Comparison of Hamstring Strain Injury Rates Between Male and Female Intercollegiate Soccer Athletes

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Comparison of Hamstring Strain Injury Rates Between Male and Female Intercollegiate Soccer Athletes

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Background: Hamstring strains are common among soccer athletes, and they have a high incidence of recurrence. Among American collegiate soccer players, men have an overall higher incidence rate of hamstring strains than women.

Purpose: This research compares the hamstring strain injury rates in event and athlete characteristics between male and female college soccer athletes.

Study Design: Descriptive epidemiology study.

Methods: Data describing partial and complete hamstring strains were obtained from the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) for men's and women's soccer from 2004 to 2009. Incidence rate ratios (IRRs) comparing the incidence of hamstring strains between the sexes as well as during games versus practices and the preseason versus the in-season were calculated. χ^2 tests were used to compare the occurrence of hamstring strains across different event and athlete characteristics.

Results: Men were 64% more likely than women to sustain a hamstring strain (IRR, 1.64; 95% CI, 1.37-1.96). Men had significantly higher rates of hamstring strains than women during both games (IRR, 2.42; 95% CI, 1.82-3.23) and practices (IRR, 1.34; 95% CI, 1.06-1.68). There were no differences between men and women in injury rates during the preseason, but men were significantly more likely to sustain a hamstring strain during the in-season (IRR, 1.98; 95% CI, 1.56-2.52). Men had a significantly higher proportion of recurrent hamstring strains compared with women (men, 22%; women, 12%; $P = .003$). There were no significant differences in the distribution of strains in event or athlete characteristics between men and women for first-time or recurrent hamstring strains.

Conclusion: In collegiate soccer, men have significantly higher rates of hamstring strains than women, and regardless of the recurrence status, the event and athlete characteristics were similar for both sexes. Identifying common characteristics may assist in the targeted development of preventive and rehabilitative programs as well as continued research on hamstring strains among collegiate soccer players.

Keywords: sports injury; male; female; epidemiology

Hamstring strains are a very common injury in soccer. Among professional soccer athletes, hamstring strains account for as many as 16% of all reported injuries and 42% of all reported muscle injuries.[1,7,8,17,28,36,37,39] Incidence rates among professional male athletes vary from 0.35 to 1.5 per 1000 hours of soccer,[1,28,37] but they are considerably lower (0.02 per 1000 hours) among female professional athletes.[24] Similar differences between sexes have been reported in collegiate soccer.[6] Hamstring strain recurrence among soccer players is also very high and accounts for 12% to 48% of all reported hamstring strains.[1,6,7,18,29,39]

To explain injury causation, an injury model must include intrinsic and extrinsic factors. Intrinsic factors are those that come from within the athlete, such as flexibility and strength. Extrinsic factors are those that occur in the athlete's environment, such as time of game or player position. Unique combinations of intrinsic and extrinsic factors are required for each athlete to be predisposed to a specific injury. Strong risk factors are those that occur most frequently among each individual athlete's injury model.[26] It is important to understand the nuances of the injury event to develop an accurate causal model

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that may be used to design evidence-based preventive and rehabilitative programs.

Hamstring strains among soccer players have been described predominantly among professional soccer players.[1,17,39] Woods et al[39] exclusively described the circumstances surrounding the occurrence of a hamstring strain. Most injuries occurred during games, specifically at the end of each half. The majority of hamstring strains occurred during running activities, and the distribution was similar among field position players.[39] The population was limited to professional male soccer players, and the data did not separate first-time from recurrent hamstring strains.

Given the limitations in the current literature, it is unknown whether a hamstring injury is influenced by the athlete's sex. This study analyzed the hamstring strains that were reported to the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) during the 2004 to 2009 competitive collegiate soccer seasons. The primary purpose of this study was to compare hamstring strain rates between male and female collegiate soccer players.

MATERIALS AND METHODS

The injury and exposure data were collected annually during the 2004 to 2009 seasons by the ISS. For the purposes of this study, only the data acquired during the traditional fall collegiate soccer seasons were used for analysis. The ISS collects exposure and injury data from a national volunteer sample of NCAA institutions via an Internet-based application. Each year, a diverse sample of Division I (DI), II (DII), and III (DIII) institutions provides data to the ISS for men's and women's soccer. During the 5 years of data collection, the division structure of ISS-participating schools for men's soccer was 12.0% (DI), 4.7% (DII), and 9.9% (DIII) of the number of sponsoring institutions. For women's soccer, the division structure of ISS-participating schools was 10.5% (DI), 4.6% (DII), and 8.8% (DIII) of the number of sponsoring institutions.[23]

Data for each injury event as well as athlete-exposure data are entered by members of the medical staff at each participating institution. Details of this system, including sampling and data collection methods, are outlined in detail elsewhere.[25]

For each injury entered in the ISS, the injured body part, type of injury, and recurrence status are specified. Per the ISS definition, a hamstring injury was reported if it occurred during an activity in an organized intercollegiate practice or game that resulted in the inability to participate for at least 1 day beyond the day of injury. Possible hamstring injuries include complete tear, contusion, myositis ossificans, partial tear, spasm, and tendinitis. Only hamstring injuries classified as partial tears or complete tears as assessed by a certified athletic trainer or physician were included in this analysis. The recurrence status is separated into 4 categories: new, recurrent, recurrent from previous year, and recurrent from before participation at college. All hamstring strains classified as recurrent, recurrent from previous year, and recurrent from before participation in college were combined for analysis into a single category of recurrent strain. To calculate incidence rates, the ISS defined an athlete-exposure (AE) as 1 athlete participating in 1 organized practice or competition in which he or she is exposed to the possibility of an athletic injury.

TABLE 1
Event Characteristics and Categories Used During Data Analysis

Variable	Variable Levels
Season	Preseason
	In-season (in-season/postseason)
Event type	Game
	Practice
Practice type	Regular
	Scrimmage
	Walk-through
Practice segment	Drill (individual drill/team drill)
	Conditioning
	Warm-up
Time of game	First half (warm-up/first half)
	Second half (second half/overtime)
Field location (games only)	Defensive end
	Offensive end
Player position (games only)	Defender
	Forward
	Midfield
	Goalkeeper
Soccer activities	Ball handling/dribbling
	Defending
	Passing/shooting (passing/receiving pass/shooting)
	Running activities (general play/conditioning)

The event and athlete characteristics and their respective categories were standardized by the ISS for all reported injuries during participation in soccer. Specifically, we analyzed the following characteristics: season, event type, practice type, practice segment, time of game, field location, player position, and soccer activity. Because of the low counts of hamstring strain within certain categories, one or more categories was combined. The operational definitions for the categories of each characteristic that were used for data analysis are shown in Table 1.

Statistical Analysis

The incidence rates of hamstring strains by sex were calculated for total exposures, competition and practice exposures, and preseason and in-season exposures using the unweighted counts per 1000 AEs. Incidence rate ratios (IRRs) adjusted for division and academic year were calculated.

The Datalys Center calculated the national estimates of hamstring strain by weighting the data based on poststratification by division, academic year, and the underreporting of injuries.[25] The formula for the sampling weight that adjusted for the yearly variation in the division structure was the inverse of the sampling proportions for each division per year. To account for underreporting, a previous validation analysis of the ISS suggested that it captures 88.2% of all time-loss medical care injury events.

TABLE 2
Rates per 1000 Athlete-Exposures (AEs) of Hamstring Strains Among Collegiate Soccer Players by Select Exposures and Sex

	Injuries, n	AEs, n	Injury Rate (per 1000 AEs)	Adjusted Incidence Rate Ratio[a] (95% CI)
Total	519	1,083,752	0.479	
Male	309	527,194	0.586	1.64 (1.37-1.96)
Female	210	556,558	0.377	Referent
Game				
Male	139	114,034	1.20	2.42 (1.82-3.23)
Female	71	136,837	0.500	Referent
Practice				
Male	170	413,460	0.411	1.34 (1.06-1.68)
Female	130	419,721	0.310	Referent
Preseason				
Male	121	147,577	0.820	1.04 (0.79-1.37)
Female	98	150,397	0.651	Referent
In-season				
Male	188	379,623	0.495	1.98 (1.56-2.52)
Female	103	406,161	0.253	Referent

[a]Adjusted by division and academic year.

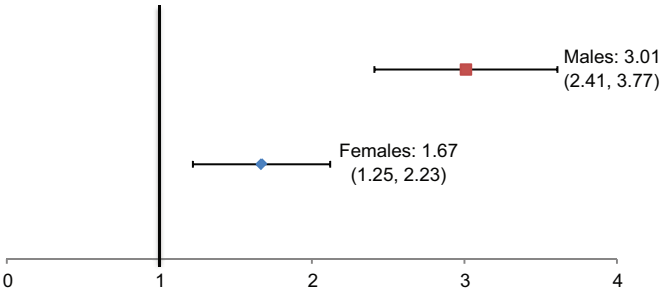

Figure 1. Incidence rate ratios and corresponding 95% confidence intervals for hamstring strains among National Collegiate Athletic Association (NCAA) soccer players during games versus practices adjusted for division and academic year.

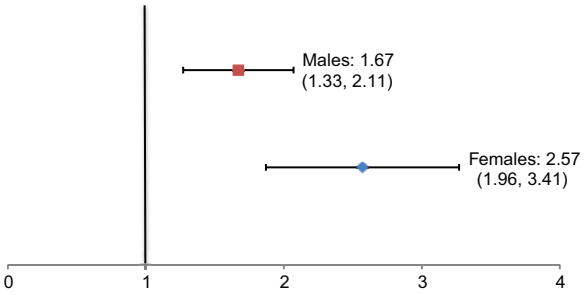

Figure 2. Incidence rate ratios and corresponding 95% confidence intervals for hamstring strains among National Collegiate Athletic Association (NCAA) soccer players during the preseason versus the in-season adjusted for division and academic year.

Therefore, the weighted counts were scaled up by a fixed constant of 1/0.882.[23] χ^2 analyses of the national estimates of hamstring strains were used to determine if the distribution of hamstring strains across the categories of each characteristic was independent of sex. These analyses were performed separately for first-time and recurrent hamstring strains. If cell counts for event data were ≤ 5, a Fisher exact test was performed to assess for differences between sexes. Data were analyzed using SAS Version 9.1 (SAS Institute Inc, Cary, North Carolina).

RESULTS

Hamstring Strain Incidence Rates

Participating schools in the ISS reported a total of 519 hamstring strains and 1,083,752 exposures. Men were 64% more likely than women to sustain a hamstring strain (IRR, 1.64; 95% confidence interval [CI], 1.37-1.96). Men had significantly higher rates of hamstring strains than women during games and practices (Table 2). There were no differences between sexes in the injury rates during the preseason, but men were significantly more likely to sustain a hamstring strain during the season (Table 2). Both men and women had significantly higher incidence rates of hamstring strains during games compared to practices (Figure 1) and during the preseason compared to the in-season (Figure 2).

Hamstring Strain Event Factor Frequencies

There was a national estimate of 6776 hamstring strains (95% CI, 6723-6828) among all NCAA soccer teams. Men accounted for 4032 strains (59.5%), and women composed the remaining 2744 (40.5%). There were no differences in the distribution of strains in the injury characteristics between the sexes for first-time or recurrent hamstring strains. There was a significant difference in the distribution of recurrent hamstring strains between men and

TABLE 3
National Estimates of Hamstring Strain Frequencies and 95% Confidence Intervals (in Parentheses) for Event Characteristics

	First-Time Hamstring Strains		Recurrent Hamstring Strains	
Event Factor	Male	Female	Male	Female
Season				
Preseason	41.1 (34.3-47.9)	48.9 (41.0-56.8)	38.5 (27.8-49.3)	36.4 (16.3-56.4)
In-season	58.9 (52.1-65.7)	51.1 (43.2-59.1)	61.5 (50.7-72.2)	63.6 (43.5-83.6)
Event type				
Game	42.8 (36.2-49.5)	34.4 (26.8-42.1)	50.7 (38.9-62.6)	50.5 (28.5-72.4)
Practice	57.1 (50.5-63.8)	65.6 (57.9-73.2)	49.2 (37.4-61.1)	49.5 (27.5-71.5)
Practice type				
Regular	92.2 (87.6-96.7)	93.7 (89.8-97.6)	86.3 (72.2-100)	100 (0-100)
Scrimmage	5.9 (2.2-9.6)	4.9 (1.4-8.5)	9.3 (0-23.3)	—
Walk-through	1.9 (0-4.7)	1.4 (0-3.2)	4.3 (3.6-5.0)	—
Practice segment				
Conditioning	26.9 (18.5-35.4)	28.2 (17.9-38.6)	24.6 (11.4-37.8)	37.3 (7.2-67.5)
Drill	68.5 (59.5-77.3)	66.7 (55.9-77.5)	68.9 (49.9-87.8)	53.7 (23.7-83.6)
Warm-up	4.6 (0.1-9.2)	5.1 (0.5-9.5)	6.6 (0-20.1)	8.9 (0-26.2)
Time of game				
First half	46.9 (35.1-58.9)	37.2 (22.8-51.4)	42.1 (24.1-60.1)	23.5 (4.4-42.6)
Second half	53.1 (41.1-64.9)	62.8 (48.5-77.1)	57.9 (39.8-75.9)	76.5 (57.4-95.6)
Field location				
Defensive	49.8 (36.8-62.8)	59.8 (43.5-76.1)	41.1 (21.3-60.9)	65.7 (31.9-99.3)
Offensive	50.2 (37.1-63.2)	40.2 (23.9-56.5)	58.9 (39.0-78.7)	34.3 (0.6-68.0)
Player position				
Defender	32.5 (21.9-43.0)	32.9 (20.1-45.7)	27.2 (11.0-43.3)	14.5 (0-33.5)
Forward	28.6 (18.9-38.4)	36.8 (23.6-50.1)	50.7 (33.4-68.1)	47.2 (23.2-71.3)
Goalkeeper	0.01 (0.0-1.6)	—	—	—
Midfield	38.9 (28.5-49.2)	30.2 (17.6-42.8)	22.1 (5.5-38.6)	38.2 (15.6-60.8)
Soccer activity				
Ball handling	7.7 (4.2-11.2)	9.7 (4.7-14.7)	3.0 (0-7.25)	—
Defending	12.5 (7.9-17.1)	7.1 (3.4-10.7)	11.7 (3.8-19.7)	18.2 (0-38.4)
Passing/shooting	10.4 (6.3-14.5)	11.8 (6.7-16.7)	3.7 (0-8.7)	6.1 (0-14.6)
Running activities	69.4 (63.1-75.4)	71.4 (63.6-79.9)	81.5 (68.2-94.1)	75.7 (54.4-97.9)

women ($P = .003$), as men had a higher frequency of recurrent hamstring strains compared with women (men, 20%; women, 10%). Frequencies of national estimates and 95% CIs are listed in Table 3.

DISCUSSION

Our results agree with recent research that men have an overall higher incidence rate of hamstring strains than women in collegiate soccer.[6] This was confirmed for the practices and games as well as during the season. Interestingly, both sexes had a significantly greater incidence rate during games as compared with practices, but the incidence of hamstring strains was greater during the preseason, when there were no games, compared with the in-season. Recurrence was the only characteristic that was different between sexes, as men had a disproportionately larger frequency of recurrent strains.

Direct comparisons of our results with previous studies are difficult. Frequently, epidemiological studies refer to thigh injuries with minimal distinction between specific muscle groups during the data analysis. Furthermore, incidence rates of hamstring strains have not been commonly reported in the literature. When reported, the hours of participation have been used as the exposure units for the denominator.[1,28,37] Incidence rates have varied among male professional soccer players from 0.35 to 1.5 hamstring strains per 1000 hours of soccer participation[1,28,37] and 0.2 hamstring strains per 1000 hours of soccer participation among professional female soccer players.[24] Our analysis used AEs as predetermined by the ISS, which defines an AE as 1 athlete participating in 1 activity for any length of time. Therefore, we cannot directly compare values with different units of measure. Also, our population consisted of American collegiate athletes that included both men and women. Previous research using this population reported similar results of men having a higher incidence rate of hamstring strains (IRR, 1.62; 95% CI, 1.28-2.05).[6]

Our observation of an increased frequency of hamstring strains during practices as compared with games is similar to previous studies among professional soccer athletes reporting 2 to 3 times more strains during practices.[17,36] These distributions are misleading, however, as men

(IRR, 3.01; 95% CI, 2.41-3.77) and women (IRR, 1.67; 95% CI, 1.25-2.24) were significantly more likely to sustain a hamstring strain during games than practices. The discrepancy between the injury frequency and incidence rates may be explained by the difference in the number of exposures. During the data collection period, there were 3 times as many opportunities (exposures) to be injured during practices. This is similar to professional soccer players who are exposed 5 to 6 times more hours during practices compared with games.[8,10,15,19] Consequently, there is a higher frequency of strains reported during practices. The incidence rate accounts for the differences in exposures during practices and games, thereby normalizing the injury frequency. This permits a fair comparison of the injury incidence across different event characteristics.

Differences in activity intensity between practices and games may explain the differences in the incidence rate within each sex. Among professionals of both sexes, there is an increased volume of high-intensity runs and an increased frequency of extremely large exercise-to-rest ratios during games as compared with practices.[3,13] The influence of fatigue on game-related physical activities and technical performance has been documented.[27,30] If these descriptions are true among collegiate soccer athletes, then the more intense activity during games may be more likely to cause muscle fatigue. Thus, athletes may become more susceptible to a hamstring strain during games as opposed to practices.

When considering only games, men were 2.42 times more likely to sustain a hamstring strain than women. Potential differences in game-related activities may explain the increased incidence rate among men. A comparison of data within the literature suggests that male professional athletes participate in a larger volume of high-intensity runs and sprinting activities during each half and throughout the game as compared with female professional athletes.[21,27] Because of their relatively slow recovery from repeated sprints,[2] men may have fatigued more quickly, resulting in decreased eccentric hamstring strength and kinetic and kinematic adjustments in the sprinting mechanics.[32-34] Our results support this hypothesis, as men had a fairly even distribution of hamstring strains between game halves, which agrees with the professional soccer literature.[39] Women, however, had a larger proportion of first-time strains in the second half (62%), and this was magnified for recurrent strains (76%). These explanations, however, must be interpreted with caution, as they were not statistically significant because of large CIs.

When assessing the incidence rates for the time of season, both sexes had a higher incidence rate of hamstring strains during the preseason compared with the in-season. Also, the preseason was the only event factor that had similar incidence rates between sexes. While a recent study of professional European soccer teams indicates an increased incidence of hamstring strains during the season,[8] other authors have reported findings similar to ours of an increased hamstring strain incidence during the preseason.[17,36] As noted by Volpi et al[36] in an assessment of professional Italian soccer leagues, the preseason is often overintense, and the athletes are not compliant with their pre-established training programs. In collegiate soccer, the preseason lasts approximately 2 weeks compared with approximately 6 weeks for professional soccer, so Volpi et al's[36] statements may be magnified in collegiate soccer. The influence of a shortened preseason on the occurrence of hamstring strains would be similar for men and women because the NCAA rules dictate similar schedules.

Using national estimates, an increased proportion of recurrent hamstring strains were observed among men. If collegiate male athletes are similar to professionals and perform more high-intensity activities,[21,27] the lingering impairments from previous hamstring strains[4,5,20,40] may be more likely to result in a recurrent strain. This is especially true considering the aforementioned kinetic and kinematic changes in running that accompany muscle fatigue during soccer activities.[34] Inadequate rehabilitation must also be considered, not only for the impairments identified in the literature but also toward re-establishing the injured athlete's baseline fitness.[17] Perhaps end stages of rehabilitation should include more high-intensity intermittent activities, especially for men, to replicate their specific activity patterns upon a full return to soccer activities. Furthermore, a functional test that replicates the physical demands of soccer by taxing the aerobic and anaerobic energy systems, such as the Yo-Yo intermittent recovery test,[22] may be useful in determining medical clearance after a hamstring strain.

When reviewing the literature for risk factor analysis and treatment efficacy, authors have rarely differentiated between first-time and recurrent strains. This may be necessary to control for external influences on the results. There is variability in the muscle's intrinsic characteristics, as athletes with a history of a previous hamstring strain demonstrate decreased strength and flexibility compared with athletes without a history.[5,20,40,41] Furthermore, previous strains have commonly been identified as a risk factor for subsequent hamstring injuries.[9,11,12,14,35,38] Hamilton et al[16] argue, however, that typical statistical analyses of previous injuries as risk factors are biased by individual predispositions to injury. Prior injury may not necessarily be a risk factor for a recurrent injury, but it may be a surrogate for an individual athlete's unique predisposition for a specific injury, such as a hamstring strain.[16] Thus, injury models may differ between the injury's recurrence status or by an individual athlete's unique risk factors toward hamstring strains. Future research must use prospective individualized clinical data to identify the determinants of hamstring strains.

Given that this is a descriptive epidemiological study using a general sports injury database, the study is observational research that may be considered hypothesis generating and needing further analytic study. These results may identify those at greatest risk and provide clues for making hypotheses on the relationships between event and athlete characteristics and hamstring strain. We believe that our results identify that men have a greater incidence of hamstring strains than women, specifically during games. Furthermore, this is the first evidence that men and women have a greater incidence of hamstring strains during games compared with practices and

during the preseason as compared with the in-season. Future research should capitalize on these findings to design prospective studies that will improve our understanding of the determinants of hamstring strains while preventing or controlling for potential confounding factors. Until then, the identification of these common characteristics may guide the development of prevention and rehabilitation strategies.[31]

Limitations

The group reporting the injury data for this study is composed of a volunteer sample of athletic trainers at NCAA institutions. Although adjustments were made to account for the variability in participating institutions from each division, the results may not be representative of all collegiate soccer players, and thus, a sampling bias may have occurred. Various information biases might have also occurred. Clinical assessment and data entry relied upon the education and interpretation of the individual athletic trainers. The ISS did not provide a specific definition, using patient history or a list of impairments, to assist in a definitive assessment of a hamstring strain. Similarly, no formal definitions were provided to assist the medical staff with choosing the appropriate category of each characteristic to describe the event. Therefore, misclassification of the outcome may have occurred, but there is no evidence to suggest that the misclassification differed by sex. Furthermore, only injuries that are reported to the athletic trainer or that result in an actual time loss of at least 1 day were included in the dataset. Lastly, in analyzing incidence rates, first-time and recurrent hamstring strains could not be calculated separately because the AEs were not identified by recurrence status.

CONCLUSION

Using a large 5-year sample of intercollegiate soccer players, we provided more evidence that men have a higher incidence rate of hamstring strains overall as well as during games, practices, and the in-season compared with women. Both men and women were more likely to sustain a hamstring strain during games compared with practices and during the preseason as compared with the in-season. We observed no differences between the sexes by the event and athlete characteristics describing first-time or recurrent hamstring strains. The proportion of recurrent hamstring strains, however, was significantly greater among men as compared with women. These findings provide evidence to assist in the development of further research on hamstring strains as well as the design and implementation of preventive and rehabilitation programs.

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REFERENCES

1. Arnason A, Gudmundsson A, Dahl HA, Johannsson E. Soccer injuries in Iceland. *Scand J Med Sci Sports*. 1996;6(1):40-45.
2. Billaut F, Bishop D. Muscle fatigue in males and females during multiple-sprint exercise. *Sports Med*. 2009;39(4):257-278.
3. Casamichana D, Castellano J, Castagna C. Comparing the physical demands of friendly matches and small-sided games in semiprofessional soccer players. *J Strength Cond Res*. 2012;26(3):837-843.
4. Croisier JL. Factors associated with recurrent hamstring injuries. *Sports Med*. 2004;34(10):681-695.
5. Croisier JL, Forthomme B, Namurois MH, Vanderthommen M, Crielaard JM. Hamstring muscle strain recurrence and strength performance disorders. *Am J Sports Med*. 2002;30(2):199-203.
6. Cross KM, Gurka KK, Conaway M, et al. Hamstring strain incidence among genders and sports in NCAA athletics. *Athl Train Sports Health Care*. 2010;2(3):124-130.
7. Ekstrand J, Hagglund M, Walden M. Epidemiology of muscle injuries in professional football (soccer). *Am J Sports Med*. 2011;39(6):1226-1232.
8. Ekstrand J, Hagglund M, Walden M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med*. 2011;45(7):553-558.
9. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Intrinsic risk factors for hamstring injuries among male soccer players: a prospective cohort study. *Am J Sports Med*. 2010;38(6):1147-1153.
10. Faude O, Junge A, Kindermann W, Dvorak J. Injuries in female soccer players: a prospective study in the German national league. *Am J Sports Med*. 2005;33(11):1694-1700.
11. Gabbe BJ, Bennell KL, Finch CF, Wajswelner H, Orchard JW. Predictors of hamstring injury at the elite level of Australian football. *Scand J Med Sci Sports*. 2006;16(1):7-13.
12. Gabbe BJ, Finch CF, Bennell KL, Wajswelner H. Risk factors for hamstring injuries in community level Australian football. *Br J Sports Med*. 2005;39(2):106-110.
13. Gabbett TJ, Mulvey MJ. Time-motion analysis of small-sided training games and competition in elite women soccer players. *J Strength Cond Res*. 2008;22(2):543-552.
14. Hagglund M, Walden M, Ekstrand J. Injury incidence and distribution in elite football: a prospective study of the Danish and the Swedish top divisions. *Scand J Med Sci Sports*. 2005;15(1):21-28.
15. Hagglund M, Walden M, Ekstrand J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *Br J Sports Med*. 2006;40(9):767-772.
16. Hamilton GM, Meeuwisse WH, Emery CA, Steele RJ, Shrier I. Past injury as a risk factor: an illustrative example where appearances are deceiving. *Am J Epidemiol*. 2011;173(8):941-948.
17. Hawkins RD, Fuller CW. A prospective epidemiological study of injuries in four English professional football clubs. *Br J Sports Med*. 1999;33(3):196-203.
18. Hawkins RD, Hulse MA, Wilkinson C, Hodson A, Gibson M. The association football medical research programme: an audit of injuries in professional football. *Br J Sports Med*. 2001;35(1):43-47.
19. Jacobson I, Tegner Y. Injuries among Swedish female elite football players: a prospective population study. *Scand J Med Sci Sports*. 2007;17(1):84-91.
20. Jonhagen S, Nemeth G, Eriksson E. Hamstring injuries in sprinters: the role of concentric and eccentric hamstring muscle strength and flexibility. *Am J Sports Med*. 1994;22(2):262-266.
21. Krustrup P, Mohr M, Ellingsgaard H, Bangsbo J. Physical demands during an elite female soccer game: importance of training status. *Med Sci Sports Exerc*. 2005;37(7):1242-1248.
22. Krustrup P, Mohr M, Nybo L, et al. The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. *Med Sci Sports Exerc*. 2006;38(9):1666-1673.
23. Kucera KL, Marshall SW, Bell DR, et al. Validity of soccer injury data from the National Collegiate Athletic Association's Injury Surveillance System. *J Athl Train*. 2011;46(5):489-499.

24. Le Gall F, Carling C, Reilly T. Injuries in young elite female soccer players: an 8-season prospective study. *Am J Sports Med*. 2008;36(2):276-284.
25. Marshall S, Corlette J, eds. *Fall Sports Qualifying Report: 2004-2009 Academic Year*. Indianapolis: Datalys Center for Sports Injury and Prevention; 2009.
26. Meeuwisse WH. Assessing causation in sport injury: a multifactorial model. *Clin J Sport Med*. 1994;4:166-170.
27. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci*. 2003;21(7):519-528.
28. Morgan BE, Oberlander MA. An examination of injuries in Major League Soccer: the inaugural season. *Am J Sports Med*. 2001; 29(4):426-430.
29. Orchard J, Seward H. Epidemiology of injuries in the Australian Football League, seasons 1997-2000. *Br J Sports Med*. 2002;36(1):39-44.
30. Rampinini E, Impellizzeri FM, Castagna C, Coutts AJ, Wisloff U. Technical performance during soccer matches of the Italian Serie A league: effect of fatigue and competitive level. *J Sci Med Sport*. 2009;12(1):227-233.
31. Rothman KJ, Greeland S, Lash TL, eds. *Modern Epidemiology*. Philadelphia: Lippincott, Williams & Wilkins; 2008.
32. Small K, McNaughton L, Greig M, Lovell R. The effects of multidirectional soccer-specific fatigue on markers of hamstring injury risk. *J Sci Med Sport*. 2010;13(1):120-125.
33. Small K, McNaughton L, Greig M, Lovell R. Effect of timing of eccentric hamstring strengthening exercises during soccer training: implications for muscle fatigability. *J Strength Cond Res*. 2009;23(4):1077-1083.
34. Small K, McNaughton LR, Greig M, Lohkamp M, Lovell R. Soccer fatigue, sprinting and hamstring injury risk. *Int J Sports Med*. 2009;30(8):573-578.
35. Verrall GM, Slavotinek JP, Barnes PG, Fon GT, Spriggins AJ. Clinical risk factor for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging. *Br J Sports Med*. 2001;35(6):435-440.
36. Volpi P, Melegati G, Tornese D, Bandi M. Muscle strains in soccer: a five-year survey of an Italian major league team. *Knee Surg Sports Traumatol Arthrosc*. 2004;12(5):482-485.
37. Walden M, Hagglund M, Ekstrand J. UEFA Champions League study: a prospective study of injuries in professional football during the 2001-2002 season. *Br J Sports Med*. 2005;39(8):542-546.
38. Warren P, Gabbe BJ, Schneider-Kolsky M, Bennell KL. Clinical predictors of time to return to competition and of recurrence following hamstring strain in elite Australian footballers. *Br J Sports Med*. 2010;44(6):415-419.
39. Woods C, Hawkins RD, Maltby S, et al. The Football Association Medical Research Programme. An audit of injuries in professional football: analysis of hamstring injuries. *Br J Sports Med*. 2004; 38(1):36-41.
40. Worrell TW, Perrin DH, Gansneder BM, Gieck JH. Comparison of isokinetic strength and flexibility measures between hamstring injured and noninjured athletes. *J Orthop Sports Phys Ther*. 1991;13(3): 118-125.
41. Yamamoto T. Relationship between hamstring strains and leg muscle strength: a follow-up study of collegiate track and field athletes. *J Sports Med Phys Fitness*. 1993;33(2):194-199.