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Acute hamstring strain injury in track-and-field athletes: A 3-year observational study at the Penn Relay Carnival

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This study aimed to observe the incidence rates of hamstring strain injuries (HSIs) across different competition levels and ages during the Penn Relays Carnival. Over a 3-year period, all injuries treated by the medical staff were recorded. The type of injury, anatomic location, event in which the injury occurred, competition level, and demographic data were documented. Absolute and relative HSI (per 1000 participants) were determined, and odds ratios (ORs) were calculated between sexes, competition levels, and events. Throughout the study period 48 473 athletes registered to participate in the Penn Relays Carnival, with 118 HSIs treated by the medical team. High school girls displayed lesser risk of HSI than high school boys (OR = 0.55, $P = 0.021$), and masters athletes were more likely than high school- (OR = 4.26, $P < 0.001$) and college-level (OR = 3.55, $P = 0.001$) athletes to suffer HSI. The 4 × 400-m relay displayed a greater likelihood of HSI compared with the 4 × 100-m relay (OR = 1.77, $P = 0.008$). High school boys and masters-level athletes are most likely to suffer HSI, and there is higher risk in 400-m events compared with 100-m events.

Track and field is one of the most popular sports worldwide across a range of age groups (Alonso et al., 2012). Despite improvements in sports medicine knowledge and practice, injuries remain common (Alonso et al., 2009, 2010; Junge et al., 2009). Most reports in the literature on the incidence of hamstring strain injuries (HSIs) in track and field are limited to observations from single-meet events (e.g., the Olympic games and World Championships; Alonso et al., 2009, 2010, 2012; Junge et al., 2009) or retrospective data sets (Bennell & Crossley, 1996; Reid et al., 2012), which are often limited by reporting only thigh strains (Alonso et al., 2009, 2010; Junge et al., 2009). Epidemiological data collected from single-meet events are at risk of over- or underestimating HSIs, and studies of longer duration are important to assess trends in injury rates (Bjørneboe et al., 2014). Furthermore, most previous reports focus on elite competition (Alonso et al., 2009, 2010, 2012; Junge et al., 2009), which involves a mostly homogenous group of athletes with respect to age and performance. As a consequence, reports in junior- (< 18 years) and masters-level (> 40 years) competition are lacking.

The Penn Relays Carnival, held annually by the University of Pennsylvania, is the oldest and largest track-and-field competition in the U.S. The large number of athletes who participate in the Penn Relays Carnival makes this event ideal for the observations of acute HSI rates in track and field, and the diversity in the participant pool allows for comparisons across different age groups, sex, and event types. The purpose of this study was to determine the relative incidence rates of HSIs in track-and-field events at the Penn Relays Carnival. 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 HSI. A better understanding of the profile of HSI across a wide-ranging demographic in track and field may inform future preventive strategies.

Methods

Ethical approval

The Institutional Review Board at the University of Pennsylvania granted ethical exemption for the study based on the observational

Table 1. Participation data of athletes who competed in the Penn Relays Carnival between 2002 and 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	4473	3151	231	8163	312	4758	2697	25	7792	15 955
2003	312	4560	3124	242	8238	308	4563	2636	17	7524	15 762
2004	292	5481	2838	220	8831	292	5051	2582	0	7925	16 756
Total	912	14 514	9113	693	25 232	912	14 372	7915	42	23 241	48 473

nature of the investigation, given that no patient identifiers were collected.

Data collection

Over a 3-year period from 2002 to 2004, all injuries treated by the medical staff at the Penn Relays Carnival were classified and recorded by the treatment team, using a standardized reporting form. The type of injury, anatomic location, event in which the injury occurred, competition level [junior high school, ≤13 years of age; high school, 14–18 years; college/elite (including pre-Olympic/professional athletes), 19–40 years; or masters, >40 years] and demographic data (i.e., age, sex) were recorded. During the same time period, athlete participation data were collected by the Penn Relays Carnival organizers and supplied to the investigators (Table 1). Weather conditions were monitored across the 3-day period each year to account for year-to-year variability in temperature.

Definition of HSI

HSI was defined as an insult that was reported to have caused acute pain in the posterior thigh, resulting in immediate cessation from competition. Upon clinical examination, HSI was confirmed by a combination of pain with passive stretch of the hamstring muscle, pain and/or weakness of knee flexion, and tenderness on palpation to the affected area.

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. Relative HSI rates were calculated and expressed as injuries per 1000 participants. Statistical analysis was performed using JMP version 10.0 Pro Statistical Discovery Software (SAS Inc., Cary, North Carolina, USA). Measures of association included odds ratios (OR) and chi-square testing of HSI rates by sex, competition level (junior high school/high school/college and elite/masters), and event (4×100, 4×200, and 4×400 m), with significance set at $P < 0.05$.

Results

Athlete participation information

Across the 3-year observational period, 48 473 athletes registered to participate in the Penn Relays Carnival, with slightly more men ($n = 25\,232$) than women ($n = 23\,241$) competing (Table 1).

Weather conditions

Across the 3-year period, there was a gradual increase in 3-day average maximum temperature (year 1 = 17.0°C; year 2 = 20.7°C; year 3 = 25.2°C). There was no rainfall recorded on any of the days of the carnival across the observational period.

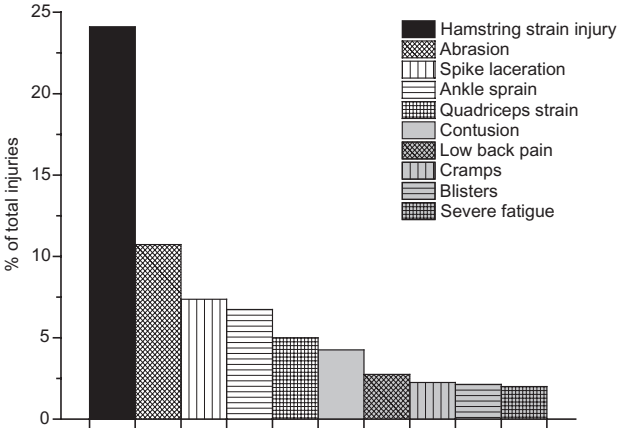

Fig. 1. The top 10 injuries presenting to the medical staff at the Penn Relays Carnival between 2002 and 2004, expressed as a percentage of total injuries.

Injury data collection

During the observational period of the study, there were 489 injuries treated by the medical staff. Figure 1 displays the 10 most common injuries treated by the medical team during the study. HSI was the most common injury evaluated, accounting for 24.1% ($n = 118$) of all injuries. HSIs accounted for over 75% of all lower limb strains treated.

Sex

The comparison of relative HSI rates can be found in Fig. 2. Over the duration of the 3-year observational period men displayed a greater likelihood of suffering HSI compared with female athletes [OR = 1.79, 95% confidence interval (CI) = 1.23–2.63; $\chi^2 = 9.353$, $P = 0.002$]. Given the large discrepancy in male and female masters athletes that has the potential to confound the previous analysis, a sex comparison with only high school and college athletes was also completed. In this subgroup, men were still at a greater risk of HSI than women (OR = 1.68, 95% CI = 1.14–2.47; $\chi^2 = 6.970$, $P = 0.009$).

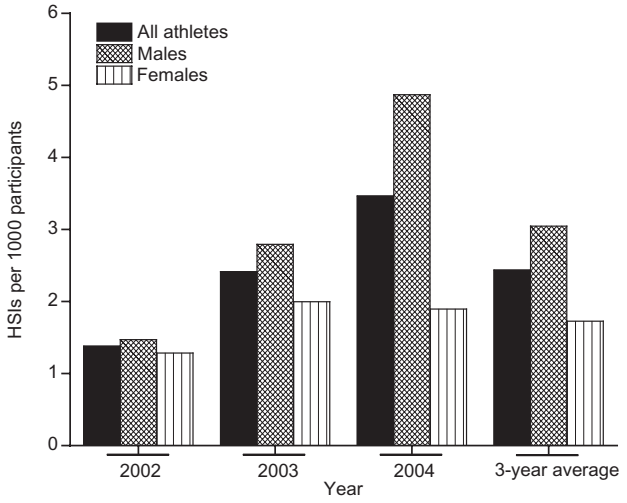

Fig. 2. Relative hamstring strain injury (HSI) rates by sex from the Penn Relays Carnival between 2002 and 2004.

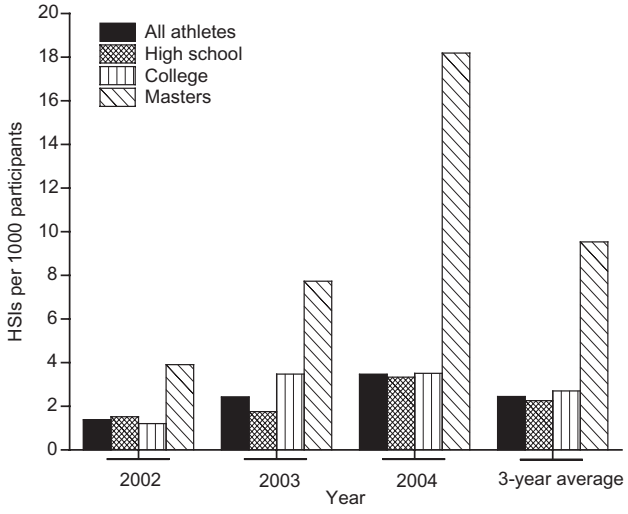

Fig. 3. Relative hamstring strain injury (HSI) rates by competition levels from the Penn Relays Carnival between 2002 and 2004. No "junior" athletes reported HSIs.

Competition level

The relative rates of HSI in high school-, college/elite-, and masters-level athletes are depicted in Fig. 3. It should be noted that no junior high school athletes were diagnosed as suffering HSI. Masters athletes were significantly more likely to sustain HSI compared with high school (OR = 4.26, 95% CI = 1.95–9.33; $\chi^2 = 15.64$, $P < 0.001$) and college/elite-level (OR = 3.55, 95% CI = 1.60–7.89; $\chi^2 = 11.02$, $P = 0.001$) athletes. There was no significant difference in the likelihood for high school- and college/elite-level athletes to suffer HSI (OR = 0.83, 95% CI = 0.57–1.22; $\chi^2 = 0.90$, $P = 0.342$).

Sex and competition level

The relative rates of HSI calculated by both sex and competition level can be seen in Fig. 4. It should be noted that no junior high school or masters women reported HSIs during the study period. Across the 3 years high school girls were at a lesser risk of HSI than their male counterparts (OR = 0.55, 95% CI = 0.33–0.92; $\chi^2 = 5.36$, $P = 0.021$); however, there was no significant difference between the HSI injury rates of college-level men and women (OR = 0.67, 95% CI = 0.37–1.23; $\chi^2 = 1.68$, $P = 0.195$).

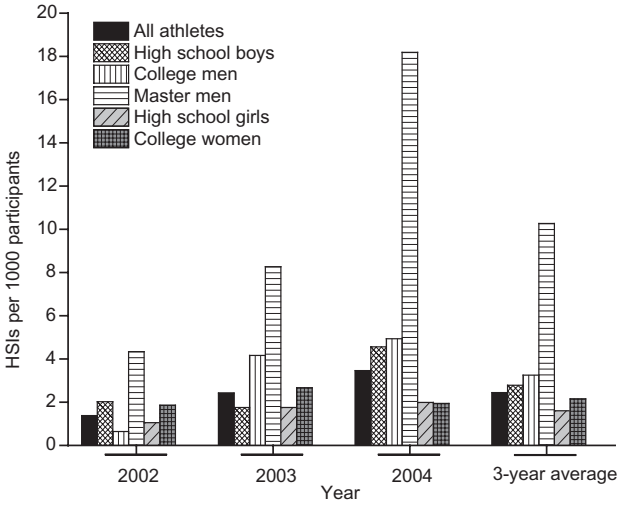

Fig. 4. Relative hamstring strain injury (HSI) rates by competition level and sex from the Penn Relays Carnival between 2002 and 2004. No "junior" or "masters women" reported HSIs.

Event

Event participation data can be found in Table 2. Of the three most heavily participated events, the 4×400-m relay displayed a higher risk to sustain HSI compared with the 4×100-m relay (OR = 1.77, 95% CI = 1.15–2.70; $\chi^2 = 7.05$, $P = 0.008$) but not compared with the 4×200-m relay (OR = 1.59, 95% CI = 0.83–3.04; $\chi^2 = 1.96$, $P = 0.162$; Fig. 5). There was no difference in the risk of HSIs between the 4×100 and the 4×200-m relay (OR = 0.89, 95% CI = 0.46–1.76; $\chi^2 = 0.10$, $P = 0.754$). Although participation rates in a number of other events were too low to run valid statistical analysis, the 100 m, 110-m hurdles, and triple jump all showed high relative rates of HSIs (Table 3).

Discussion

The aim of this study was to report the incidence of HSIs at the Penn Relays Carnival, one of the largest track-and-field meets in the world, over a 3-year period to better understand the HSI profile in track and field across a wide demographic of athletes. The major findings were that during the Penn Relays Carnival across 3 years of observation, (a) HSIs were the most commonly treated acute injury by the medical staff, (b) high school boys were more susceptible to HSIs than high school girls,

Table 2. Individual event participation data of athletes who competed in the Penn Relays Carnival between 2002 and 2004

Year	Male athletes				Female athletes				All athletes
	Junior high school	High school	College	Masters	Junior high school	High school	College	Masters	Total
100 m			109	167			94		370
100-m hurdles							120		120
110-m hurdles			138						138
Shuttle hurdles			160				168		328
4 × 100 m	912	6100	1694	216	912	6256	1516		17 606
4 × 200 m		2960	1116			32	721		4829
4 × 400 m		3996	1992	168		6420	1844		14 420
400-m hurdles		68	211			62	167		508
Sprint medley			506				512		1018
4 × 800 m		731	560			944	500		2735
Mile		42	41			45	45		173
4 × mile			176						176
4 × 1500 m							164		164
3000 m		69				66	96		231
5000 m			334				205		539
3000-m steeplechase			174				102		276
10 000 m			127				109		236
Distance medley		196	552	92		180	336		1356
5000-m walk				20			23	42	85
10 000-m 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	14 514	9113	693	912	14 372	7915	42	48 473

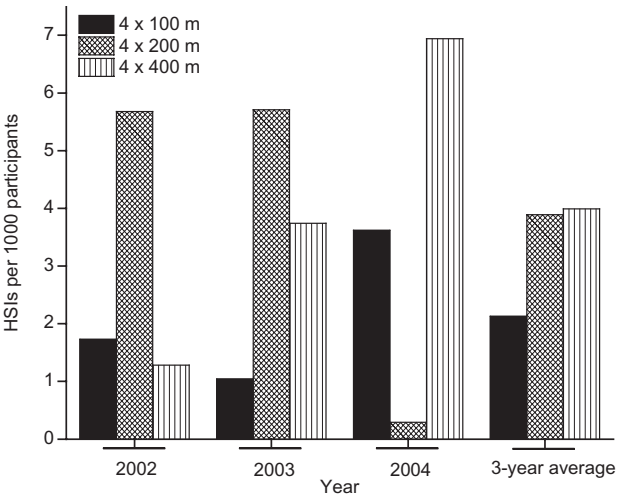

Fig. 5. Relative hamstring strain injury (HSI) rates during sprint relay events from the Penn Relays Carnival between 2002 and 2004.

Table 3. Absolute number and relative hamstring strain injury rates between 2002 and 2004 at the Penn Relays Carnival for each event

Event	Hamstring strain injury incidence	
	Absolute	Relative*
100 m	3	8.1
110-m hurdles	1	7.2
Triple jump	2	4.3
4 × 400-m relay	52	3.6
Pole vault	1	2.8
4 × 200-m relay	11	2.3
Shot put	1	2.3
Long jump	1	2.2
4 × 100-m relay	36	2.0
Sprint medley	2	2.0
4 × 800-m relay	4	1.5
Distance medley	2	1.5

*Relative injury rates reported as number of hamstring strain injuries per 1000 participants.

and (c) masters-aged athletes were more susceptible than high school- and college-aged athletes to HSI.

Not surprisingly, older athletes reported the highest incidence of HSI in the current study, which is consistent with previous reports having identified increasing age as a significant independent risk factor for HSI in other sports (Orchard, 2001; Woods et al., 2004; Gabbe et al., 2006b). One investigation into why older athletes are at a greater risk of HSI has reported that older (≥25 years) community-level Australian footballers displayed reduced hip flexor flexibility and increased body weight compared with their younger (≤20 years old) counterparts (Gabbe et al., 2006a), and this may partly explain

the association between HSI and increasing age. However, a stronger explanation, particularly for masters-aged athletes (> 40 years old), may be related to lower levels of eccentric knee flexor strength compared with younger competitors (i.e., high school- and college-aged athletes) having an associated increased risk of HSI (Croisier et al., 2008; Sugiura et al., 2008). Eccentric quadriceps strength has been reported to begin to decline, from the forth decade for men and the fifth decade for women, at a rate of ~8–10% per decade (Lindle et al., 1997), and the same may be true for the knee flexors. Further work is required to determine why older athletes are most susceptible to HSIs so that prevention strategies might be optimized (Opar et al., 2012).

The observation that high school boys are more susceptible than high school girls to HSI is of interest, particularly given the dearth of HSI literature examining female athletes. It should be noted that the direct comparison between sexes across all age groups is confounded by the fact that male masters participated in greater numbers compared with female masters, and as such the comparison between men and women with masters-level athletes exclude is more robust. In support of this potential sex effect, previous evidence has shown that elite-level male track-and-field athletes were more prone to HSI than their female counterparts (Alonso et al., 2012). Interestingly, in the current study there was no difference between male and female college athletes in the risk to sustain HSI, which may suggest that more mature female athletes are just as likely to sustain HSI compared with men; however, this would require further confirmation. Numerous studies comparing neuromuscular hamstring function across sexes have identified a number of deficits that may increase the risk of anterior cruciate ligament injury in women (Hewett et al., 2006). From the current data, it would appear that these neuromuscular deficits do not augment the risk of HSI in female athletes above that of male athletes. It would stand to reason that the injury etiology of HSIs would be similar regardless of sex, so the reason for the discrepancy between high school-aged male and female athletes remains unknown.

Interestingly, the relative incidence of HSIs was greater in the 4×400-m relay compared with the 4×100-m relay. This relationship suggests that the 4×400-m relay, which requires high-speed running and greater anaerobic-induced fatigue (Hirvonen et al., 1992), place athletes at an elevated risk of HSI. It should be noted, however, that fatigue of different energy systems may also contribute to the incidence of HSI during shorter sprint races (i.e., 100 m), and as such continued efforts to better understand the potential role of fatigue in the etiology of HSI is a critical area for further research.

There are some limitations inherent to this investigation. First, the reporting of injuries was dependent on athletes seeking a medical assessment or treatment, and as such it is impossible to determine what percentage of injuries was captured by the medical team. The medical team actively evaluated athletes who started but did not finish a race because of injury. As a result, the observations from this data are valid only for HSIs that cause immediate cessation of activity and should not be used to compare rates of more chronic injuries (such as lower back-related posterior thigh pain). Although clinical judgment was used to diagnose HSI, no follow-up was performed on injured athletes to ascertain the duration they were limited from activity following their injuries. Further, it was also not possible to ascertain accurate data from injured athletes as to their HSI history, which is another variable that may have influences the current findings. The discrepancy in male and female masters participants has the potential to skew the HSI rates toward high levels in male athletes; however, data examining a sex effect was also examined with masters athletes excluded (i.e., high school, college athletes only) and the effect of sex still persisted. Finally, the number of events each athlete participated in prior to injury during the carnival was not known. It is highly likely that athletes from different competition levels would have participated in a varying number of events, and this is not accounted for in the current work.

In conclusion, to the knowledge of the authors, this study is the largest observational injury study in track and field to date. The data presented here indicate that men and masters-level athletes are most likely to suffer HSI. Furthermore, 400-m relays involve a significantly greater incidence of HSIs compared with 100-m relay. The provision of preventative strategies should be targeted toward these athletes who have been identified as highest risk. Investigations into female athletes are lacking, and although their risk of HSI was lower than male athletes, HSI was still common and this population warrants further attention. Efforts to reduce the incidence of this prevalent injury in track and field are important at the elite level as well as at the community level to ensure ongoing participation in sport across the life span.

Perspectives

Although HSIs are known as a common injury type in track and field, there are limited epidemiological papers that mostly focus on the elite-level athletes at single-meet events. More detailed studies are required to better understand the incidence of HSIs across different sexes, age groups, and levels of performance. The current paper is the first paper to examine the rates of acute HSIs in track and field across a number of years and across a wide spectrum of athletes ($n = 48\,473$). This paper provides empirical evidence that men and master athletes are at an elevated risk to sustain HSI compared with women and younger athletes, respectively. Of the most participated events, the 4×400-m relay was found to significantly increase the risk to sustain HSI compared with a 4×100-m relay. This finding implicates both

high-speed running and fatigue in the etiology of HSI. The large participant numbers and multiple year data collection make this one of the more definitive epidemiology papers in track and field to date. Clinically, these data suggest that greater attention be given to prevention of HSI in older male athletes, particularly those running 400-m races. It would be suspected that eccentric strength interventions would be most successful; however, the factors that increase the risk of older runners are still to be determined.

Key words: Epidemiology, muscle injury, athletics.

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