) (Table 4). The knee (11.9% of total injuries), lumbar spine/low back  
269 (11.3% of total injuries) and lower leg (10.7% of total injuries) were the next most commonly  
270 injured anatomical regions. Ambulant athletes competing in track most commonly injured the  
271 thigh (n=19), compared to ambulant athletes competing in field who most commonly injured the  
272 knee (n=12) or ankle (n=10). In the total ambulant group, injuries to the lower trunk and lower  
273 extremity accounted for 83.7% of all injuries.

274 *Wheelchair/seated athletes*

275 Wheelchair or seated athletes experienced the greatest proportion (% of injuries) of injuries to  
276 the shoulder/clavicle (19.3% of total injuries) (Table 5). The elbow (15.8% of total injuries),  
277 knee (10.5% of all injuries) and upper arm (8.8% of total injuries) were the next most commonly  
278 injured anatomical regions. Wheelchair athletes competing in track most commonly injured the  
279 shoulder/clavicle, upper arm, or neck/cervical spine (for each, n=2), compared to seated athletes  
280 competing in field who most commonly injured the shoulder/clavicle (n=9). In the total  
281 wheelchair or seated group, injuries to the neck or upper extremity accounted for 61.5% of all  
282 injuries.

283

284 **DISCUSSION:**

285 This study is the first to report detail on the incidence and factors associated with injury in the  
286 sport of athletics (track and field) at the Paralympic Games. For the 10-day competition period,  
287 the injury incidence rate was 22.1/1000 athlete-days. The injury IR in track disciplines was

288 similar to the injury IR in field disciplines. Regarding factors associated with injuries and  
289 characteristics of injury during major competition in Paralympic athletics, the main findings of  
290 this study are that: 1) in track disciplines overall, male athletes experience a higher IR of injury  
291 than female athletes (IRR 1.84), 2) ambulant jumps athletes experience a higher IR of injury than  
292 ambulant throws athletes, 3) ambulant athletes with visual impairment and amputation  
293 experience a higher IR of injury in track disciplines when compared to ambulant athletes with  
294 cerebral palsy (IRR 2.27 and IRR 2.92, respectively), 4) wheelchair/seated athletes competing in  
295 seated throws (field) experience a higher IR of injury than those competing in wheelchair racing  
296 (track) (IR 23.7 and IR 10.6, respectively), 5) for both ambulant and wheelchair/seated athletes,  
297 the majority of injuries are not time-loss, 6) age group is not associated with injury in Paralympic  
298 athletics, and 7) the location of injury varies dependent upon athlete impairment category and  
299 athletics event discipline.

300 When comparing the results of this study to other investigations involving the sport of athletics,  
301 it is noted that injury patterns involving able-bodied athletes also reveal a higher incidence of  
302 injury in competition than in training, although able-bodied athletes experienced a higher  
303 incidence of time loss-injuries (36% of total injuries across 13 international athletics  
304 championships) compared to the athletes in this study<sup>10</sup>. Additionally, in ambulant athletes  
305 without an impairment, the most frequently observed diagnosis was thigh strain<sup>1,2,3,10</sup>, similar to  
306 the findings of this study in which the thigh was the most common anatomical region injured in  
307 ambulant athletes with an impairment. Given varied definitions of injury incidence rate and  
308 injury incidence proportion across studies, it is somewhat difficult to create a direct comparison  
309 of these descriptors for athletes with and without an impairment. The majority of prior studies  
310 involving large, international athletics competitions in able-bodied athletes utilized “injuries per

311 1000 registered athletes” to describe injury incidence proportion data<sup>1,2,3</sup>. When comparing  
312 injury incidence proportion utilizing “injuries per 1000 registered athletes” versus “injuries per  
313 100 athletes” (such as was utilized in this study), it appears that athletes with disabilities  
314 experience more injuries (18.4 injuries per 100 athletes in the current study) than able-bodied  
315 athletes competing in the sport of athletics (range of 97.0 - 135.4 injuries per 1000 registered  
316 athletes across studies). It should be noted, however, that the aforementioned studies within a  
317 population of athletes without a disability did not utilize injury incidence rate as a primary  
318 outcome measure, and thus it is difficult to compare the injury experience over competitions of  
319 varying duration.

320 One important finding of this study was that ambulant athletes with cerebral palsy were less  
321 likely to experience injury in track disciplines (IR10.2) when compared to ambulant athletes who  
322 have either an amputation (IR 29.8) or whom are visually impaired (IR 23.1). When comparing  
323 these impairment groups, it is noted that athletes with CP are likely to have an increase in muscle  
324 tone that may prohibit full, forceful lower extremity eccentric muscle contraction during sprints  
325 and distance running events. This physiological difference amongst athletes with and without CP  
326 may in fact be protective against lower extremity injury, although further studies are needed to  
327 determine the full nature of the biomechanical changes that occur in ambulant athletes with  
328 increased lower extremity tone.

329 Additionally, this study revealed that wheelchair/seated athletes are more likely to experience  
330 upper extremity injury in throws when compared to wheelchair racing. This is contrary to prior  
331 assumptions regarding injury patterns in wheelchair/seated athletes, for whom wheelchair racers  
332 were assumed to be at highest risk. Although further biomechanical studies are necessary to  
333 define the mechanism of injury, one hypothesis is that seated throws athletes are more likely to

334 experience upper extremity injury due to the explosive nature the throw itself, with an injury  
335 mechanism similar to what has been defined in other overhead throwing athletes<sup>14</sup>. Furthermore,  
336 wheelchair/seated athletes typically lack function in the legs and core, which are known to be  
337 important power generators in explosive throwing events. Thus, the upper extremity may be  
338 subject to increased forces throughout the throwing mechanism. Given these findings, future  
339 shoulder injury prevention programs should focus on athletes participating in seated throws, with  
340 a focus on scapular stabilization, mitigating kinetic chain dysfunction such as the presence of  
341 glenohumeral internal rotation deficit (GIRD), and closed kinetic chain strengthening with focus  
342 on muscle balance.

343 This is the first and largest prospective cohort study of injury incidence and risk factors for injury  
344 in the sport of Paralympic athletics. As athletics is the largest and one of the most high-profile  
345 sports on the Paralympic Games program, a greater understanding of athlete injury patterns is  
346 critical for sport injury prevention. Additionally, this study is the first to report injury incidence  
347 rates in Paralympic athletics, accounting for athlete exposure and thus enabling comparison to  
348 other events of varied sport discipline and duration. Through the development of a custom-built,  
349 web-based injury surveillance tool, the authors were able to gather greater detail on injuries as  
350 well as the nature of each athlete's impairment, thus enabling comparison of injury incidence  
351 rates across impairment types.

352 This study is inherently limited by several factors. First, given that injury data collection was  
353 dependent on London Organizing Committee medical personnel and team physicians entering a  
354 daily report of injuries, it is possible that the injury IR is underestimated. Additionally, the  
355 medical encounter forms at the Organizing Committee medical stations (EMDCS) included  
356 several non-mandatory fields and did not include information regarding injury severity, injury



357 mechanism, and/or associated risk factors. Thus, some injury logs could be submitted with empty  
358 data fields, and did not include detailed information. As the Paralympic Injury and Illness  
359 Surveillance Study continues, developments to the Organizing Committee medical record system  
360 are expected to enhance the ability of researchers to acquire meaningful detail on the types and  
361 quantity of injuries sustained. Although compliance was good in the present study (86.4% of  
362 athletes competing in the sport of athletics), further effort will be necessary to engage the full  
363 participation of all athletes, which could further limit selection bias. It is noted that these results  
364 only describe information on injuries sustained during the competition period of the Paralympic  
365 Games, whereas many injuries in the sport of athletics likely occur out of competition given that  
366 athletes often train individually and in non-centralized locations. This limitation is similar to  
367 other large epidemiological studies in the sport of athletics<sup>9</sup>. Finally, the number of injuries  
368 recorded was not large enough to allow for a multivariate analysis, which limited the authors'  
369 ability to determine independent risk factors for injury. As data collection will continue at the  
370 Rio 2016 Summer Paralympic Games, it is expected that compiled athletics data will enable  
371 multivariate analysis into the future.

372

### 373 **CONCLUSION:**

374 This study is the first prospective comprehensive assessment of the incidence, characteristics,  
375 and factors associated with injury in the sport of Paralympic athletics, the largest sport on the  
376 Paralympic Games program. Ambulant athletes are particularly at risk for lower extremity injury,  
377 although athletes with cerebral palsy may be at decreased risk compared to athletes from other  
378 ambulant impairment categories. Amongst wheelchair/seated athletes, those involved in throws  
379 are at particularly high risk for shoulder injury. Importantly, these sport-specific findings can

380 inform the work of physicians, therapists, athletic trainers, and coaches when planning for injury  
381 prevention programs that protect the health of Paralympic athletes, noting that the incidence and  
382 anatomical region of injury varies based on athlete impairment category and event discipline.

383

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448 **Table 1: Injury incidence proportion (IP) and incidence rate (IR) by sex, age, and impairment category for track events at the**  
 449 **London Paralympic Games during the athletics competition period (10 days)**

		Total number of athletes participating	Athlete days	Number of injuries	Injury incidence proportion (IP) (injuries per 100 athletes)	Injury incidence rate (IR) (injuries per 1000 athlete-days)	Injury incidence rate (IR) 95% confidence Intervals	Incidence rate ratio (IRR)	Incidence Rate Ratio (IRR) 95% confidence intervals
Overall		497	4970	95	17.1	19.1	15.7 - 22.6		
Male		355	3550	78	19.2	22.0	17.7 - 26.3	1.84	1.08 – 3.31
Female		142	1420	17	12.0	12.0	6.6 - 17.3	1	
Age 13-25		210	2100	37	15.2	17.6	12.5 - 22.8	1.07	0.59-2.02
Age 26-34		184	1840	41	21.2	22.3	16.3 - 28.3	1.35	0.75-2.53
Age 35+		103	1030	17	13.6	16.5	9.3 - 23.7	1	
Ambulant track (all)		402	4020	88	19.4	21.9	17.8 – 25.9	2.07	1.19-3.86
	Ambulant amputee	121	1210	36	26.4	29.8	21.6 - 37.9		
	Ambulant VI†	160	1600	37	20.0	23.1	16.6 - 29.7		
	Ambulant CP*	98	980	10	9.2	10.2	4.2 - 16.2		

racing									
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450 †VI = visually impaired \*CP = cerebral palsy

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453 **Table 2: Injury incidence proportion (IP) and incidence rate (IR) by sex, age, and impairment category for field events at the**  
 454 **London Paralympic Games during the athletics competition period (10 days)**

		Total number of athletes participating	Total number of athlete days	Number of injuries	Injury incidence proportion (IP) (injuries per 100 athletes)	Injury incidence rate (IR) (injuries per 1000 athlete-days)	Injury incidence rate (IR) 95% confidence Intervals	Incidence Rate Ratio (IRR)	Incidence Rate Ratio (IRR) 95% confidence intervals
Overall		480	4800	121	19.8	25.2	21.3 - 29.1		
Male		315	3150	81	20.3	25.7	20.9 - 30.5	1.06	0.72-1.59
Female		165	1650	40	18.8	24.2	17.7 - 30.8	1	
Age 13-25		155	1550	37	18.7	23.9	17.2 - 30.6	1.09	0.67-1.81
Age 26-34		173	1730	51	22.0	29.5	22.7 - 36.3	1.35	0.85-2.17
Age 35+		152	1520	33	18.4	21.7	15.2 - 28.3	1	
Ambulant jumps (all)		137	1370	45	24.1	32.8	25.0 – 40.7		
	Ambulant VI†	50	500	20	26.0	40.0	26.4 – 53.6	2.16	0.79-7.36
	Ambulant amputee	43	430	14	27.9	32.6	18.6 – 46.6	1.76	0.6-6.23
	Ambulant CP*	27	270	5	14.8	18.5	3.9 – 33.2	1	

Ambulant throws (all)		240	2400	50	14.2	20.5	15.7 – 26.0		
	Ambulant short stature	20	200	10	35.0	50.0	28.1 - 71.9	3.23	1.77-7.98*
	Ambulant VI†	49	490	9	14.3	18.4	7.5 – 29.2	1.19	0.45-3.0
	Ambulant amputee	87	870	18	18.4	20.7	12.2 – 29.2	1.34	0.62-2.97
	Ambulant CP*	84	840	13	13.1	15.5	7.7 – 23.2	1	
Seated throws		177	1770	42	19.2	23.7	17.5 – 30.0	1.53	0.81-3.11

455 \*CP = cerebral palsy †VI = visually impaired

456

457 **Table 3: Number of injuries and Injury incidence rate (IR) by track or field discipline, and characteristics of injury at the London**  
 458 **Paralympic Games during the athletics competition period (10 days)**

		Ambulant					Wheelchair/Seated			
		Sprints* n (IR)	Distance† n (IR)	Jumps n (IR)	Throws n (IR)	Total n (IR)	Sprints* n (IR)	Distance† n (IR)	Throws n (IR)	Total n (IR)
Athletes participating		233	122	137	166	658	110	32	177	319
Total number of injuries		56 (24.0)	24 (19.7)	45 (32.8)	34 (20.5)	159 (24.2)	11 (10.0)	4 (12.5)	42 (23.7)	57 (17.9)
Timing of injuries										
	In training	7 (3.0)	3 (2.5)	6 (4.4)	5 (3.0)	21 (3.2)	3 (2.7)	0 (0.0)	4 (2.3)	7 (2.2)
	In competition total	21 (9.0)	14 (11.5)	19 (13.9)	13 (7.8)	67 (10.2)	4 (3.6)	3 (9.4)	17 (9.6)	24 (7.5)
	Warm-up	8 (3.4)	1 (2.5)	4 (2.9)	9 (5.4)	24 (3.6)	2 (1.8)	0 (0.0)	5 (2.8)	7 (2.2)
	Competition	13 (5.6)	7 (8.2)	14 (10.2)	4 (2.4)	41 (6.2)	2 (1.8)	3 (9.4)	9 (5.1)	14 (4.4)
	Cool-down / recovery	0 (0.0)	1 (0.8)	1 (0.7)	0 (0.0)	2 (0.3)	0 (0.0)	0 (0.0)	3 (1.7)	3 (0.9)
Non-sport-related injuries		1 (0.4)	0 (0.0)	3 (2.2)	0 (0.0)	4 (0.6)	1 (0.9)	0 (0.0)	2 (1.1)	3 (0.9)
Acuity of injury										
	Acute traumatic	28 (12.0)	11 (9.0)	22 (16.1)	19 (11.4)	80 (12.2)	6 (5.5)	4 (12.5)	18 (10.2)	28 (8.8)
	Acute on chronic	9 (3.9)	6 (4.9)	9 (6.6)	9 (5.4)	33 (5.0)	2 (1.8)	0 (0)	10 (5.6)	12 (3.8)
	Overuse injury	19 (8.2)	7 (5.7)	14 (10.2)	6 (3.6)	46 (7.0)	3 (2.7)	0 (0)	14 (7.9)	17 (5.3)
Time-loss injuries										
	0-1 days missed	39 (16.7)	17 (13.9)	29 (21.2)	29 (17.5)	114 (17.3)	9 (8.2)	3 (9.4)	32 (18.1)	44 (13.8)
	> 1 day missed	17 (7.3)	7 (5.7)	15 (10.9)	5 (3.0)	44 (6.7)	2 (1.8)	1 (3.1)	10 (5.6)	13 (4.1)

459

460 \*Sprint events are classified as the 100 m, 200 m, and 400 m

461 †Distance events are classified as the 800 m, 1500 m, 5000 m, and marathon



462 **Table 4: Injury incidence rate (IR) per anatomical region in ambulant athletes at the London Paralympic Games during the**  
 463 **athletics competition period (10 days)**

Anatomical region	Track	Field	Number of injuries	Proportion of all injuries
Thigh	19	7	26	16.4%
Knee	7	12	19	11.9%
Lumbar spine/lower back	11	7	18	11.3%
Lower leg	11	6	17	10.7%
Foot	8	6	14	8.8%
Ankle	4	10	14	8.8%
Shoulder/clavicle	2	9	11	6.9%
Hip and Groin	6	4	10	6.3%
Elbow	0	5	5	3.1%
Wrist	2	3	5	3.1%
Pelvis/sacrum/buttock	2	1	3	1.9%
Trunk and abdomen	2	1	3	1.9%
Upper arm	1	1	2	1.3%
Thoracic spine/upper back	0	2	2	1.3%
Neck/cervical spine	0	2	2	1.3%
Multiple body locations	1	1	2	1.3%
Stump	1	1	2	1.3%
Toe	2	0	2	1.3%
Head and face	0	1	1	0.6%
Genitalia	1	0	1	0.6%
Total	80	79	159	100%

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465

466 **Table 5: Injury incidence rate (IR) per anatomical region in wheelchair or seated athletes at the London Paralympic Games during**  
 467 **the athletics competition period (10 days)**

Anatomical region	Track	Field	Number of injuries	Proportion of all injuries
Shoulder/clavicle	2	9	11	19.3%
Elbow	1	8	9	15.8%
Knee	1	5	6	10.5%
Upper arm	2	3	5	8.8%
Wrist	1	3	4	7.0%
Thigh	1	3	4	7.0%
Lumbar spine/lower back	1	2	3	5.3%
Pelvis/sacrum/buttock	1	2	3	5.3%
Thoracic spine/upper back	0	2	2	3.5%
Lower leg	1	1	2	3.5%
Neck/cervical spine	2	0	2	3.5%
Chest	0	1	1	1.8%
Forearm	0	1	1	1.8%
Thumb	0	1	1	1.8%
Foot	0	1	1	1.8%
Hip and Groin	1	0	1	1.8%
Multiple body locations	1	0	1	1.8%
Total	15	42	57	100%

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