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Intrinsic and Extrinsic Risk Factors for Muscle Strains in Australian Football*

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ABSTRACT

Muscle strains are common injuries in Australian football and other sports involving sprinting. Between 1992 and 1999, 83,503 player-matches in the Australian Football League were analyzed for risk of muscle strain injuries using logistic regression analysis. There were 672 hamstring, 163 quadriceps, and 140 calf muscle strain injuries. All three types of muscle strains were associated with significant risk factors. For all injuries, the strongest risk factor was a recent history of that same injury and the next strongest risk factor was a past history of the same injury. History of one type of muscle strain increased the risk for certain types of other muscle strains. Age was a risk factor for hamstring and calf muscle strains (even when adjusted for injury history) but was not a risk factor for quadriceps muscle strains. Quadriceps muscle injuries were more common in shorter players and were more likely when there had been less rainfall at the match venue in the previous week. Quadriceps muscle injuries were significantly more common in the dominant kicking leg, whereas hamstring and calf muscle injuries showed no difference in frequency between the dominant and nondominant legs.

Muscle strains are common injuries in Australian football players and in other athletes involved in sports that include sprinting. The muscle groups that are commonly injured in Australian football players are the hamstring, the quadriceps, the calf (triceps surae), and the adductors,[20] the same muscle groups that are commonly injured in other athletes.[6]

Australian football is a unique game played outdoors on natural grass on a large playing field that varies from 140 to 185 meters in length. The most important means of ball progression is punt kicking. In terms of physiologic demands, the sport is similar to soccer, with repetitive kicking and running efforts. The regular season consists of 22 matches per team, with teams playing once weekly. There are 18 players on the field in each team, with up to 4 players on an interchange bench. Games are played over four quarters lasting 20 minutes each, plus time added for breaks in play. Australian football is known to have higher rates of muscle strains than rugby football.[23]

The pathogenesis of hamstring muscle injuries has been studied as extensively as any other single sports injury, but it is still not clear. Sports medicine dogma advises that low muscle strength, poor flexibility, lack of warm-up, failure to stretch, and muscle fatigue are risk factors for muscle strains, and that these injuries can therefore be prevented. The scientific evidence to support these beliefs is sadly lacking. The only reversible risk factor for hamstring muscle injuries for which there is any good degree of clinical evidence is low strength. Past injury history is a recognized risk factor but is not reversible.[2,5,6,21] There are a number of prospective studies suggesting that low hamstring muscle strength is associated with future injury,[3,4,9,18,26] but one recent study in Australian football contradicts these.[2] It is likely that injury history, age, muscle fiber type, and player speed are all confounders of hamstring and quadriceps muscle strength, and no study to date has been able to take account of all these factors together.

Less is known about the risk factors for strains of muscle groups other than the hamstring muscles. A radiologic study found that the rectus femoris muscle was the location of clinical quadriceps strains, whereas calf strains commonly occurred in the distal muscle-tendon junction of the medial head of the gastrocnemius muscle.[24] Rectus femoris muscle strain has been shown to occur in either the distal muscle-tendon junction or in the midbelly of the muscle as a lesion of the intramuscular indirect head tendon.[8,10]

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The aim of this study was to analyze potential risk factors for muscle strain injury using data obtained prospectively from an injury surveillance system.

MATERIALS AND METHODS

This was a prospective cohort study involving players and matches in the Australian Football League (AFL) between 1992 and 1999. A total of 2255 matches were studied (all regular season first and second grade matches that occurred from 1992 through 1999 except for the final round of each season) involving 1607 individual players. Preseason and finals games were not included.

Dependent variables were the occurrence of a hamstring, quadriceps, or calf muscle strain during a player-match exposure during the study period. Injury occurrence was determined using the AFL Injury Surveillance System, which has been in place since 1992.[20] The survey methods have been described in detail previously.[16,19] The injury definition required the muscle strain to be severe enough to cause a subsequent game to be missed, hence the exclusion of games in the final round of each season in the analysis (as there were no games the following week). The injury incident was closed once the player returned to play, with any further episodes that caused subsequent missed games defined as a further injury (recurrence). During the seasons under study, 96% of all games missed by players were accounted for by the injury surveillance system.[17]

The diagnosis of a muscle strain was clinical and made by the club medical staff (team doctor), with radiologic investigations optional. "Back-related" muscle strains (localized muscle signs in conjunction with positive signs in the lumbar spine) were included. Specific lumbar abnormalities (for example, disc prolapse) that may have referred pain to a muscle group were not included. Injuries that did not occur during matches (such as training injuries) were not included in this study.

The other major muscle group that was commonly injured was the adductor group (groin area). Adductor muscle strains were not included in this analysis because the diagnosis and onset of injury were often not specific. Whereas calf, hamstring, and quadriceps muscle strains usually have an onset in a specific match, groin injuries often have an insidious onset. In addition, many doctors have reported difficulty in differentiating a muscle strain from a tendon tear, tendinitis, and osteitis pubis, which is not surprising as these diagnoses are often coexisting.[14] The diagnosis for hamstring, calf, and quadriceps muscle strains is occasionally difficult to make in a clinical setting, but there is usually a far greater level of diagnostic clarity than for groin injuries.

Potential risk factors for injury (in a specific player-match exposure) were divided into intrinsic (player-related) and extrinsic (match-related) variables. Intrinsic variables considered for inclusion in logistic regression equations were history of injury to the hamstring, calf, and quadriceps muscles; age; height; weight; body mass index; and race. Player details were obtained from an AFL official database; players were not examined for this study. Injury history for each of the muscle groups was subdivided into recent injuries (within the previous 8 weeks) and past injuries (more than 8 weeks ago). Injury side and dominant kicking foot were not considered in the main equation, but for each injury type these factors were the subject of a separate analysis.

Extrinsic variables considered for inclusion were grade of match, time of match (day or night), month, maximum and minimum temperatures on the day of the match, maximum wind speed on the day of the match, and rainfall and evaporation measures on the day of the match and in the previous 7, 14, 28, 90, and 365 days. Daily weather variables were measured during the period of study by the Australian Bureau of Meteorology (Sydney, Australia) for the cities of Adelaide, Brisbane, Canberra, Geelong, Hobart, Melbourne, Perth, and Sydney at central locations in each city.

Variables were initially correlated with injury occurrence using *t*-tests. Variables based on continuous data were converted to binary variables for consideration in a logistic regression procedure. The logistic regression procedure was done with a forward stepwise method, with a significance level of 0.05 required for inclusion.

RESULTS

There were 83,503 player-matches (games) with all variables available for analysis. During matches under study, 672 hamstring, 163 quadriceps, and 140 calf muscle strain injuries occurred.

For inclusion in logistic regression equations, height was divided into shorter stature (182 cm or less, which was the 33rd percentile) and average/taller stature. Other variables were divided based on mean values (for example, mean age = 23.53 years, mean 7-day rainfall = 13.28 mm).

The results of logistic regression equations are detailed in Table 1. Hamstring muscle injury was associated with recent hamstring injury in the previous 8 weeks, past hamstring injury, past calf injury, and older player age.

Calf muscle injury was associated with recent calf injury in the previous 8 weeks, past calf injury, older player age, and past quadriceps muscle injury.

Quadriceps muscle injury was associated with recent quadriceps injury in the previous 8 weeks, past quadriceps injury, hamstring muscle injury in the previous 8 weeks, shorter players, and low rainfall at the match venue in the previous week.

Quadriceps muscle injury was more common in the dominant kicking leg (relative risk, 2.13; 95% confidence interval, 1.59 to 2.86), whereas hamstring and calf muscle injuries were distributed equally between legs.

Some variables that could not be entered into logistic regression equations as significant showed a significant association with injury in the *t*-tests (Table 2). There was a trend toward more calf injuries occurring on drier days with higher temperatures. There were more hamstring and calf injuries in players with higher body mass index; however, as body mass index correlated highly with player age and previous injury, this association may be a result of confounding.

TABLE 1
Analysis of Significant Variables in Logistic Regression Equations[a]

Injury	Variable	B	SE	Risk ratio	95% CI
Hamstring	Hamstring injury within previous 8 weeks	1.85	0.10	6.33	5.21– 7.70
	Past hamstring injury (>8 weeks ago)	0.88	0.08	2.42	2.05– 2.85
	Older player (>23 years)	0.29	0.08	1.34	1.14– 1.57
	Past calf injury (>8 weeks ago)	0.32	0.13	1.37	1.08– 1.76
Quadriceps	Quadriceps injury within the previous 8 weeks	2.75	0.21	15.61	10.27–23.74
	Past quadriceps injury (>8 weeks ago)	1.30	0.18	3.67	2.60– 5.19
	Hamstring injury within the previous 8 weeks	0.73	0.32	2.08	1.12– 3.86
	Low rainfall at match venue in the previous 7 days	0.37	0.18	1.45	1.01– 2.08
	Shorter player (≤182 cm)	0.39	0.16	1.48	1.09– 2.02
Calf	Calf injury within the previous 8 weeks	2.19	0.29	8.94	5.10–15.66
	Past calf injury (>8 weeks ago)	1.45	0.20	4.28	2.91– 6.29
	Older player (>23 years)	0.95	0.20	2.59	1.75– 3.83
	Past quadriceps injury (>8 weeks ago)	0.56	0.22	1.74	1.14– 2.67

[a] B, regression coefficient; SE, standard error; 95% CI, 95% confidence interval.

TABLE 2
Analysis of *t*-tests for Selected Variables

Variable	Hamstring injury		Quadriceps injury		Calf injury	
	t	*P*	*t*	*P*	*t*	*P*
Player age	8.99	0.000	0.10	0.919	7.88	0.000
Height	−1.81	0.071	−2.39	0.017	−0.25	0.806
Weight	3.17	0.002	−0.88	0.378	1.46	0.144
Body mass index	8.13	0.000	1.01	0.311	2.15	0.032
Month of year	−0.355	0.737	0.32	0.752	−0.53	0.958
Rainfall on day of game	0.85	0.397	−0.41	0.682	−1.15	0.249
Rainfall in previous 7 days	−1.03	0.305	−2.72	0.007	0.13	0.896
Evaporation in previous 7 days	0.59	0.953	−1.53	0.126	0.28	0.780
Maximum temperature on day of game	1.12	0.263	−1.50	0.133	1.84	0.067

DISCUSSION

Based on the analysis of this study, intrinsic (player-related) factors are more predictive of muscle strain injury than are extrinsic (environment-related) factors. This study confirms previous findings that a history of injury to a muscle group (hamstring, calf, or quadriceps) is the most important risk factor for future injury of that group.

A history of previous calf muscle injury was independently predictive of hamstring muscle injury, and a history of quadriceps muscle injury was independently predictive of calf muscle injury. A recent hamstring muscle injury was a risk factor for quadriceps muscle injury. It is possible that after injury, changes occur in the biomechanics of running that predispose athletes to injury in different muscle groups. It is also likely that there are confounding factors that were not included in the equations that are predictors of all muscle strains. Player maximum speed is a likely risk factor for all muscle strain injuries, and there may be genetic types that are at increased risk for all muscle strains; for example, blood group O has been associated with tendon rupture.[12]

The finding that injury history is such a strong risk factor for muscle strains shows that this factor must be considered when other variables are studied. Although numerous prospective studies have found an association between low hamstring muscle strength and hamstring injury,[3,4,9,18,26] past injury has also been associated with low hamstring muscle strength[11] and may be a confounder. Muscle strength (particularly of type II fibers) is known to decrease with age,[13] with the implication that age may be a confounder of low muscle strength, or that relative weakness may be a mechanism by which older players are more likely to sustain hamstring and calf muscle injuries. Contracted muscle is known to resist more force than relaxed muscle,[7] adding biologic plausibility to low muscle strength being a risk factor for muscle strain injury. There is only one study suggesting that correcting muscle strength deficits can lower the injury rate.[9]

In this study, age (when considered independently of past history) was a risk factor for hamstring and calf muscle strains but not for quadriceps muscle strains. This finding is consistent with the theory that abnormalities of the lumbar spine are implicated in the development of muscle strains, since the lumbar nerve roots of L5 and S1, which supply the hamstring and calf muscles, are more likely to be affected by age-related spinal degeneration than the nerve supply of the quadriceps muscles (L2, L3, and L4). The age-related loss of muscle strength is known to be caused by denervation of type II muscle fibers.[13] A plausible mechanism for the increased age-related susceptibility is low lumbar degeneration leading to L5 and S1 nerve impingement, leading to hamstring and calf muscle fiber denervation, and then leading to decreased muscle strength.

Quadriceps muscle injuries are related to dry weather and kicking (in the dominant kicking leg). It has not been established whether, in a kicking injury, the quadriceps muscles fail 1) during ball contact, 2) during the backswing phase of kicking, or 3) during the kicking foot ground-contact phase in the final step before the backswing. The association with dry weather suggests that the mechanism of quadriceps muscle strains while kicking may involve a closed chain activity, as in 3. It is also possible that a greater rate of deceleration at the final step of the kicking leg somehow changes the biomechanics of the kick and makes a quadriceps muscle strain more likely. Quadriceps muscle strains were also more likely in shorter players, which may also possibly be related to deceleration. Anecdotal evidence suggests that calf muscle strains generally occur during acceleration, hamstring muscle strains occur during maximal speed sprinting or bending forward to pick up the ball at speed, and quadriceps muscle strains occur during kicking or deceleration. Quadriceps muscle strains appear to be more common during kicks when running at a fast speed than during kicks from a standing start (such as those performed by a punter in American football). The forces acting on the various muscle groups during these activities cannot be directly measured, and hence little is known about why muscles are likely to fail.

Further study is recommended to determine whether ball inflation pressure is a risk factor for quadriceps muscle strain, which would be expected if the muscle fails during the ball-contact phase. A lowered ball pressure results in the ball deforming more, increasing the time of foot-to-ball contact.[1] This may lower the peak force transmitted from the leg to the ball, and vice versa. A wet ball may be expected to increase the force involved because of the increased mass of the ball, but this study did not find an increase in quadriceps muscle strains on wet days.

Previous correlation study using this same cohort has found that quadriceps and calf muscle strains (but not hamstring muscle strains) are more likely in players based in northern (warmer) cities.[16] Further study is in progress to directly measure ground hardness at matches to assess its relationship to injuries, particularly lower-limb noncontact injuries. The pathogenesis of noncontact injury is not currently well understood. Some of these injuries may be directly related to contact between the player and the playing surface, whereas others may be caused entirely by the internally created forces of muscle contraction.

There was no significant relationship between maximum temperature on the day of the match and the risk of muscle strains. Although this finding is not conclusive, since temperature at the time of injury was not measured, it does suggest that temperature is probably not a strong risk factor. Isometrically preconditioned muscle has been shown to require a greater force to cause strain injury,[22] but passively warmed muscle requires less force to cause strain injury.[15,25] The true value of warm-up in prevention of muscle strain injury is not known, but active warm-up is more likely to be of value than passive warm-up (which would be provided by a warm day).

In conclusion, previous muscle strain injury is a strong risk factor for injury in the same muscle group and in some cases confers increased risk to other muscle groups. Calf and hamstring muscle injuries (but not quadriceps muscle injuries) are more common in older players. Quadriceps muscle injuries (but not calf or hamstring muscle injuries) are more common in the dominant leg and are related to kicking in Australian football.

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