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TITLE

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

ABSTRACT

Background: Few studies have examined acute injuries in track and field in both elite and sub-elite athletes. **Purpose:** To observe the absolute and relative rates of injury in track and field athletes across a wide range of competition levels and ages during three years of the Penn Relays Carnival to assist with future medical coverage planning and injury prevention strategies. **Study design:** Descriptive epidemiology study. **Methods:** Over a 3-year period all injuries treated by the medical staff were recorded on a standardised injury report form. Absolute injury rates (absolute number of injuries) and relative injury rates (number of injuries per 1000 participants) were determined and odds ratios (OR) of injury rates were calculated between sexes, competition levels and events. Injuries were also broken down into major or minor medical or orthopedic injuries. **Results:** Throughout the study period 48,473 competing athletes participated in the Penn Relays Carnival, and 436 injuries were sustained. For medical coverage purposes, the relative rate of injury subtypes was greatest for minor orthopedic injuries (5.71 injuries per 1000 participants), followed by minor medical injuries (3.42 injuries per 1000 participants), major medical injuries (0.69 injuries per 1000 participants) and major orthopedic injuries (0.18 injuries per 1000 participants). College/elite level athletes displayed the lowest relative injury rate (7.99 injuries per 1000 participants), which was significantly less than high school (9.87 injuries per 1000 participants) and masters level athletes (16.33 injuries per 1000 participants). Males displayed a greater likelihood of suffering a minor orthopedic injury compared to females (OR = 1.36, 95% CI = 1.06 to 1.75; $\chi2 = 5.73$, $p = 0.017$) but were less likely to sustain a major medical injury (OR = 0.33, 95% CI = 0.15 to 0.75; $\chi2 = 7.75$, $p = 0.005$). Of the three most heavily participated in events, the 4 x 400m relay displayed the greatest relative injury rate (13.6 injuries per 1000 participants) compared to the 4 x 100 and 4 x 200m relay. **Conclusions:** Medical coverage teams for future large scale track and field events need to plan for at least two major orthopedic and seven major medical injuries per 1000 participants. Male track and field athletes, particularly masters level male athletes, are at greater risk of injury compared to other genders and competition levels.

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

Key terms: Epidemiology, injury, athletics, medical coverage

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

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

INTRODUCTION

Track and field is one of the most popular sports worldwide across a range of age groups.[1] Despite the well reported injury risk associated with track and field competition at the elite level,[1-3 5 14 25] reports in the literature mostly focus on observations from Olympic games, World and European championships,[1-3 14 17 25] with some exceptions[13 24 31] There is a risk of over- or under-estimating injury incidence from observational single-meet (Olympic, world championships) studies.[6] Additionally, these single-meet studies do not allow for the assessment of trends across time which requires studies of longer duration.[6 16 28] Furthermore, given the interest in preventing injuries in elite competitors, much of the injury epidemiology evidence has focused on this homogenous group of athletes with respect to age and performance.[1-3 25] Reports in younger (< 18 years)[15 23 28] and older (>40 years)[21 28] athletes, across a wide spectrum of pathologies, are limited. From a population health perspective, the prevention of injury in these cohorts is of far greater significance than the elite athlete population, as injury is often reported as a barrier for physical activity participation.[8 18] The limited observations of non-elite injury statistics also presents a challenge for institutes/organisations which require data to plan medical coverage in large track and field meets in sub-elite athletes. Much focus has centered on medical coverage of summer,[9] winter[12] and youth[7] Olympic and Paralympic[32] games. Reports on medical coverage issues in track and field at multiple levels of competition are less common.

The Penn Relays Carnival, held annually by the University of Pennsylvania, is the oldest and largest track and field competition in the United States. Between 2002 and 2004, over 48,000 athletes, ranging from junior high school to masters level, participated in the Penn Relays Carnival across 30 different track and field events.[28] The large number of athletes who participate in this event makes this event ideal for the observations of injury rates in track and field, and the diversity in the participant pool allows for comparisons across different age groups, sex, and event types. Furthermore, the size and breadth of the participant pool allows relative injury rates to be determined across a variety of cohorts and events, which can be helpful in the planning of medical coverage for future, large track and field events. The purpose of this study was to report the absolute number of injuries (absolute injury rate) and relative injury rates (number of injuries per 1000 participants) sustained in track and field events at the Penn Relays Carnival across a three year period. Comparisons were made between athletes of male and female sex, from different age groups, and in different events to determine which track and field athletes are at the greatest risk of injury. Injuries were also broken down into relevant sub-categories for further detailed analyses. A better understanding of the profile of injuries across a wide ranging demographic in track and field is required to better inform authorities as to which populations require a greater focus on preventative strategies and to give organisers of future track and field events objective data to plan medical coverage procedures.

MATERIALS & METHODS

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

Ethical approval

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

Data collection

Over a three-year period from 2002 to 2004, all injuries treated by the treatment team at the Penn Relays Carnival were classified and recorded, using a standardised reporting form. All injuries that resulted in cessation of participation in an event, as well as self-reported injuries were assessed by the treatment team. The team consisted of athletic trainers, emergency medical technicians, physical therapists, primary care physicians, podiatrists and orthopaedic surgeons. The type of injury, anatomic location, event in which the injury occurred, competition level (junior high school, ≤ 13 years of age; high school, 14 to 18 years; college/elite (including pre-Olympic/professional athletes), 19 to 40 years; or masters, > 40 years) and demographic data (i.e. age, sex) were recorded. During the same time period, athlete participation data (defined as competing athletes as per recent consensus statement[34]) was collected by the Penn Relays Carnival organisers and supplied to the investigators (Table 1).

Injury classification

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

Statistical Analysis

All athlete participation and injury information was entered into an Excel™ spreadsheet with patient identifiers removed. Injury rates were determined for different sexes (males, females), competition levels (junior high school, high school, college/elite, and masters) and the events during which the injury occurred. Comparisons of sex and competition level combinations were carried out in homogenous groups and were as follows: male masters vs male college/elite vs male high school; female college/elite vs female high school; male high school vs female high school; male college/elite vs female college/elite; male high school vs female high school. Due to junior high school athletes and masters females reporting relatively few injuries (three and one injuries/injury respectively) these cohorts were excluded from gender by competition analyses. Relative total injury rates were calculated and expressed as injuries per 1000 participants. The sub-categories of major/minor injuries considered medical/orthopedic are also reported as relative injury rates. Statistical analysis was performed using JMP version 10.0 Pro Statistical Discovery Software (SAS Inc.). Measures of association included odds ratios (OR), 95% confidence intervals (95% CI) and $\chi 2$-testing of injury rates by sex (male/female), competition level (junior high school/high school/college & elite/masters), and event (4x100m, 4x200m and 4x400m), with significance set at $p < 0.05$. When injury frequencies were too low to calculate $\chi 2$, Fisher's exact test was employed.

RESULTS

Athlete participation information

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

Injury data collection

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

Sex

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

Competition level

College/elite athletes were less likely to sustain an injury compared to high school (OR = 0.81, 95% 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 = 0.001) level athletes. Similarly college/elite athletes were less likely to sustain a minor medical injury compared to high school level athletes (OR = 0.56, 95% CI = 0.38 to 0.82; $\chi 2$ = 9.37, p = 0.002). High school athletes were less likely to sustain a major (OR = 0.05, 95% CI = 0.00 to 0.56; p = 0.003) or minor (OR = 0.43, 95% CI = 0.22 to 0.85; p = 0.012) orthopedic injury compared with masters level athletes.

Sex and competition level

The relative rates of injuries calculated by sex and competition level can be seen in Figure 1. Due to the low number of major medical and major orthopedic injuries sustained in each group, no comparisons were performed for this injury sub-category. College/elite females level athletes were less likely to sustain an injury compared to high school female athletes (OR = 0.71, 95% CI = 0.52 to 0.98; $\chi2 = 4.41$, $p = 0.036$). College males were more likely to sustain a minor orthopedic injury compared with college females (OR = 1.77, 95% CI = 1.13 to 2.79; $\chi2 = 6.3$, $p = 0.012$). With respect to minor medical injuries, college females were less likely to sustain this injury type compared to high school female level athletes (OR = 0.56, 95% CI = 0.32 to 0.98; $p = 0.039$). College males were also less likely to sustain this injury type compared with high school level male athletes (OR = 0.56, 95% CI = 0.33 to 0.93; $\chi2 = 4.28$, $p = 0.023$).

Event

Event participation data can be found in Table 3 and the absolute and relative incidence rates for all events for which at least one injury was recorded is presented in Table 4. When comparing total injuries of the three events with the highest participant numbers (4 x 100 m, 4 x 200 m and 4 x 400m relays), the 4 x 400 m relays involved a greater likelihood of injury compared to the 4 x 100 m relays (OR = 2.27, 95% CI = 1.79 to 2.88; $\chi2 = 48.65$, $p < 0.001$) and the 4 x 200m relay (OR = 4.42, 95% CI = 2.61 to 7.48; $\chi2 = 36.69$, $p < 0.001$). The 4 x 100m relay had a greater likelihood of injury compared to the 4 x 200 m relay (OR = 1.94, 95% CI = 1.13 to 3.34; $\chi2 = 6.00$, $p = 0.014$). The distribution of injuries sustained in the four major relay events (4 x 400m, 4 x 100m, 4 x 200m and 4 x 800m) amongst different genders and competition levels can be found as supplementary tables 1-4.

DISCUSSION

The major findings from the current study, which observed the incidence of injuries reported to medicial staff between 2002 and 2004 at the Penn Relays carnival, were that 1) female track and field athletes were generally less likely to sustain minor orthopedic injuries compared to their male counterparts; 2) college/elite level track and field athletes were significantly less likely to sustain injuries compared to younger (high school) and older (masters) athletes and; 3) for a track and field event of similar scope, one should plan and resource for major orthopedic and major medical incidents at a rate of at least 2- and 7-per 1000 participants respecitvely.

The observation that female track and field athletes were less likely to sustain orthopedic and lower body strain injuries compared to male athletes confirms earlier observations.[1 3 14 28] Studies examining the injuries sustained by elite athletes during the 2011 International Association of Athletics Federations (IAAF) World Athletics Championships[1] and 2012 European Athletics Championships[14], respectively, found that females were less likely to sustain an injury of any type compared with male athletes ($\chi2$ = 4.17, Ref [1]; $\chi2$ = 10.3, Ref [14]). The findings from the current study suggest that the reduced risk of injury in female athletes might be restricted to college/elite level athletes, as the injury rates of high school female athletes was not different to high school male athletes. That females were less likely to sustain a minor orthopedic injury is similar to observations from an earlier study examining the incidence of hamstring strain injuries in the same cohort.[28] In the aforementioned study,[28] male track and field athletes were found to be have a greater likelihood of sustaining a hamstring strain injury compared to females (OR = 1.68 to 1.79), which is somewhat similar to the between sex data presented in the current study for minor orthopedic injury (OR = 1.36). An additional post hoc sub-analysis, whereby hamstring strain injuries were removed, revealed no significant difference between lower limb strain injuries between male and female athletes (OR = 0.93, 95% CI = 0.50 to 1.75), suggesting that the sex bias towards injury might be mediated mostly by a greater likelihood for males to sustain hamstring strain injuries than females. More work is needed to confirm if the bias towards injury in male athletes is true for athletes of all ages, or whether it is only confined to those at the elite level. Regardless, the mechanims responsible for the lesser likelihood of injury in college/elite level track and field females athletes is worthy of investigation.

Advancing age is often idenfitied as a risk factor for many injury types in running based sports [4 29] and evidence from elite competitions suggest that track and field athletes over the age of 30 years are at an elevated risk of all injuries[1] or time-loss injuries[14] compared to their younger counterparts. Whilst the current study did not look directly at age, the split of participants into different competitions levels acording to age groups allows for some comparions across the age specturm of the competing athletes. The current study found that, compared to masters level male track and field athletes, college and high school athletes had a smaller likelihood of sustaining a minor orthopedic injury (OR ranging from 0.27 to 0.48). Despite the consistent identification of older athletes being at an increased risk of injury, in multiple sports[4 20 29] to the authors' knowledge, few studies[19 21 26] have been carried out to determine why, physiologically, older athletes are at greater risk of injury and this body of evidence is too limited to draw any discernable conclusions. The limited evidence base may be due, in part, to the classification of increasing age as a non-modifiable risk factor.[29] Whilst it is not possible to modify an individuals age, the physioloigical changes that occur in the ageing athlete (e.g. declines in strength, muscle voluntary activiation capacity, etc[10 27]), which might confer the increased risk of future injury, can most probably be ameliorated via intervention. For example, recent research in elite Australian footballers has found that older athletes in this cohort are exposed to a greater risk of hamstring injury compared to their younger counter-parts only if they also display low levels of eccentric strength.[30] The interaction of risk factors for injury in older athletes is certainly an area worthy of further exploration. Additionally, what is also required are longitudinal observations of track and field athletes, across the age spectrum, followed for multiple years, to determine age related declines in function that might predispose to injury. Whilst logistically and fiscally challenging, these barriers should not be a deterrant. Track and field is one of the most popular sports worldwide[28] and participation in the sport as an adolscent is associated with greater physical activity levels later in life.[33] As such, strategies to reduce the risk of injury in track and field, and thereby presumably increase ongoing participation, are important and should be a key focus of the major organisational (IAAF) and government bodies.

The difference in relative injury rates between high school, college/elite and masters athletes has implications for medical coverage. The current findings suggest that previous epidemiological reports in track and field athletes at the elite level[1-3 5 14 25] are not suitable data to utilise when planning medical coverage for competitions that involve younger or older athletes. For example, masters level athletes are more likely to sustain major and minor orthopedic injuries than their younger counterparts. Furthermore, individual events impose variable levels of injury risk. Table 4 from the current study provides an excellent resource on the relative incidence of injury in each event participated in across the three year observation period. This information could be used when calculating expected injury occurrences for particular events. If multiple events are running simultaneously, it may be wise to consider the proximity of medical support to events where injury occurrence is likely to be higher, as successfully employed previously during the winter youth Olympic games.[7]

As per previous work examining hamstring strain injury rates from the same cohort,[28] the 4 x 400 m relay was found to be the most injurious event compared to the two other most heavily participated events, the 4 x 100 and 4 x 200 m relays. Of interest, minor medical injuries featured far greater in the 4 x 400 m relay compared to the shorter distance relay events and explained the observed higher rates of all injury (Table 4). The majority of these minor medical injuries were made up of abrasions and spike lacerations. Such injury types are less common during the 4 x 100 and 200 m relays as athletes remain in their respective lanes during the duration of the event, minimising the risk of falls and close proximity to other competitiors' footwear. In general, the greater anaerobic fatigue experienced during 400 m racing[22] may impose an additional risk of injury above the other, shorter relay events. The link between fatigue and increased incidence of injury is established in other field-based team sports,[11 16 35] however the duration of the these sports (80-90 minutes) and physiological demands differ significantly compared with short duration high intensity sprint events. Yet a simialr pattern of elevated minor medical injury rates was observed for 800m x 4 realy, supporting the perported association between anaerobic fatigue and increased minor medical injury risk. As such? the possible link between anaerobic fatigue during during 400 m compared to 100 and 200 m sprint events and risk of injury requires further examination.

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

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