

1 **TITLE**

2 Acute injuries in track and field athletes: a 3-year observational study at the Penn Relay Carnival with
3 epidemiology and medical coverage implications.

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30 **ABSTRACT**

31 **Background:** Few studies have examined acute injuries in track and field in both elite and sub-elite
32 athletes. **Purpose:** To observe the absolute and relative rates of injury in track and field athletes
33 across a wide range of competition levels and ages during three years of the Penn Relays Carnival to
34 assist with future medical coverage planning and injury prevention strategies. **Study design:**
35 Descriptive epidemiology study. **Methods:** Over a 3-year period all injuries treated by the medical
36 staff were recorded on a standardised injury report form. Absolute injury rates (absolute number of
37 injuries) and relative injury rates (number of injuries per 1000 participants) were determined and odds
38 ratios (OR) of injury rates were calculated between sexes, competition levels and events. Injuries were
39 also broken down into major or minor medical or orthopedic injuries. **Results:** Throughout the study
40 period 48,473 competing athletes participated in the Penn Relays Carnival, and 436 injuries were
41 sustained. For medical coverage purposes, the relative rate of injury subtypes was greatest for minor
42 orthopedic injuries (5.71 injuries per 1000 participants), followed by minor medical injuries (3.42
43 injuries per 1000 participants), major medical injuries (0.69 injuries per 1000 participants) and major
44 orthopedic injuries (0.18 injuries per 1000 participants). College/elite level athletes displayed the
45 lowest relative injury rate (7.99 injuries per 1000 participants), which was significantly less than high
46 school (9.87 injuries per 1000 participants) and masters level athletes (16.33 injuries per 1000
47 participants). Males displayed a greater likelihood of suffering a minor orthopedic injury compared to
48 females (OR = 1.36, 95% CI = 1.06 to 1.75; $\chi^2 = 5.73$, $p = 0.017$) but were less likely to sustain a
49 major medical injury (OR = 0.33, 95% CI = 0.15 to 0.75; $\chi^2 = 7.75$, $p = 0.005$). Of the three most
50 heavily participated in events, the 4 x 400m relay displayed the greatest relative injury rate (13.6
51 injuries per 1000 participants) compared to the 4 x 100 and 4 x 200m relay. **Conclusions:** Medical
52 coverage teams for future large scale track and field events need to plan for at least two major
53 orthopedic and seven major medical injuries per 1000 participants. Male track and field athletes,
54 particularly masters level male athletes, are at greater risk of injury compared to other genders and
55 competition levels.

56 **Clinical relevance:** Track and field is one of the most heavily participated in sports world-wide, with
57 a wide spectrum of ages and competitions levels. Prevention of injury is paramount, however
58 preventative strategies need to be tailored to the risk profile of the athlete and or the sport. This paper
59 gives clinicians guidance as to the distribution of injury in track and field across sex, age and
60 competition level to help focus preventative efforts. Further to this, the relative rates of injury also
61 serve to assist organisers of track and field events of similar scope to plan medical coverage needs.

62 **Key terms:** Epidemiology, injury, athletics, medical coverage

63 **What is known about the subject:** Much work has been published on the incidence of injury in track
64 and field athletes at the elite level, from the Olympic Games, World and European Championships.
65 However there is little information on the injury profile in non-elite track and field athletes. There is
66 also a dearth of multiple year injury data in track and field and a lack of information to assist with the
67 planning of medical coverage of large scale track and field events.

68 **What this study adds to the existing knowledge:** The current study is the single largest multi-year
69 observation of injuries in track and field in athletes of both sexes from different ages and competition
70 levels. This study adds to the existing evidence base by demonstrating the difference in injury
71 incidence in male and female track and field athletes at the high school, college/elite and masters
72 level. There is also pertinent information relating to medical coverage considerations for a track and
73 field event of a similar scope.

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82 INTRODUCTION

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84 Track and field is one of the most popular sports worldwide across a range of age groups.¹ Despite the
85 well reported injury risk associated with track and field competition at the elite level,^{1-3 5 14 25} reports in
86 the literature mostly focus on observations from Olympic games, World and European
87 championships,^{1-3 14 17 25} with some exceptions^{13 24 31} There is a risk of over- or under-estimating injury
88 incidence from observational single-meet (Olympic, world championships) studies.⁶ Additionally,
89 these single-meet studies do not allow for the assessment of trends across time which requires studies
90 of longer duration.^{6 16 28} Furthermore, given the interest in preventing injuries in elite competitors,
91 much of the injury epidemiology evidence has focused on this homogenous group of athletes with
92 respect to age and performance.^{1-3 25} Reports in younger (< 18 years)^{15 23 28} and older (>40 years)^{21 28}
93 athletes, across a wide spectrum of pathologies, are limited. From a population health perspective, the
94 prevention of injury in these cohorts is of far greater significance than the elite athlete population, as
95 injury is often reported as a barrier for physical activity participation.^{8 18} The limited observations of
96 non-elite injury statistics also presents a challenge for institutes/organisations which require data to
97 plan medical coverage in large track and field meets in sub-elite athletes. Much focus has centered on
98 medical coverage of summer,⁹ winter¹² and youth⁷ Olympic and Paralympic³² games. Reports on
99 medical coverage issues in track and field at multiple levels of competition are less common.

100 The Penn Relays Carnival, held annually by the University of Pennsylvania, is the oldest and largest
101 track and field competition in the United States. Between 2002 and 2004, over 48,000 athletes,
102 ranging from junior high school to masters level, participated in the Penn Relays Carnival across 30
103 different track and field events.²⁸ The large number of athletes who participate in this event makes this
104 event ideal for the observations of injury rates in track and field, and the diversity in the participant
105 pool allows for comparisons across different age groups, sex, and event types. Furthermore, the size
106 and breadth of the participant pool allows relative injury rates to be determined across a variety of
107 cohorts and events, which can be helpful in the planning of medical coverage for future, large track
108 and field events. The purpose of this study was to report the absolute number of injuries (absolute

109 injury rate) and relative injury rates (number of injuries per 1000 participants) sustained in track and
110 field events at the Penn Relays Carnival across a three year period. Comparisons were made between
111 athletes of male and female sex, from different age groups, and in different events to determine which
112 track and field athletes are at the greatest risk of injury. Injuries were also broken down into relevant
113 sub-categories for further detailed analyses. A better understanding of the profile of injuries across a
114 wide ranging demographic in track and field is required to better inform authorities as to which
115 populations require a greater focus on preventative strategies and to give organisers of future track
116 and field events objective data to plan medical coverage procedures.

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119 **MATERIALS & METHODS**

120 The methodology for the current study has been reported previously.²⁸

121 **Ethical approval**

122 The Institutional Review Board at the XXXX granted ethical exemption for the study based on the
123 observational nature of the investigation and given that no patient identifiers were collected.

124 **Data collection**

125 Over a three-year period from 2002 to 2004, all injuries treated by the treatment team at the Penn
126 Relays Carnival were classified and recorded, using a standardised reporting form. All injuries that
127 resulted in cessation of participation in an event, as well as self-reported injuries were assessed by the
128 treatment team. The team consisted of athletic trainers, emergency medical technicians, physical
129 therapists, primary care physicians, podiatrists and orthopaedic surgeons. The type of injury, anatomic
130 location, event in which the injury occurred, competition level (junior high school, ≤ 13 years of age;
131 high school, 14 to 18 years; college/elite (including pre-Olympic/professional athletes), 19 to 40
132 years; or masters, > 40 years) and demographic data (i.e. age, sex) were recorded. During the same
133 time period, athlete participation data (defined as competing athletes as per recent consensus

134 statement³⁴) was collected by the Penn Relays Carnival organisers and supplied to the investigators
135 (Table 1).

136 **Injury classification**

137 Injuries were classified into four major categories at the discretion of the medical team following
138 diagnosis; major or minor medical and major or minor orthopedic injuries. These classifications were
139 subsequently reviewed at the completion of each carnival by the treatment team to ensure there were
140 no errors in classification. . Medical injuries were defined as all non-musculoskeletal injuries
141 including asthma exacerbation, pre-syncope and syncope, dehydration, concussion, etc. Orthopaedic
142 injuries were defined as any musculoskeletal injury. Each injury was further sub-classified as major or
143 minor or major. Major injuries were defined as any injury that was potentially life-threatening,
144 required immediate intervention by EMS or a physician, required >30 minutes direct observation or
145 transfer to the ED, lacerations requiring sutures, fractures, dislocations, and major tendon or ligament
146 disruption. Minor injuries included routine, non-life threatening conditions such as abrasions, muscle
147 cramps, bruises, ligamentous and tendinous strains. A list of all injuries under each classification can
148 be found in Table 2.

149 **Statistical Analysis**

150 All athlete participation and injury information was entered into an ExcelTM spreadsheet with patient
151 identifiers removed. Injury rates were determined for different sexes (males, females), competition
152 levels (junior high school, high school, college/elite, and masters) and the events during which the
153 injury occurred. Comparisons of sex and competition level combinations were carried out in
154 homogenous groups and were as follows: male masters vs male college/elite vs male high school;
155 female college/elite vs female high school; male high school vs female high school; male college/elite
156 vs female college/elite; male high school vs female high school. Due to junior high school athletes
157 and masters females reporting relatively few injuries (three and one injuries/injury respectively) these
158 cohorts were excluded from gender by competition analyses. Relative total injury rates were
159 calculated and expressed as injuries per 1000 participants. The sub-categories of major/minor injuries

160 considered medical/orthopedic are also reported as relative injury rates. Statistical analysis was
161 performed using JMP version 10.0 Pro Statistical Discovery Software (SAS Inc.). Measures of
162 association included odds ratios (OR), 95% confidence intervals (95% CI) and χ^2 -testing of injury
163 rates by sex (male/female), competition level (junior high school/high school/college & elite/masters),
164 and event (4x100m, 4x200m and 4x400m), with significance set at $p < 0.05$. When injury frequencies
165 were too low to calculate χ^2 , Fisher's exact test was employed.

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169 **RESULTS**

170 **Athlete participation information**

171 Across the three-year observational period 48,473 athletes registered to participate in the Penn Relays
172 Carnival, with slightly more males ($n=25,232$) than females ($n=23,241$) competing (Table 1).

173 **Injury data collection**

174 During the observational period of the study there were 489 injuries treated by the medical staff. Of
175 these, non-competing individuals (spectators, staff and coaches) accounted for 53 of these cases and
176 were excluded from further analysis, leaving a total of 436 injuries sustained by competing athletes.
177 The relative rates of injury subtypes was greatest for minor orthopedic injuries (5.71 injuries per 1000
178 participants), followed by minor medical injuries (3.42 injuries per 1000 participants), major medical
179 injuries (0.69 injuries per 1000 participants) and major orthopedic injuries (0.18 injuries per 1000
180 participants). The two most common major medical issues were: asthma attack (10 cases) and severe
181 fatigue/light headedness (nine cases). The eight major orthopaedic cases were: Achilles tendon
182 rupture, clavicle fracture, metacarpal fracture, metatarsal fracture (two cases), scapula fracture, patella
183 dislocation and a severe ankle sprain.

184 **Sex**

185 Over the duration of the three year observational period, males displayed a greater likelihood of
186 suffering a minor orthopedic injuries compared to female athletes (OR = 1.36, 95% CI = 1.06 to 1.75;
187 $\chi^2 = 5.73$, $p = 0.017$). Males also had a smaller chance of sustaining a major medical injury compared
188 to females (OR = 0.33, 95% CI = 0.15 to 0.75; $\chi^2 = 7.75$, $p = 0.005$). Given the large discrepancy in
189 the number of masters male (n=693) compared to masters female (n=42) athletes, which has the
190 potential to confound the injury analysis by sex, a secondary analysis excluding all masters athletes
191 was also performed. With this analysis there was still no difference in the rates of total injuries (OR =
192 1.10, 95% CI = 0.91 to 1.33; $\chi^2 = 1.06$, $p = 0.303$), minor medical injuries (OR = 1.07, 95% CI = 0.78
193 to 1.48; $\chi^2 = 0.22$, $p = 0.639$) and major orthopedic injuries (OR = 0.71, 95% CI = 0.16 to 3.17; $p =$
194 0.651) when male athletes were compared with female athletes. Even with all masters athletes
195 removed, male athletes were still less likely to sustain a major medical injury (OR = 0.34, 95% CI =
196 0.16 to 0.73; $\chi^2 = 8.47$, $p = 0.004$) and more likely to sustain a minor orthopedic injury (OR = 1.32,
197 95% CI = 1.02 to 1.69; $\chi^2 = 4.62$, $p = 0.032$) compared to female athletes.

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199 **Competition level**

200 College/elite athletes were less likely to sustain an injury compared to high school (OR = 0.81, 95%
201 CI = 0.66 to 0.99; $\chi^2 = 4.17$, $p = 0.041$) and masters (OR = 0.49, 95% CI = 0.27 to 0.88; $\chi^2 = 5.93$, p
202 = 0.001) level athletes. Similarly college/elite athletes were less likely to sustain a minor medical
203 injury compared to high school level athletes (OR = 0.56, 95% CI = 0.38 to 0.82; $\chi^2 = 9.37$, $p =$
204 0.002). High school athletes were less likely to sustain a major (OR = 0.05, 95% CI = 0.00 to 0.56; $p =$
205 = 0.003) or minor (OR = 0.43, 95% CI = 0.22 to 0.85; $p = 0.012$) orthopedic injury compared with
206 masters level athletes.

207 **Sex and competition level**

208 The relative rates of injuries calculated by sex and competition level can be seen in Figure 1. Due to
209 the low number of major medical and major orthopedic injuries sustained in each group, no
210 comparisons were performed for this injury sub-category. College/elite females level athletes were
211 less likely to sustain an injury compared to high school female athletes (OR = 0.71, 95% CI = 0.52 to
212 0.98; $\chi^2 = 4.41$, $p = 0.036$). College males were more likely to sustain a minor orthopedic injury
213 compared with college females (OR = 1.77, 95% CI = 1.13 to 2.79; $\chi^2 = 6.3$, $p = 0.012$). With respect
214 to minor medical injuries, college females were less likely to sustain this injury type compared to high
215 school female level athletes (OR = 0.56, 95% CI = 0.32 to 0.98; $p = 0.039$). College males were also
216 less likely to sustain this injury type compared with high school level male athletes (OR = 0.56, 95%
217 CI = 0.33 to 0.93; $\chi^2 = 4.28$, $p = 0.023$).

218 **Event**

219 Event participation data can be found in Table 3 and the absolute and relative incidence rates for all
220 events for which at least one injury was recorded is presented in Table 4. When comparing total
221 injuries of the three events with the highest participant numbers (4 x 100 m, 4 x 200 m and 4 x 400m
222 relays), the 4 x 400 m relays involved a greater likelihood of injury compared to the 4 x 100 m relays
223 (OR = 2.27, 95% CI = 1.79 to 2.88; $\chi^2 = 48.65$, $p < 0.001$) and the 4 x 200m relay (OR = 4.42, 95%
224 CI = 2.61 to 7.48; $\chi^2 = 36.69$, $p < 0.001$). The 4 x 100m relay had a greater likelihood of injury
225 compared to the 4 x 200 m relay (OR = 1.94, 95% CI = 1.13 to 3.34; $\chi^2 = 6.00$, $p = 0.014$). The
226 distribution of injuries sustained in the four major relay events (4 x 400m, 4 x 100m, 4 x 200m and 4
227 x 800m) amongst different genders and competition levels can be found as supplementary tables 1-4.

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229 **DISCUSSION**

230 The major findings from the current study, which observed the incidence of injuries reported to
231 medical staff between 2002 and 2004 at the Penn Relays carnival, were that 1) female track and field
232 athletes were generally less likely to sustain minor orthopedic injuries compared to their male
233 counterparts; 2) college/elite level track and field athletes were significantly less likely to sustain

234 injuries compared to younger (high school) and older (masters) athletes and; 3) for a track and field
235 event of similar scope, one should plan and resource for major orthopedic and major medical
236 incidents at a rate of at least 2- and 7-per 1000 participants respectively.

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238 The observation that female track and field athletes were less likely to sustain orthopedic and lower
239 body strain injuries compared to male athletes confirms earlier observations.^{1 3 14 28} Studies examining
240 the injuries sustained by elite athletes during the 2011 International Association of Athletics
241 Federations (IAAF) World Athletics Championships¹ and 2012 European Athletics Championships¹⁴,
242 respectively, found that females were less likely to sustain an injury of any type compared with male
243 athletes ($\chi^2 = 4.17$, Ref ¹; $\chi^2 = 10.3$, Ref ¹⁴). The findings from the current study suggest that the
244 reduced risk of injury in female athletes might be restricted to college/elite level athletes, as the injury
245 rates of high school female athletes was not different to high school male athletes. That females were
246 less likely to sustain a minor orthopedic injury is similar to observations from an earlier study
247 examining the incidence of hamstring strain injuries in the same cohort.²⁸ In the aforementioned
248 study,²⁸ male track and field athletes were found to be have a greater likelihood of sustaining a
249 hamstring strain injury compared to females (OR = 1.68 to 1.79), which is somewhat similar to the
250 between sex data presented in the current study for minor orthopedic injury (OR = 1.36). An
251 additional post hoc sub-analysis, whereby hamstring strain injuries were removed, revealed no
252 significant difference between lower limb strain injuries between male and female athletes (OR =
253 0.93, 95% CI = 0.50 to 1.75), suggesting that the sex bias towards injury might be mediated mostly by
254 a greater likelihood for males to sustain hamstring strain injuries than females. More work is needed
255 to confirm if the bias towards injury in male athletes is true for athletes of all ages, or whether it is
256 only confined to those at the elite level. Regardless, the mechanisms responsible for the lesser
257 likelihood of injury in college/elite level track and field females athletes is worthy of investigation.

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259 Advancing age is often identified as a risk factor for many injury types in running based sports^{4 29} and
260 evidence from elite competitions suggest that track and field athletes over the age of 30 years are at an

261 elevated risk of all injuries¹ or time-loss injuries¹⁴ compared to their younger counterparts. Whilst the
262 current study did not look directly at age, the split of participants into different competitions levels
263 according to age groups allows for some comparisons across the age spectrum of the competing
264 athletes. The current study found that, compared to masters level male track and field athletes, college
265 and high school athletes had a smaller likelihood of sustaining a minor orthopedic injury (OR ranging
266 from 0.27 to 0.48). Despite the consistent identification of older athletes being at an increased risk of
267 injury, in multiple sports^{4 20 29} to the authors' knowledge, few studies^{19 21 26} have been carried out to
268 determine why, physiologically, older athletes are at greater risk of injury and this body of evidence is
269 too limited to draw any discernable conclusions. The limited evidence base may be due, in part, to the
270 classification of increasing age as a non-modifiable risk factor.²⁹ Whilst it is not possible to modify an
271 individuals age, the physiological changes that occur in the ageing athlete (e.g. declines in strength,
272 muscle voluntary activation capacity, etc^{10 27}), which might confer the increased risk of future injury,
273 can most probably be ameliorated via intervention. For example, recent research in elite Australian
274 footballers has found that older athletes in this cohort are exposed to a greater risk of hamstring injury
275 compared to their younger counter-parts only if they also display low levels of eccentric strength.³⁰
276 The interaction of risk factors for injury in older athletes is certainly an area worthy of further
277 exploration. Additionally, what is also required are longitudinal observations of track and field
278 athletes, across the age spectrum, followed for multiple years, to determine age related declines in
279 function that might predispose to injury. Whilst logistically and fiscally challenging, these barriers
280 should not be a deterrent. Track and field is one of the most popular sports worldwide²⁸ and
281 participation in the sport as an adolescent is associated with greater physical activity levels later in
282 life.³³ As such, strategies to reduce the risk of injury in track and field, and thereby presumably
283 increase ongoing participation, are important and should be a key focus of the major organisational
284 (IAAF) and government bodies.

285 The difference in relative injury rates between high school, college/elite and masters athletes has
286 implications for medical coverage. The current findings suggest that previous epidemiological reports
287 in track and field athletes at the elite level^{1-3 5 14 25} are not suitable data to utilise when planning

288 medical coverage for competitions that involve younger or older athletes. For example, masters level
289 athletes are more likely to sustain major and minor orthopedic injuries than their younger
290 counterparts. Furthermore, individual events impose variable levels of injury risk. Table 4 from the
291 current study provides an excellent resource on the relative incidence of injury in each event
292 participated in across the three year observation period. This information could be used when
293 calculating expected injury occurrences for particular events. If multiple events are running
294 simultaneously, it may be wise to consider the proximity of medical support to events where injury
295 occurrence is likely to be higher, as successfully employed previously during the winter youth
296 Olympic games.⁷

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298 As per previous work examining hamstring strain injury rates from the same cohort,²⁸ the 4 x 400 m
299 relay was found to be the most injurious event compared to the two other most heavily participated
300 events, the 4 x 100 and 4 x 200 m relays. Of interest, minor medical injuries featured far greater in the
301 4 x 400 m relay compared to the shorter distance relay events and explained the observed higher rates
302 of all injury (Table 4). The majority of these minor medical injuries were made up of abrasions and
303 spike lacerations. Such injury types are less common during the 4 x 100 and 200 m relays as athletes
304 remain in their respective lanes during the duration of the event, minimising the risk of falls and close
305 proximity to other competitors' footwear. In general, the greater anaerobic fatigue experienced
306 during 400 m racing²² may impose an additional risk of injury above the other, shorter relay events.
307 The link between fatigue and increased incidence of injury is established in other field-based team
308 sports,^{11 16 35} however the duration of these sports (80-90 minutes) and physiological demands
309 differ significantly compared with short duration high intensity sprint events. Yet a similar pattern of
310 elevated minor medical injury rates was observed for 800m x 4 relay, supporting the reported
311 association between anaerobic fatigue and increased minor medical injury risk. As such, the possible
312 link between anaerobic fatigue during 400 m compared to 100 and 200 m sprint events and risk
313 of injury requires further examination.

314 There are some limitations in the current study. Firstly, injury data was only captured if an athlete
315 self-reported to the medical team or failed to complete an event due to injury. As a result it is not
316 possible to determine the capture rate of injuries and whether certain cohorts under or over reported
317 injuries, which may confound the findings from the current study. Secondly, there was no
318 determination as to whether the injuries resulted in lost time from training/competition (i.e. a time-
319 loss injury), which has been reported in other track and field epidemiology papers.^{1 3 14} The
320 relationship between time-loss injuries and different competition levels and sexes requires further
321 examination. Finally, the number of events that each participant competed in prior to sustaining an
322 injury was not accounted for in the current study. It is possible that prior events that athletes
323 participated in had some influence on the injury occurrence in later events.

324 In conclusion, male and particularly male masters level athletes, were at an elevated risk of injury
325 compared to their female and younger counterparts, respectively. Further examination as to why these
326 cohorts are more prone to injury should form the impetus for further work in injury prevention in
327 track and field. Similarly, the higher incidence of injury in events involving greater anaerobically-
328 induced fatigue requires attention. The current study presents detailed epidemiological data in track
329 and field athletes of varying ages and competition levels that can aid in determining medical coverage
330 at non-elite track and field events. Additionally, the findings from the current study should assist with
331 future injury prevention strategies across all ages and sexes of track and field athletes.

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Table 1. Participation data of athletes who competed in the Penn Relays Carnival between 2002 to 2004.

Year	Male Athletes					Female Athletes					All Athletes
	Junior High School	High School	College	Masters	Total	Junior High School	High School	College	Masters	Total	Total
2002	308	4,473	3,151	231	8,163	312	4,758	2,697	25	7,792	15,955
2003	312	4,560	3,124	242	8,238	308	4,563	2,636	17	7,524	15,762
2004	292	5,481	2,838	220	8,831	292	5,051	2,582	0	7,925	16,756
Total	912	14,514	9,113	693	25,232	912	14,372	7,915	42	23,241	48,473

Table 2. Specific injury diagnoses classified as major or minor, medical or orthopaedic injuries from the Penn Relays Carnival between 2002 and 2004.

Medical		Orthopaedic	
Minor	Major	Minor	Major
Abdominal pain (mild)	Abdominal pain (severe)	Contusion	Achilles tendon rupture
Abrasion	Animal bite	Back pain – lumbar	Anterior cruciate ligament rupture
Blisters	Arrhythmia	Back pain - thoracic	Fracture - metacarpal
Corneal abrasion	Asthma attack	Bone pain	Fracture - metatarsal
Epistaxis	Chest pain	Iliotibial band syndrome	Fracture - clavicle
Fatigue/light headedness (mild)	Concussion	Plantar faciitis	Fracture - scapula
Foreign body (eye)	Fatigue & light headedness (severe)	Shin pain	Patella dislocation
Foreign body (throat)	Seizure	Sprain - ankle (mild)	
Rash urticarial	Syncope	Sprain - foot	Sprain - ankle (severe)
Spike laceration	Severe nausea	Sprain - knee	
Subungual hematoma		Sprain – toe	
		Sprain - wrist	
		Sprain - shoulder	
		Strain - calf	
		Strain - hamstring	
		Strain – hip flexor	
		Strain - hip abductor	
		Strain – hip adductor	
		Strain - quadriceps	
		Tendinopathy – Achilles	
		Tendinopathy - patellar	
		Tendinopathy - peroneal	

Table 3. Individual event participation data of athletes who competed in the Penn Relays Carnival between 2002 and 2004.

	Male Athletes				Female Athletes				All Athletes
	Junior High School	High School	College	Masters	Junior High School	High School	College	Masters	Total
100m			109	167			94		370
100m Hurdles							120		120
110m Hurdles			138						138
Shuttle Hurdles			160				168		328
4x100m	912	6100	1694	216	912	6256	1516		17606
4x200m		2960	1116			32	721		4829
4x400m		3996	1992	168		6420	1844		14420
400m Hurdles		68	211			62	167		508
Sprint Medley			506				512		1018
4x800m		731	560			944	500		2735
Mile		42	41			45	45		173
4xMile			176						176
4x1500m							164		164
3000m		69				66	96		231
5000m			334				205		539
3000m Steeplechase			174				102		276
10,000m			127				109		236
Distance Medley		196	552	92		180	336		1356
5,000m Walk				20			23	42	85
10,000m Walk			27	30					57
Pole Vault		60	128			53	115		356
High Jump		29	180			49	182		440
Long Jump		48	165			51	186		450
Triple Jump		51	200			51	168		470
Shot Put		55	154			52	175		436
Discus		58	110			54	117		339
Hammer			114				146		260

Javelin	51	145			57	104			357
Total	912	14514	9113	693	912	14372	7915	42	48473

Table 4. Absolute number of injuries and relative injury rates (per 1000 competing athletes) between 2002 to 2004 at the Penn Relays Carnival in events for which at least one injury was reported.

Event	All injuries		Minor medical injuries		Major medical injuries		Minor orthopaedic injuries		Major orthopaedic injuries	
	Absolute	Relative*	Absolute	Relative*	Absolute	Relative*	Absolute	Relative*	Absolute	Relative*
100m	5	13.5	0	0.0	0	0.0	5	13.5	0	0.0
110m Hurdles	3	21.7	1	7.2	0	0.0	2	14.5	0	0.0
Shuttle Hurdles	6	18.3	3	9.1	0	0.0	3	9.1	0	0.0
4x100m	106	6.0	21	1.2	3	0.2	80	4.5	2	0.1
4x200m	15	3.1	1	0.2	1	0.2	13	2.7	0	0.0
4x400m	196	13.6	82	5.7	19	1.3	93	6.4	2	0.1
400m Hurdles	7	13.8	0	0.0	0	0.0	7	13.8	0	0.0
Sprint Medley	7	6.9	2	2.0	1	1.0	4	3.9	0	0.0
4x800m	38	13.9	26	9.5	1	0.4	11	4.0	0	0.0
Mile	3	17.3	0	0.0	1	5.8	2	11.6	0	0.0
4xMile	1	5.7	0	0.0	0	0.0	1	5.7	0	0.0
5000m	7	13.0	4	7.4	0	0.0	2	3.7	1	1.9
3000m Steeplechase	10	36.2	3	10.9	0	0.0	5	18.1	2	7.2
10,000m	3	12.7	1	4.2	0	0.0	2	8.5	0	0.0
Distance Medley	5	3.7	3	2.2	0	0.0	2	1.5	0	0.0
5,000m Walk	3	35.3	1	11.8	1	11.8	1	11.8	0	0.0
Pole Vault	5	14.0	1	2.8	0	0.0	3	8.4	1	2.8
High Jump	2	4.5	0	0.0	0	0.0	2	4.5	0	0.0
Long Jump	2	4.4	0	0.0	0	0.0	2	4.4	0	0.0
Triple Jump	5	10.6	0	0.0	0	0.0	5	10.6	0	0.0
Shot Put	2	4.6	0	0.0	0	0.0	2	4.6	0	0.0

*Relative injury rates reported as number of injuries per 1000 competing athletes.

Figure 1. Relative injury rates and sub-category injury rates by competition level and sex from the Penn Relays Carnival between 2002 and 2004. * indicates significant difference compared to college/elite female athletes ($p < 0.05$), # indicates significant difference compared to masters male athletes ($p < 0.05$), ^ indicates significant difference compared to college/elite males athletes ($p < 0.05$). Note that groups that were both the opposite sex and competitions level (i.e. masters male vs college/elite female) were not compared in the analysis. Masters level females were not included in this figure, as only one injury was sustained (a major medical injury) by this sub-group.