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TITLE PAGE

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

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Hamstring injury in track and field athletes

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ABSTRACT

Purpose: To observe the incidence rates of hamstring strain injuries (HSIs) across different competition levels and ages during the Penn Relays Carnival. **Methods:** 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 (OR) were calculated between genders, competition levels and events. **Results:** 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 females displayed lesser risk of HSI than high school males (OR = 0.55, p = 0.021), and masters athletes were more likely than high school (OR = 4.26, p < 0.001) and college (OR = 3.55, p = 0.001) level athletes to suffer a HSI. The 4x400m relay displayed a greater likelihood of HSI compared to the 4x100m relay (OR = 1.77, p = 0.008). **Conclusions:** High school males and masters levels athletes are most likely to suffer HSI, and there is higher risk in 400m events compared to 100m events.

KEY TERMS

Epidemiology, muscle injury, athletics.

INTRODUCTION

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; Alonso et al., 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., 2012; Alonso et al., 2009; Alonso et al., 2010; 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; Alonso et al., 2010; Junge et al., 2009). Epidemiological data collected from single-meet events are at risk of over- or under-estimating HSIs and studies of longer duration are important to assess trends in injury rates (Bjorneboe et al., 2012). Furthermore, most previous reports focus on elite competition (Alonso et al., 2012; Alonso et al., 2009; Alonso et al., 2010; 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 (>40 years) level competition are lacking.

The Penn Relays Carnival, held annually by the University of XXXX, is the oldest and largest track and field competition in the United States. 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.

MATERIALS & METHODS

Ethical approval

The Institutional Review Board at the Queensland University of Technology 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 medical staff at the Penn Relays Carnival were classified and recorded by the treatment team, using a standardised reporting form (supplementary material). 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, gender) were recorded. During the same time period athlete participation data was collected by the Penn Relays Carnival organisers and supplied to the investigators (Table 1). Weather conditions were monitored across the three day period each year to account for year-to-year variability in temperature.

Definition of hamstring strain injury

An 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 genders (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.). Measures of association included odds ratios (OR) and $\chi 2$-testing of HSI rates by sex, competition level (junior high school/high school/college & elite/masters), and event (4x100m, 4x200m and 4x400m), with significance set at $p < 0.05$.

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).

Weather conditions

Across the three year period there was a gradual increase in 3-day average maximum temperature (Year 1 = 17.0^{o}C; Year 2 = 20.7^{o}C; Year 3 = 25.2^{o}C).There was no rain fall recorded on any of the days of the carnival across the observational period.

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 Figure 2. Over the duration of the three year observational period males displayed a greater likelihood of suffering a HSI compared to female athletes (OR = 1.79, 95% CI = 1.23 to 2.63; $\chi 2 = 9.353$, p = 0.002). Given the large discrepancy in male and female masters athletes which has the potential to confound the previous analysis, a gender comparisons with only high school and college athletes was also completed. In this subgroup, males were still at a greater risk of HSI than females (OR = 1.68, 95% CI = 1.14 to 2.47; $\chi 2 = 6.970$, p = 0.009).

Competition level

The relative rates of HSI in high school, college/elite, and masters level athletes is depicted in Figure 3. It should be noted that no junior high school athletes were diagnosed as suffering a HSI. Masters

athletes were significantly more likely to sustain a HSI compared to high school (OR = 4.26, 95% CI = 1.95 to 9.33; $\chi 2 = 15.64$, $p < 0.001$) and college/elite (OR = 3.55, 95% CI = 1.60 to 7.89; $\chi 2 = 11.02$, $p = 0.001$) level athletes. There was no significant difference in the likelihood for high school and college/elite level athletes to suffer a HSI (OR = 0.83, 95% CI = 0.57 to 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 Figure 4. It should be noted that no junior high school or masters women reported HSIs during the study period. Across the three years high school females were at a lesser risk of HSI than their male counterparts (OR = 0.55, 95% CI = 0.33 to 0.92; $\chi 2 = 5.36$, $p = 0.021$), however there was no significant difference between the HSI injury rates of college level male and females (OR = 0.67, 95%CI = 0.37 to 1.23; $\chi 2 = 1.68$, $p = 0.195$).

Event

Event participation data can be found in Table 2. Of the three most heavily participated events, the 4x400m relay displayed a higher risk to sustain a HSI compared to the 4x100m relay (OR = 1.77, 95%CI = 1.15 to 2.70; $\chi 2 = 7.05$, $p = 0.008$) but not compared to the 4x200m relay (OR = 1.59, 95%CI = 0.83 to 3.04; $\chi 2 = 1.96$, $p = 0.162$) (Figure 5). There was no difference in the risk of HSIs between the 4x100m and 4x 200 m relay (OR = 0.89, 95% CI = 0.46 to 1.76; $\chi 2 = 0.10$, $p = 0.754$). Whilst participation rates in a number of other events were too low to run valid statistical analysis, the 100m, 110m 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 three 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 three years of observation: 1) HSIs were the most commonly treated acute injury by the medial staff, 2) high school males were more susceptible to HSIs than high school females, and 3) masters aged athletes were more susceptible than high school and college aged athletes to HSI.

Not surprsingly, 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 (Gabbe, et al., 2006; Orchard, 2001; Woods et al., 2004). 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 bodyweight compared to their younger (≤ 20 years old) counterparts (Gabbe, et al., 2006) 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 to 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 males and the fifth decade for females, 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 optimised.

The observation that high school males are more susceptible than high school females to HSI is of interest, particularly given the dearth of HSI literature examining female athletes. It should be noted that the direct comparison between genders across all age groups is confounded by the fact that masters males participated in greater numbers compared to female masters, and as such the

comparison between males and females with masters level athletes exclude is more robust. In support of this potential gender 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 a HSI which may suggest that more mature female athletes are just as likely to sustain a HSI compared to males, however this would require further confirmation. Numerous studies comparing neuromuscular hamstring function across genders have identified a number of deficits that may increase the risk of anterior cruciate ligament injury in females.(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 the male athlete. It would stand to reason that the injury aetilogy of HSIs would be similar regardless of gender, so the reason for the descrepancy between high school aged male and female athletes remains unknown.

Interestingly, the relative incidence of HSIs was greater in the 4 x 400m relay compared to the 4 x 100m relay. This relationship suggests that the 4 x 400m 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.100m) and as such continued efforts to better understand the potential role of fatigue in the aetiology of HSI is a critical area for further research.

There are some limitations inherent to this investigation. Firstly the reporting of injuries was dependent upon athletes seeking a medical assessment or treatment and as such it is impossible to determine what percentage of injuries were captured by the medical team. The medical team actively evaluated athletes who started but did not finish a race due to injury. As a result the observations from this data is 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). Whilst clinical judgement 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 which may have influences the current findings. The discrepancy in male and female masters particpants has the potential to skew the HSI rates towards high levels in male athletes, however data examining a gender effect was also examined with masters athletes excluded (i.e. high school, college athletes only) and the effect of gender 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.

Inconclusion, to the knowledge of the authors, this study is the largest observational injury study in track and field to date. The data presented here indicates that males and masters levels athletes are most likely to suffer HSI. Furthemore, 400m relays involve a signifcantly greater incidence of HSIs compared to 100m relay. The provision of preventative strategies should be targeted towards 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 is important at the elite level as well as at the community level to ensure ongoing particpation in sport across the lifespan.

PERSPECTIVE

Whilst hamstring strain injuries are known as a common injury type in track and field there are limited epidemiological papers which mostly focus on the elite level athletes at single meet event. More detailed studies are required to better understand the incidence of hamstring strain injuries across different genders, age groups and levels of performance. The current paper is the first paper to examine the rates of acute hamstring strain injuries 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 males and master athletes are at an elevated risk of sustain a HSI compared to female and younger athletes respectively. Of the most participated events, the 4x400m relay was found to significantly increase the risk of sustain a HSI compared to a 4x100m relay. This finding implicates both high speed running

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

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

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

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

Figure 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.

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

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

Figure 4. Relative hamstring strain injury (HSI) rates by competition level and gender from the Penn Relays Carnival between 2002 and 2004. No 'Junior' or 'Masters Women' reported HSIs.

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