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The Effect of Previous Hamstring Strain Injuries on the Change in Eccentric Hamstring Strength During Preseason Training in Elite Australian Footballers

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Background: Hamstring strain injuries (HSIs) are the most common injury type in Australian football, and the rate of recurrence has been consistently high for a number of years. Long-lasting neuromuscular inhibition has been noted in previously injured athletes, but it is not known if this influences the athlete's adaptive response to training.

Purpose: To determine if elite Australian footballers with a prior unilateral HSI (previously injured group) display less improvement in eccentric hamstring strength during preseason training compared with athletes without a history of HSIs (control group).

Study Design: Cohort study; Level of evidence, 2.

Methods: A total of 99 elite Australian footballers (17 with a history of unilateral HSIs in the previous 12-month period) participated in this study. Eccentric hamstring strength was assessed at the start and end of preseason training using an instrumented Nordic hamstring device. The change in eccentric strength across the preseason was determined in absolute terms and normalized to the start of preseason strength. The start of preseason strength was used as a covariate to control for differences in starting strength.

Results: The left and right limbs in the control group showed no difference in absolute or relative change (left limb: 60.7 ± 72.9 N and 1.28 ± 0.34 N, respectively; right limb: 48.6 ± 83.8 N and 1.24 ± 0.43 N, respectively). Similarly, the injured and uninjured limbs in the previously injured group showed no difference in either absolute or relative change (injured limb: 13.1 ± 57.7 N and 1.07 ± 0.18 N, respectively; uninjured limb: 14.7 ± 54.0 N and 1.07 ± 0.22 N, respectively). The previously injured group displayed significantly less increase in eccentric hamstring strength across the preseason (absolute change, 13.9 ± 55.0 N; relative change, 1.07 ± 0.20 N) compared with the control group (absolute change, 54.6 ± 78.5 N; relative change, 1.26 ± 0.39 N) for both absolute and relative measures ($P < .001$), even after controlling for differences in the start of preseason eccentric hamstring strength, which had a significant effect on strength improvement.

Conclusion: Elite Australian footballers with a unilateral history of HSIs displayed less improvement in eccentric hamstring strength across preseason training. The smaller improvements were not restricted to the previously injured limb as the contralateral limb also displayed similarly small improvements in eccentric strength. Whether this is the cause of or the result of an injury remains to be seen, but it has the potential to contribute to the risk of hamstring strain reinjuries.

Keywords: hamstring; muscle injury; eccentric strength; Nordic hamstring exercise

Over the past 20 seasons, hamstring strain injuries (HSIs) have been the most prevalent injuries in Australian football,[18] and they impose a significant financial burden on athletes and their associated clubs.[9] While the rate of recurrent HSIs in the elite Australian Football League has fallen in recent years,[17] it still remains one of the most common types of injury for recurrence.[18] In Australian football, much like other sports,[1,8] the history of HSIs is repeatedly identified as the primary risk factor for future injuries[6,25] and is often considered a nonmodifiable risk factor (ie, it cannot be changed).[14] However, a growing body of evidence indicates that neuromuscular maladaptations associated with previous HSIs may be responsible for the elevated risk of future injuries, despite returning to play and "successful" rehabilitation.[15,16,21,22] Most notably, hamstring muscles that have previously sustained a strain injury display signs of neuromuscular inhibition during eccentric contractions when compared with contralateral, uninjured hamstring muscles.[15,16,22] The

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resultant deficits in eccentric knee flexor strength might reasonably be expected to increase the likelihood of future HSIs in this limb, given that lower levels of eccentric hamstring strength increase the risk of future injuries.[4,23]

A recent review[5] proposed a novel framework, suggesting that persistent neuromuscular inhibition during eccentric contraction after an HSI[15,16,22] could lead to continued eccentric weakness and thus an elevated risk of reinjuries.[14] Based on the proposed framework, it would be expected that this inhibition has the potential to limit the extent of muscular adaptations in response to rehabilitative and prophylactic exercises, given the need for high levels of activation to drive adaptation.[5,14] If this were the case, athletes with a previous HSI might not only show deficits in eccentric hamstring strength in the previously injured limb but may also show a suppressed response to eccentric training interventions that are commonly utilized in prophylactic programs. The effect of a prior HSI on the adaptive capacity of a previously injured athlete is, however, yet to be examined.

In the elite Australian Football League, the preseason training period spans up to 4 months between November and February.[24] It is a time in the training cycle when teams focus on increasing physical fitness with an aim to improve performance and avoid injuries.[24] From the perspective of preventing HSIs, it is common to target gains in eccentric hamstring strength as one of the major outcomes during the preseason period. Much of this philosophy is based on evidence showing the preventive benefits of eccentric hamstring strengthening during the preseason in other sports.[2,4,19] There is currently no work that examines the improvements in eccentric hamstring strength throughout the preseason training period in elite Australian footballers and whether a previous HSI affects the athlete's ability to improve eccentric hamstring strength.

The purpose of this investigation was to assess eccentric hamstring strength changes during the preseason training period in elite Australian footballers with and without a history of unilateral HSIs. We hypothesized that athletes with a history of HSIs would exhibit a minimal increase in eccentric hamstring strength during the preseason training period compared with uninjured athletes.

MATERIALS AND METHODS

Sample Size Calculations

Based on a previous study,[22] which used a similar research design, an a priori sample size of 15 for the previously injured group and 75 for the control group was determined using G*Power (v 3.1.7). The input parameters for the power analysis were the following: independent t test, effect size (d) = 0.8, α = .05, β = .20, and allocation ratio of 5:1. An independent t test was selected because the change in eccentric hamstring strength for both limbs was expected to be averaged and then compared between groups, as performed previously,[22] given that the adaptive capacity would be centrally impaired and not limb specific.[5] A large effect size was anticipated based on Rhea et al,[20] and the 5:1 sample ratio was based on typical hamstring injury rates of 15% to 20%.[14]

Participants

A total of 99 Australian footballers from 5 elite teams were eligible to participate (from an overall pool of 210) in the study, of whom 17 had a history of unilateral HSIs (previously injured group), confirmed by magnetic resonance imaging (MRI), in the previous 12-month period. All participants were free of injuries to the lower limbs (able to participate fully in training), which would be expected to influence knee flexor strength at the time of testing. Exclusion criteria included any athlete with a history of bilateral HSIs in the prior 12 months, any athlete with a history of clinically diagnosed HSIs that were negative on MRI scans in the prior 12 months, any athlete who sustained an HSI during the preseason, and any athlete who had sustained an anterior cruciate ligament rupture previously or who had sustained an injury to the quadriceps, calf, or groin/hip in the prior 12 months. All testing procedures were approved by the university's human research ethics committee, and participants gave informed written consent before testing after having all procedures explained to them.

Experimental Design

The current study employed a prospective cohort design. All athletes reported for testing during the first and final weeks of preseason training (November-February). On each occasion, all athletes completed a submaximal warm-up set of the Nordic hamstring exercise, followed by a single set of 3 maximal repetitions of the Nordic hamstring exercise, during which eccentric knee flexor forces of the left and right limbs were recorded using a custom-made device. All testing was performed after similar levels (duration and intensity) of training completed in the days previously.

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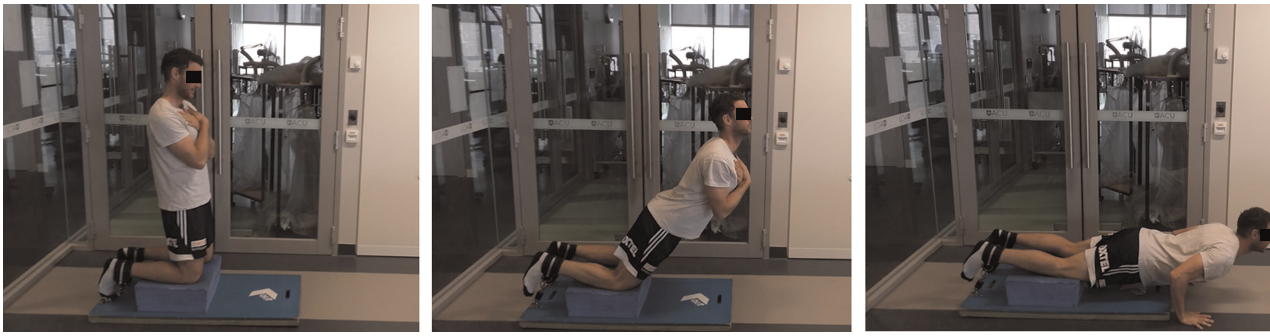

Figure 1. Performing the Nordic hamstring exercise using the novel device (progressing from left to right). The participant controls the speed of the fall by forceful eccentric contraction of the knee flexors. After completion of the exercise, the participant slowly returns to the starting position by pushing back up with both hands (not shown). The ankles are secured independently in individual custom-made braces.

Eccentric Knee Flexor Strength Assessment

The device used to determine eccentric knee flexor strength during the Nordic hamstring exercise and its reliability have been described previously and can be seen in Figures 1 and 2.[13] Participants knelt on a padded board, with the ankles secured immediately superior to the lateral malleolus by individual ankle braces that were attached to custom-made uniaxial load cells (Delphi Force Measurement) with wireless data acquisition capabilities (Mantracourt). The ankle braces and load cells were secured to a pivot, which allowed the force to always be measured through the long axis of the load cells, with an individual load cell for both the left and right limbs, allowing for separate measurements from each limb. After a warm-up set, participants performed 1 set of 3 maximal repetitions of the bilateral Nordic hamstring exercise. Instructions to players were to gradually lean forward at the slowest possible speed while maximally resisting this movement with both limbs, while keeping the trunk and hips held in a neutral position throughout and the hands held across the chest.[13] Participants were loudly exhorted to provide maximal effort throughout each repetition. A trial was deemed acceptable when the force output reached a distinct peak (indicative of maximal eccentric strength), followed by a rapid decline in force that occurred when the athlete was no longer able to resist the effects of gravity acting on the segment above the knee joint.

History of Injuries

For all athletes recruited who had sustained a unilateral HSI in the 12 months before the first testing session, details of their history of injuries were obtained from their club clinician. Details obtained included which limb was injured (dominant/nondominant limb), muscle injured (long head of the biceps femoris/short head of the biceps femoris/semimembranosus/semitendinosus), location of injury (proximal/distal, muscle belly/muscle-tendon junction), activity type performed at the time of injury (running/kicking, etc), and grade of injury (I, II, or III). Importantly, all diagnoses were confirmed by MRI performed 48 to 72 hours after the insult.

Figure 2. Close-up view of the ankle brace and load cell organization with the participant's limb in position during the Nordic hamstring exercise.

Preseason Training Programs

With regard to prophylactic programs for the prevention of HSIs, all clubs utilized the Nordic hamstring exercise and stiff-legged (or Romanian) deadlift as part of their training regimen. Typical set and repetition ranges for the Nordic hamstring exercise were 2 to 4 sets with 6 to 10 repetitions. These prophylactic exercises were completed at least on a weekly basis by all teams included in the study. In addition, there was a strong focus on exercises that aimed to increase eccentric hamstring strength using a combination of bilateral and unilateral movements. Often, athletes with a history of HSIs were prescribed additional eccentric exercises as part of the effort to further reduce their risk of reinjuries.

Data Analysis

Force data for both limbs during the Nordic hamstring exercise were logged into a personal computer at 100 Hz through a wireless USB base station receiver (Mantracourt). For both limbs (left/right for the control group or injured/uninjured for the previously injured group), peak force for each contraction was determined, and maximal force-

TABLE 1
Details of Prior Hamstring Strain Injuries Sustained by Athletes in the Injured Group[a]

Participant	Limb Injured	Muscle Injured	Location of Injury	Activity at Time of Injury	Rehabilitation Time for Most Recent Injury, d	Time Between Most Recent Injury and First Strength Testing Session, wk
1	D	SM	Proximal MTJ	Running	62	14
2	D	BFlh	Distal MTJ	Running	31	17
3	D	BFlh	Proximal MTJ	Kicking	76	31
4	ND	ST	Muscle belly	Running	25	24
5	ND	BFlh	Proximal MTJ	Running	19	9
6	ND	SM	Proximal tendon	Bending forward	79	30
7	D	ST	Distal MTJ	Running	21	52
8	D	BFlh	Proximal MTJ	Running	72	32
9	D	BFlh	Muscle belly	Running/kicking	32	15
10	D	BFlh	Muscle belly	Running	23	40
11	ND	BFlh	Muscle belly	Not defined	26	25
12	ND	BFlh	Proximal MTJ	Running	33	35
13	ND	BFlh	Proximal MTJ	Running	60	16
14	ND	BFlh	Distal MTJ	Running	23	19
15	D	BFlh	Proximal MTJ	Bending forward	35	6
16	ND	BFlh	Proximal MTJ	Running	21	12
17	D	BFlh	Proximal MTJ	Running	19	13

[a]BFlh, long head of the biceps femoris; D, dominant; MTJ, muscle-tendon junction; ND, nondominant; SM, semimembranosus; ST, semitendinosus.

generating capacity was expressed as the mean of the peak from 3 contractions (mean peak force). This method of analysis was chosen because it has displayed high test-retest reliability (intraclass correlation coefficient, 0.85-0.89).[13] The change in eccentric strength across the preseason was expressed in absolute units (newtons) as well as relative to the early preseason strength measure by taking the quotient of late preseason and early preseason strength.

Statistical Analysis

Data were screened, and all test assumptions were assessed to confirm the appropriateness of the analyses. The change in eccentric hamstring strength across the preseason was compared between the left and right limbs of the control group and between the retrospectively injured and uninjured limbs in the previously injured group using a 2-tailed paired-samples t test. As no within-group differences were noted, the 2 limbs for each group were averaged. To compare between the control and previously injured groups, a univariate general linear model was employed, with eccentric knee flexor strength at the start of the preseason used as a covariate, to control for differences in baseline strength because it was different between groups. Statistical significance was set at $P < .05$ and the Cohen d used to assess the magnitude of the effect. Data are reported as mean differences ± SD or, if stated, 95% CI. All statistical analyses and assumption testing were performed using SPSS v 19.0.0.1 (IBM Corp).

RESULTS

Of the 17 athletes with a history of unilateral HSIs in the prior 12 months, the injuries were distributed accordingly: dominant limb (53%), long head of the biceps femoris (76%), and the proximal muscle-tendon junction (53%) (Table 1). Time since the most recent HSI ranged from 1.5 to 12 months (median time since injury, 4.4 months/19 weeks), with the rehabilitation time ranging from 19 to 79 days (median rehabilitation time, 31 days). The distribution of these 17 athletes at each of the 5 participating clubs was 5, 4, 4, 3, and 1, respectively. All athletes (and associated medical staff) reported a strong emphasis on eccentric conditioning and high-speed running during late-stage rehabilitation and in the lead-up to return to play.

Descriptive statistics for both groups with respect to demographic data and absolute levels of eccentric hamstring strength at the start and end of the preseason can be found in Table 2. While the previously injured athletes presented with generally higher levels of eccentric strength compared with athletes in the control group, the only significant difference was that the left limb in athletes in the control group was weaker than the uninjured limb in athletes with a previously injured limb ($P = .020$). With respect to the change in eccentric hamstring strength across the preseason, the left and right limbs of athletes in the control group showed no difference in either absolute or relative measures of change (left limb: 60.7 ± 72.9 N and 1.28 ± 0.34 N, respectively; right limb: 48.6 ± 83.8 N and 1.24 ± 0.43 N, respectively) (Table 3). Similarly, the injured and uninjured limbs of athletes in the previously injured group showed no difference in either absolute or relative measures of change (injured limb: 13.1 ± 57.7 N and 1.07 ± 0.18 N, respectively; uninjured limb: 14.7 ± 54.0 N and 1.07 ± 0.22 N, respectively) (Table 3).

Given that there were no differences in the change in eccentric hamstring strength between the left and right limbs of athletes in the control group (left vs right: absolute

TABLE 2
Demographic and Eccentric Knee Flexor Strength Data for All Athletes

Variable	Mean ± SD
Uninjured group (n = 82)	
Age, y	22.6 ± 3.3
Height, cm	188.3 ± 7.6
Weight, kg	87.8 ± 7.6
Early preseason eccentric strength, N	
Left limb	271.9 ± 74.8
Right limb	290.8 ± 84.4
Late preseason eccentric strength, N	
Left limb	327.7 ± 73.5
Right limb	336.9 ± 71.0
Previously injured group (n = 17)	
Age, y	23.3 ± 2.6
Height, cm	186.2 ± 6.5
Weight, kg	85.9 ± 6.6
Early preseason eccentric strength, N	
Injured limb	297.9 ± 89.6
Uninjured limb	310.9 ± 82.7
Late preseason eccentric strength, N	
Injured limb	311.0 ± 82.6
Uninjured limb	325.6 ± 82.0

change, P = .06, d = 0.15; relative change, P = .291, d = 0.10), the results of the 2 limbs were averaged to give a mean control group change in eccentric hamstring strength. Similarly, for the previously injured group, as there was no difference between limbs (injured vs uninjured: absolute change, P = .88, d = 0.03; relative change, P = .934, d = 0.00), the results of the injured and uninjured limbs were also averaged to give a mean injured group change in eccentric hamstring strength. Athletes in the previously injured group displayed a significantly smaller increase in eccentric hamstring strength across the preseason (absolute change, 13.9 ± 55.0 N; relative change, 1.07 ± 0.20 N) compared with those in the control group (absolute change, 54.6 ± 78.5 N; relative change, 1.26 ± 0.39 N) for both absolute and relative measures, even after controlling for differences in the start of preseason eccentric hamstring strength. The start of preseason eccentric hamstring strength had a significant effect (P < .001) on both absolute and relative strength changes (Table 4).

DISCUSSION

The present study aimed to determine if elite Australian footballers with a history of unilateral HSIs (within the prior 12 months) would display a smaller increase in eccentric hamstring strength across the preseason training period compared with athletes without a history of HSIs. The major finding was that the previously injured athletes displayed smaller increases in eccentric hamstring strength compared with the control group athletes, who had no history of HSIs in the prior 12 months. Interestingly, the smaller increase in eccentric strength across the preseason was not restricted to the previously injured limb, as increases between injured and uninjured limb strength did not differ.

This study is, to our knowledge, the first to examine the change in eccentric hamstring strength across the preseason training period in elite Australian footballers. One study, a randomized controlled trial (RCT) in elite Swedish soccer players, examined the effect of augmented eccentric training, via a flywheel ergometer, for the hamstrings across 10 weeks of preseason training and reported an approximately 19% increase in eccentric hamstring torque.[2] The improvements in the control group in the present study are similar in magnitude (15%-20%) to those reported by Askling et al[2] in the training arm of their trial; however, the effect of previous HSIs on eccentric strength improvements was not examined.

The finding that athletes with a history of HSIs displayed a smaller increase in eccentric strength during the preseason might have implications for recurrent injuries. Given the retrospective nature of these observations, it is impossible to determine whether a smaller increase in eccentric strength is the result of injury and/or a predisposing factor that leads to the initial insult. It is also possible that a heavy focus on eccentric exercise during the late stage of rehabilitation could influence the change in eccentric hamstring strength during the subsequent preseason training period. Regardless, given the established link between prior HSIs and the increased risk of future injuries in elite Australian football,[6,25] characteristics of previously injured athletes can help to identify variables that warrant further investigation. Of interest from the current data set is the possibility that athletes display variable increases in eccentric hamstring strength (ie, high and low responders) across preseason training. As eccentric strengthening interventions[2,19] and smaller between-limb eccentric strength imbalances[23] appear to reduce the risk of HSIs, players with a reduced ability to increase eccentric hamstring strength might be predisposed to a greater likelihood of future HSIs. Further work should consider the implementation of a standard eccentric hamstring strengthening intervention across a large participant pool to determine the spectrum of strength increases, with these participants followed prospectively to establish if there is a causative relationship with HSIs.

It should also be acknowledged that rehabilitation processes would likely play a critical role in the recovery of eccentric strength after an HSI and might also influence the adaptive response to eccentric exercise. It would be of interest to examine increases in eccentric strength and adaptive capacity in previously injured athletes who are exposed to standardized rehabilitation protocols, such as those reported previously.[3] It is also intriguing that the injured athletes displayed smaller increases in eccentric strength across the preseason but that there was no difference noted between the injured and uninjured limbs within this group. This raises the possibility that persistent neuromuscular inhibition noted during eccentric contractions after unilateral HSIs[15,16,22] may be mediated by central mechanisms and as such have bilateral effects. Furthermore, it is possible that differences between the injured and control groups with respect to eccentric hamstring strength at the start of the preseason (ie, baseline strength) may have affected the improvements seen in

TABLE 3
Absolute and Relative Change in Eccentric Knee Flexor Strength Between Limbs

Group	Absolute Change in Eccentric Strength, Mean ± SD, N	Between-Limb Difference (95% CI), N	*P* Value	Effect Size[a]	Relative Change in Eccentric Strength, Mean ± SD,[b] N	Between-Limb Difference (95% CI), N	*P* Value	Effect Size[a]
Previously injured group (n = 17)								
Uninjured limb	14.7 ± 54.0	1.6 (–37.4 to 40.6)	.88	0.03	1.07 ± 0.22	0.00 (–0.14 to 0.14)	.934	0.00
Injured limb	13.1 ± 57.7				1.07 ± 0.18			
Uninjured group (n = 82)								
Left limb	60.7 ± 72.9	12.1 (–12.1 to 36.3)	.06	0.15	1.28 ± 0.34	0.04 (–0.08 to 0.16)	.291	0.10
Right limb	48.6 ± 83.8				1.24 ± 0.43			

[a]Cohen *d* was used to determine the effect size.
[b]Change was determined as the quotient of late over early preseason eccentric hamstring strength.

TABLE 4
Absolute and Relative Change in Eccentric Knee Flexor Strength Between Groups

Group	Absolute Change in Eccentric Strength, Mean ± SD, N	Between-Group Difference (95% CI), N	*P* Value	Effect Size[a]	Relative Change in Eccentric Strength, Mean ± SD,[b] N	Between-Group Difference (95% CI), N	*P* Value	Effect Size[a]
Previously injured group (n = 17)	13.9 ± 55.0	40.7 (1.0-80.4)	.012[c]	0.60	1.07 ± 0.20	0.19 (0.0-0.38)	.015[c]	0.73
Uninjured group (n = 82)	54.6 ± 78.5				1.26 ± 0.39			
Covariate effect (early preseason eccentric strength)			<.001[d]				<.001[d]	

[a]Cohen *d* was used to determine the effect size.
[b]Change was determined as the quotient of late over early preseason eccentric hamstring strength.
[c]Significance was set at $P < .05$, with the start of preseason eccentric strength employed as a covariate in a general linear model.
[d]Early preseason strength had a significant effect as a covariate.

strength across the preseason. It might be argued that the higher starting strength in the injured group would limit the scope for improvement across the preseason; however, ongoing subsequent work from our group suggests that approximately 340 N is not close to the maximal strength capacity of most elite Australian footballers, with scores well in excess of 400 N noted in well-trained athletes. When the start of preseason eccentric strength was controlled for as a covariate in the analysis, differences between the groups still persisted. It should also be noted that when examining the increase in eccentric hamstring strength in athletes from both groups in the bottom quartile for eccentric strength at the start of the preseason, athletes in the control group (mean start of preseason strength, 195 N) displayed an approximately 55% increase in eccentric strength while those in the previously injured group (mean start of preseason strength, 194 N) increased approximately 20%.

The limitation of eccentric hamstring strength gains in the athlete with a previous HSI, as reported in the current study, is intriguing as a large RCT has shown that the implementation of the Nordic hamstring exercise during the preseason in soccer players resulted in a significant reduction in the rate of reinjuries.[19] It would be reasonable to posit that the significant reduction in reinjuries was conferred by an increase in eccentric hamstring strength after the Nordic hamstring exercise intervention.[12] The results from the current study suggest that eccentric strength improvements may have been restricted in the previously injured athletes; however, the cohort from the RCT[19] consisted of soccer players without a history of eccentric training of the hamstrings before the intervention. This differs significantly from the cohort of elite Australian footballers who employ targeted eccentric exercise as part of the late stages of rehabilitation and return to play and generally for the prevention of HSIs. It remains to be seen if greater magnitudes of, or larger improvements in, eccentric hamstring strength, assessed during the performance of the Nordic hamstring exercise, reduce the risk of future HSIs.

Besides a history of unilateral HSIs, other factors may be responsible for the divergent responses between the 2 groups. First, the strong focus on eccentric exercise during the late stages of rehabilitation has the potential to influence eccentric strength and the change in strength across the preseason period. Indeed, the low between-limb strength imbalance in the previously injured group at the start of the preseason (1.3%), which was much smaller than in previous reports using the current strength assessment device (15%),[13] is suggestive that rehabilitation in this cohort aimed to minimize any deficits in eccentric strength. The influence of rehabilitation procedures, across the spectrum of HSI severities, on long-lasting deficits in function and response to training stimuli is an area of great interest for future investigations. Second, the physiological demands of Australian football require athletes at the elite level to possess high aerobic and anaerobic fitness, maximal sprint speeds, repeat sprint performance, and strength and power qualities.[7] These diverse demands require an intense training load for athletes, particularly during preseason training. However speculative, it is possible that the multiple physiological demands of preseason training might minimize improvements in certain performance markers in some athletes.[10] If some athletes struggle to improve strength/power qualities (such as eccentric hamstring strength), then it would be reasonable to suggest that their risk of HSI would be greater.[4] It is possible that the athletes of the previously injured group in the current work had, in prior seasons, improved eccentric hamstring strength minimally because of the competing demands of preseason training, predisposing them to injuries, and that phenomenon (a low responder to strength training) was measured here more so than the effect of prior injuries. The complex interaction of the numerous factors that can affect strength gains during preseason training in elite athletes certainly requires greater focus, particularly given the important role that strength plays in injury prevention.[11]

There are some limitations inherent to this study. The investigators had no control over the preseason training programs of any team involved (as is to be expected in an elite sporting environment), as this study was purely observational. While we were able to report general details of the preseason HSI prophylactic program, we are not able to comment as to whether differing training programs between athletes and/or teams may have influenced the findings. In spite of this, these observations were made on 99 athletes across 5 elite Australian football teams, suggesting that the results may be generalizable within this sport. Furthermore, the history of HSIs was confined to the previous 12 months to minimize reporting errors, and this neglects HSIs that occurred before this time period. Severe HSIs sustained more than 12 months ago may have confounded the current findings. Importantly, however, all HSIs were confirmed by MRI to eliminate the inclusion of athletes suffering referred pain from posterior thigh injuries, and this is a strength of the current investigation.[25] Finally, while the study was sufficiently powered to detect between-group differences, given the relatively small sample of previously injured athletes, it was underpowered to explore the possible effect of time since injury, the number and severity of previous HSIs, rehabilitation type and length, and the possible role of other lower limb injuries on improvements in eccentric hamstring strength across the preseason. A larger study examining a more homogeneous sample of HSIs, powered to include additional covariates, is warranted in the future. A larger sample would also allow for an analysis to control for cluster effects by team, which was not possible with the current sample size.

In conclusion, elite Australian footballers with a unilateral history of HSIs within the previous 12 months displayed a greater baseline level of and a smaller increase in eccentric hamstring strength through the preseason training period compared with their control group counterparts. Interestingly, this diminished response was not confined to the previously injured limb but was also observed in the contralateral uninjured limb, which might suggest that the effects of a prior HSI may be centrally mediated. The existence of high and low responders to eccentric exercise and the effect on the risk of future HSIs are worthy of further examination.

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