

ECCENTRIC HAMSTRING STRENGTH IS ASSOCIATED WITH AGE AND DURATION OF PREVIOUS SEASON HAMSTRING INJURY IN MALE SOCCER PLAYERS

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ABSTRACT

Background: Eccentric hamstring strength seems important in reducing the odds of future hamstring injuries. While age and previous injury are well-known risk factors for future hamstring injuries, the association of age and previous hamstring injury with eccentric hamstring strength in the following season is unknown.

Purpose: To investigate the association of age and previous hamstring injury with preseason eccentric hamstring strength in soccer players, and to investigate the association between previous hamstring injury duration and preseason eccentric hamstring strength.

Study design: Descriptive, cross-sectional study

Methods: A convenience sample of 284 male amateur soccer players (age 18-38 years) was included in the analyses. Self-reported information about previous season hamstring injury and its duration (three weeks or less; more than three weeks) was collected. Preseason eccentric hamstring strength was obtained during the Nordic hamstring exercise using a field-based device.

Results: Age had a negative association with preseason eccentric hamstring strength with 0.9% reduction per year. Players with a previous hamstring injury duration of more than three weeks (n = 27) had 13% lower preseason eccentric hamstring strength compared to players without previous hamstring injury.

Conclusion: Older players have lower preseason eccentric hamstring strength than younger players. Players with a previous hamstring injury duration of more than three weeks have lower preseason eccentric hamstring strength than the rest of the players. These results highlight the need to monitor and address the identified weaknesses in eccentric hamstring strength in amateur soccer players, with specific emphasis on older players with a previous hamstring injury of longer duration.

Level of evidence: 2b

Keywords: knee-flexor, muscle injuries, hamstrings, performance, football

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Statement of the sources of grant support: No external financial support was provided for this research project.

Conflicts of interest: J. Vicens-Bordas reports no financial or other interest in the product or distribution of the product. Anthony Shield and David Opar are listed as co-inventors on a patent filed for the device employed here to assess eccentric hamstring strength (PCT/AU2012/001041.2012) as well as being shareholders in a company responsible for commercializing the device. Neither of these authors were involved in data collection or analysis in the present study.

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INTRODUCTION

Eccentric hamstring weakness has been identified as a risk factor for future hamstring strain injury (HSI) in sports with high intensity running demands, such as soccer¹ and Australian rules football (AFL).² Recently, a device has been developed to measure eccentric hamstring strength during the Nordic hamstring exercise (NHE).³ In a large prospective study including 152 professional soccer players assessed using the NHE device, those with eccentric hamstring strength below $4.35 \text{ N} \cdot \text{kg}^{-1}$ were 4.4 times more likely (RR; 95% CI 1.1 to 17.5) to sustain an HSI in the following season compared to stronger players.¹ In contrast, no association between eccentric hamstring weakness and hamstring injury risk was found in a cohort of 413 professional Qatari soccer players who were assessed using the NHE device.⁴ Univariate analysis of eccentric hamstring strength may not predict future HSI,⁴ but it seems that multivariate analyses including age, previous hamstring injury, and reduced levels of eccentric hamstring strength may identify players at a greater risk of future HSI.¹ Measuring preseason eccentric hamstring strength in amateur soccer players and identifying those with poorer results may have some merit.

Age⁴⁻⁶ and previous hamstring injury⁷ have often been linked to future HSI. Professional soccer players older than 23 years have been reported to be at an elevated risk of sustaining an HSI⁶ and each year of age has been reported to increase the risk of sustaining an HSI up to 1.8-fold (OR; 95% CI 1.2 to 2.7) in English Premier League soccer players.⁵ This apparent effect of age on injury risk could, at least in part, be due to age related changes in hamstring strength. However, the impact of age on eccentric hamstring strength has not previously been investigated in soccer players at any level.

While the effects of a previous HSI on eccentric hamstring strength have been addressed in the literature,⁸ most of the studies have been performed in mixed groups of athletes, with small sample sizes and have used isokinetic dynamometry to examine strength. Furthermore, previous studies have not accounted for injury severity.⁸ Players with previous HSI may present persistent biceps femoris long head muscle atrophy,^{9,10} and neuromuscular inhibition.^{7,11} This may limit the effectiveness of the rehabilitation

process and thereby increase the risk of re-injuries,⁷ due to persistent inadequate muscle structure and/or function. Accordingly, the observed activation and strength deficits during eccentric actions remain present despite apparently successful rehabilitation and return to pre-injury levels of training and match play.¹² As a consequence, it is plausible that a hamstring injury sustained in the previous season could negatively influence eccentric hamstring strength at the beginning of the next season. Presently, however, the association of a previous hamstring injury with eccentric hamstring strength in the following season is unknown.

The purpose of the present study was to investigate the association of age and previous hamstring injury with preseason eccentric hamstring strength in soccer players. The secondary purpose was to investigate the association between previous hamstring injury duration and preseason eccentric hamstring strength.

MATERIALS AND METHODS

Design and participants

This study employed a cross-sectional exploratory and descriptive design and includes data from a large cohort study investigating hamstring and groin injuries, self-reported outcome and muscle strength in amateur male soccer players.¹³

The reporting of the present study follows the “Strengthening the Reporting of Observational Studies in Epidemiology” (STROBE) statement, using the checklist for cross-sectional studies.¹⁴ Male players ($n = 363$) from a convenience sample of 17 sub-elite soccer teams from the northeast of Spain, competing in the 3rd national and the 1st and 2nd regional divisions (4th to 6th tier), were screened for eligibility. Players from those teams performed the baseline testing during the preseason (July-August 2015). Players were included if they were over 18 years of age, were free from current hamstring injury, were able to participate in a training session on the day of testing, could understand Catalan or Spanish, provided written informed consent and completed all testing procedures. This study was approved by a regional ethics committee (Consell Català de l'Esport, approval number = 08/2015CEICEGC).

Testing procedure

Three members of the research team who were trained in the measurement procedures, one physiotherapist (EE) and two sport scientists JVB and LS performed all the baseline measurements at the respective team facilities. Team physiotherapists, physical trainers and members of the technical staff of the respective teams collaborated in the assessments, providing questionnaires and forms and helping to conduct the standardized warm-up, which consisted of low intensity shuttle runs and active lower limb mobility exercises. Players were asked to arrive 90 minutes before the start of a regular preseason training session to perform the test battery.

Using a standardized form, players provided personal information (date of birth) and data on current hamstring injury (Yes; No), previous season hamstring injury (Yes; No), previous season hamstring injury duration in week ranges (three weeks or less; more than three weeks; as a possible surrogate measure of injury severity), side of injury (right; left). Additionally, weight and height were measured and registered for each player.

The NHE device, previously assessed for reliability (0.83-0.90 ICC and 5.8-8.5% CV),³ was used for the assessment of eccentric hamstring strength. Participants knelt on a padded board, with the ankles secured superior to the lateral malleolus by individual ankle braces attached to custom-made uniaxial load cells (Delphi Force Measurement, Gold Coast, Australia). Immediately before testing, players were provided with a demonstration of the NHE by the investigators. After a three-repetition warm-up set and one minute of rest, participants were asked to perform one set of three maximal repetitions of the NHE. Participants were instructed to gradually lean forward at the slowest possible speed while maximally resisting this movement with both limbs while keeping the trunk and hips in a neutral position throughout, and the hands held across the chest.³ Standardized verbal encouragement was given throughout the range of motion to ensure maximal effort. The investigators closely monitored all trials to ensure proper technique, which, if considered invalid, additional trials were allowed. The results were only visible to the outcome assessor during

the testing and were shown to the player after the completion of all testing. All eccentric strength testing was performed in a rested state before the team training session.

Data analysis

Force data for both limbs during the NHE were logged to a personal computer at 100Hz through base station receiver (Mantracourt, Devon, UK). Peak force for each of the three repetitions was averaged for all statistical comparisons. Average of both legs was analyzed and reported normalized to body weight ($N \cdot kg^{-1}$). Inter-limb asymmetry was analyzed using the formula: (strongest limb-weakest limb)/Total (sum of both limbs); noting that this has been suggested as an appropriate method for computing inter-limb differences from bilateral tests.¹⁵

Statistical analysis

For descriptive statistics, means and standard deviations (SD) were used for continuous variables, while numbers (percentages) were used for dichotomous variables. Simple linear regression models were performed to investigate the differences in preseason eccentric hamstring strength on soccer players including 1) age, 2) previous season hamstring injury, and 3) hamstring injury duration of three weeks or less and more than three weeks. Preseason eccentric hamstring strength was included as the dependent variable, while age, previous season hamstring injury and hamstring injury duration, respectively, were included as the independent variables of interest. Moreover, two standard multiple regressions were performed for previous season hamstring injury and hamstring injury duration, including age as covariate. Confidence intervals were set at 95% for all analyses. All the assumptions for all regression models were met. Estimates of the differences in eccentric hamstring strength were presented as absolute mean differences and percentages -by dividing the absolute mean difference by the estimated mean of the reference group. All statistical analyses were performed using SPSS v22.0.0.1 (IBM Corporation, Chicago, IL). Players with incomplete data, due to time constraints during testing or not completing three valid repetitions for other reason were not included in the analyses. Hence, data were analyzed as complete cases (no imputation of

missing data). Information regarding missing data are provided in Figure 1.

RESULTS

In total, 284 amateur male players were included in the analyses (age = 23 ± 4 years; weight = 74.0 ± 7.8 kg; height = 178.3 ± 6.4 cm; see Table 1 and Figure 1). Twenty-two players did not complete testing and were not included in the analyses. From the 284 players, 56 (19.7%) had sustained a hamstring injury in

the previous season. From those injured players, 29 (51.8%) reported having a hamstring injury duration of three weeks or less, whereas 27 players (48.2%) reported having a hamstring injury of more than three weeks. Between limb asymmetry was present in both injured and uninjured groups (Table 1).

Age had a significant negative association with pre-season eccentric hamstring strength with a mean reduction of 0.9% per year increase in player's

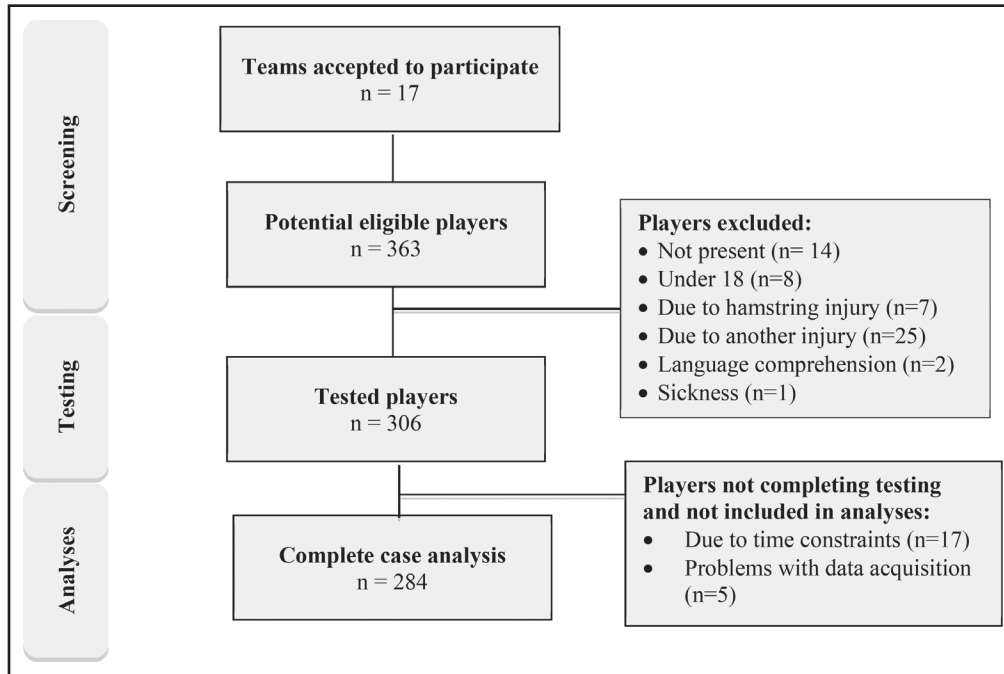


Figure 1. Flowchart of participants.

Table 1. Descriptives (Mean \pm SD) for age, weight, height and eccentric hamstring strength.				
	No hamstring injury	Previous hamstring injury	Duration \leq 3 weeks	Duration $>$ 3 weeks
N (%)*	228 (80.3)	56 (19.7)	29 (10.2)	27 (9.5)
Age (years)	23 ± 4	24 ± 4	23 ± 4	25 ± 5
Weight (kg)	74.2 ± 7.8	73.5 ± 7.8	73.9 ± 7.0	73.0 ± 8.6
Height (cm)	178.1 ± 6.1	178.7 ± 7.5	178.4 ± 7.5	179.0 ± 7.5
Eccentric hamstring strength (N \cdot kg $^{-1}$)				
Average	4.40 ± 1.01	4.09 ± 0.97	4.34 ± 1.02	3.83 ± 0.85
Injured limb	-	4.05 ± 1.14	4.43 ± 1.10	3.82 ± 1.12
Non-injured limb	-	3.92 ± 1.12	4.15 ± 1.07	3.71 ± 1.05
Right	4.47 ± 1.00	4.12 ± 1.03	4.41 ± 1.14	3.87 ± 1.01
Left	4.33 ± 1.10	4.01 ± 0.97	4.26 ± 1.00	3.79 ± 1.02
Asymmetries between limbs	$5\% \pm 5\%$	$6\% \pm 5\%$	$2\% \pm 6\%$	$1\% \pm 5\%$
* Percentage of total participants (n=284) Asymmetry = stronger-weaker/total				

Table 2. Estimates from simple linear regressions of age, previous hamstring injury and hamstring injury duration.

		B	(95% CI)	p-value
1a	Constant	5.51	(4.81 to 6.21)	<.001
	Age	-0.05	(-0.08 to -0.02)	.001**
1b	Constant	4.40	(4.27 to 4.53)	<.001
	Previous hamstring injury	-0.31	(-0.60 to -0.01)	.041*
1c	Constant	4.40	(4.27 to 4.53)	<.001
	Duration of 3 weeks or less	-0.06	(-0.45 to 0.33)	.749
	Duration of more than 3 weeks	-0.57	(-0.97 to -0.017)	.005**

N=284
* p<0.05; **p<0.01

age (Table 2, 1a; Figure 2). Players with previous hamstring injury had 7% lower preseason eccentric hamstring strength compared to players with no previous hamstring injury (Table 2, 1b). When adjusting for age (Table 3, Model A), players with a previous hamstring injury had a non-significant difference (5%) in preseason eccentric hamstring strength compared to players with no previous hamstring injury.

Players with hamstring injury duration of more than three weeks had 13% lower preseason eccentric hamstring strength compared to players with no previous hamstring injury (Table 2, 1c). When adjusting for age (Table 3, Model B), players with a hamstring injury duration of more than three weeks had 9% lower preseason eccentric hamstring strength compared to players with no previous hamstring injury. Players with a hamstring injury duration of three weeks or less had no difference in preseason eccentric hamstring strength compared to players with no previous hamstring injury in any of the analyses (Table 2, 1c; and Table 3, Model B).

DISCUSSION

This study is the first to investigate how age and previous season hamstring injury are associated with preseason eccentric hamstring strength in a large cohort of male amateur soccer players using an on-field and time-efficient testing device (the NHE device). The most important findings of this study are the negative association of age and previous hamstring injury duration (more than three weeks) with preseason eccentric hamstring strength.

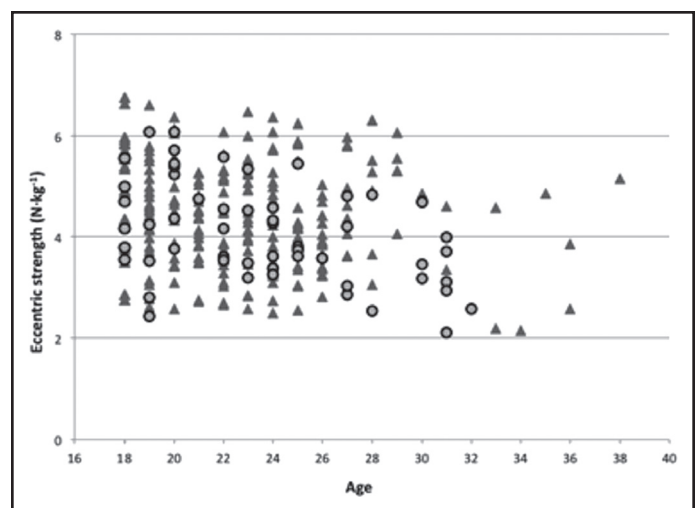


Figure 2. Scatter plot of age (years) and eccentric hamstring strength ($N \cdot kg^{-1}$). Triangles represent individual players without previous hamstring injury; circles represent individual players with previous hamstring injury.

Estimates revealed that a 0.9% decrease in strength could be expected for a year increase in player age. This is a small but important association, considering that in 10 years of age difference, a reduction of 9% on preseason eccentric hamstring strength may be present ($0.5N \cdot kg^{-1}$ or 37N for a 74kg soccer player). Moreover, players with a hamstring injury duration of more than three weeks had 9% lower preseason eccentric hamstring strength compared to players with no previous hamstring injury. Taking these results together, older and previously injured soccer players had even lower preseason eccentric hamstring strength compared to younger and non-injured counterparts. These results are relevant since prospective studies have shown that higher

Table 3. Estimates from multiple regressions of previous hamstring injury and duration including age as a covariate.

		B	(95% CI)	P-value
Model A	Constant	5.51	(4.81 to 6.20)	<.001
	Age	-0.05	(-0.08 to -0.02)	.002**
	Previous hamstring injury	-0.27	(-0.56 to 0.02)	.072
Model B	Constant	5.45	(4.79 to 6.17)	<.001
	Age	-0.05	(-0.08 to -0.02)	.003**
	Duration of 3 weeks or less	-0.06	(-0.44 to 0.32)	.755
	Duration of more than 3 weeks	-0.49	(-0.89 to -0.10)	.015**
N=284				
*p<0.05; **p<0.01				

levels of eccentric hamstring strength were important in older and previously injured soccer¹ and AFL² players to reduce the odds of sustaining future HSI injuries.

Hamstring strength deficits after a hamstring injury have been addressed in the literature before,⁸ however, those studies were performed in a mixed group of athletes, with smaller sample sizes, and using other testing devices such as isokinetic dynamometry. Furthermore, previous studies have not accounted for any possible impact of prior injury severity. The current data showing the negative association of age with preseason eccentric hamstring strength in amateur soccer players is a novel finding. Although increasing age has been identified as a potential risk factor for HSI in soccer players^{5,6} no convincing explanation has been given as to why older players are at significantly greater risk than younger players.⁷ The results of the present study, showing a decrease in strength related to increasing age, may partly explain the increased risk of future HSI in older soccer players.^{5,6} Also, this relationship between reduced eccentric hamstring strength and age could be also explained by a longer exposure to soccer or history of several HSIs (preceding the previous season), which has not been recorded in this study. Furthermore, the impact of age on eccentric hamstring strength may be greater in amateur than professional soccer players given that the former are less likely to engage in frequent and supervised strength training. Future investigations should consider prioritising serial monitoring of hamstring eccentric strength during the season to establish

trends and the relationship between strength other variables such as training load.

Previous hamstring injury duration of more than three weeks was associated with low preseason eccentric hamstring strength, regardless of player age in the present study. Conversely, previous hamstring injuries of shorter duration did not affect eccentric hamstring strength. This finding is supported by previous studies linking injury duration, which is likely a surrogate measure for injury severity, to a higher degree of neuromuscular maladaptation (neuromuscular inhibition, selective hamstring atrophy, and shifts in the torque-joint angle relationships) and consequently an increased deficit in eccentric hamstring strength.^{7,9-11} Hence, looking at hamstring injury duration instead of previous hamstring injury may be a more relevant approach to classify amateur soccer players with suspected lower levels of eccentric hamstring strength and greater propensity to sustain future HSI in the new season.

The existing evidence regarding the deficits in eccentric hamstring strength after an HSI is mixed,⁸ perhaps partly because a diversity of methods are used and heterogeneous populations are compared. One previous study has used the NHE device to measure eccentric hamstring strength in professional AFL players.¹⁶ Players with previous HSI displayed higher eccentric hamstring strength compared to players without HSI at preseason testing.¹⁶ The differences between these findings may be related to training practices, as professional AFL players may have more strictly supervised rehabilitation programs than amateur soccer players. We would assume that

a vast majority of professional AFL players might be performing intense eccentric hamstring strength exercises during rehabilitation¹⁷ while most amateur soccer players may not.

Eccentric hamstring strength can be improved through strength exercises¹⁸ and intervention studies suggest that eccentric hamstring exercises are effective at improving strength,^{19,20} hamstring muscle volume and cross-sectional area²⁰ and fascicle length in the long head of the biceps femoris.²⁰ Performing eccentric hamstring exercises such as the NHE reduces the risk of future HSI in both amateur^{21,22} and professional soccer players,²¹ possibly as a consequence of increased eccentric hamstring strength and also neuromuscular and architectural adaptations. Those studies revealed that HSI incidence, but not severity, can be reduced to approximately one-third of those in control teams by an NHE intervention.^{21,22} Moreover, previously injured players who employed the NHE were approximately six times less likely to suffer a recurrence than previously injured players from control teams.²¹ These results may give an insight into previous findings, since a decrease in eccentric hamstring strength following a hamstring injury duration of more than three weeks is likely to be carried into the following season unless it is countered by the implementation of adequate reconditioning.

Considering that training loads may also be a crucial component for injury risk management,²³ it seems that stronger and fitter players better tolerate high increases in training load²⁴ which highlights the importance of assessing players strength levels at the beginning of the season. Interestingly, the present study found that amateur soccer players with a previous history of hamstring injury of more than three weeks had reduced eccentric hamstring strength at the beginning of a soccer season, while eccentric hamstring strength was also lower in older amateur soccer players. Importantly, those two factors are not exclusive, meaning that older soccer players with a history of hamstring injury will present with even more accentuated decrements in eccentric hamstring strength. Altogether, those findings highlight the importance of monitoring eccentric strength and implementing adequate conditioning emphasising older players and players with a more severe hamstring injury history.

It should be acknowledged that some limitations are present in the current study. First, the retrospective recollection of injury history limits the accuracy of the data on injury duration. Recall bias associated with the use of a self-reported injury history questionnaire from the previous season may be present. However, in order to minimize recall bias, the injury form comprised a small number of simple questions including a clear definition of injury and also details in relation to anatomical regions, which has shown to result in better recall.²⁵ Furthermore, we also limited the time-frame of injury reporting to 12 months, since this has been shown to reduce the impact of recall bias.²⁶

CONCLUSIONS

Amateur soccer players with a hamstring injury of more than three weeks in the previous season present with lower eccentric hamstring strength at the beginning of the soccer preseason. Moreover, increasing age is associated with a decrease in eccentric hamstring strength in amateur soccer players. These results highlight the need to monitor and consequently address identified weaknesses in eccentric hamstring strength in amateur football players, with specific emphasis on older players with a previous hamstring injury of longer duration.

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