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Original research

The prognostic value of the hamstring outcome score to predict the risk of hamstring injuries

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ABSTRACT

Objectives: Hamstring injuries are common among soccer players. The hamstring outcome score (HaOS) might be useful to identify amateur players at risk of hamstring injury. Therefore the aims of this study were: To determine the association between the HaOS and prior and new hamstring injuries in amateur soccer players, and to determine the prognostic value of the HaOS for identifying players with or without previous hamstring injuries at risk of future injury.
Design: Cohort study.
Methods: HaOS scores and information about previous injuries were collected at baseline and new injuries were prospectively registered during a cluster-randomized controlled trial involving 400 amateur soccer players. Analysis of variance and t-tests were used to determine the association between the HaOS and previous and new hamstring injury, respectively. Logistic regression analysis indicated the prognostic value of the HaOS for predicting new hamstring injuries.
Results: Analysis of data of 356 players indicated that lower HaOS scores were associated with more previous hamstring injuries ($F = 17.4$; $p = 0.000$) and that players with lower HaOS scores sustained more new hamstring injuries ($T = 3.59$, $df = 67.23$, $p = 0.001$). With a conventional HaOS score cut-off of 80%, logistic regression models yielded a probability of hamstring injuries of 11%, 18%, and 28% for players with 0,1, or 2 hamstring injuries in the previous season, respectively.
Conclusions: The HaOS is associated with previous and future hamstring injury and might be a useful tool to provide players with insight into their risk of sustaining a new hamstring injury risk when used in combination with previous injuries.

Practical implications

The HaOS can be used to screen players at risk of hamstring injuries, based on symptoms, soreness, pain and symptoms during (sport-specific) activities, and quality of life. In this study, we found that lower scores on the HaOS and more hamstring injuries in the past were associated with new hamstring injuries. The prognostic value of the HaOS increased when it was used in combination with information about the number of previous hamstring injuries.

1. Introduction

Hamstring injuries are the most common muscle injuries in soccer[1] and can be responsible for a long absence from playing and have a high recurrence rate.[1] Recurrent hamstring injuries result in a longer absence from playing and require more extensive and longer rehabilitation.[2] Although game-demands have changed in the past decade,[3] hamstring injury incidence has increased annually,[4] even though the FIFA11+ and the Nordic Hamstring Exercise (NHE) programmes are found to be effective for primary (hamstring) injury prevention.[5,6]

One explanation for this annual increase is poor long-term compliance with prevention programmes.[7] This is often seen after a study is concluded, when research staff stop supervising the intervention. As a result, prevention programmes are less effective in practice than in a study setting.[8] A reason for poor compliance might be that primary preventive measures target all players, and

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not specifically those at high risk of injury. At this point all players need to perform the same preventive exercises, no matter the risk of injury.[9]

Research has shown that athletes are more willingly to participate if they have been injured in the past and have a higher risk of recurrent injury.[7,10] This suggests that players who have been injured in the past change their individual risk-taking behaviour and are more compliant with preventive measures. Following this line of reasoning, targeting only those players with a high hamstring injury risk could contribute to a more successful implementation of prevention programs than the traditional groupwise approach. In order to target a prevention program only on players with a high hamstring injury risk and provide those players with insight in their individual risk, knowledge of risk factors for hamstring injury is needed.[11] Several potential intrinsic (i.e. age, weight, ethnicity, previous injury, strength and flexibility) and extrinsic (i.e. playing position, field condition, weather) risk factors have been investigated,[12,13] but only age and previous hamstring injury have been consistently associated with the risk of hamstring injury.[12,13] That previous hamstring injury is a consistent risk factor, implies primary hamstring injuries need to be prevented in order to prevent the injury-reinjury cycle.

Having a history of a hamstring injury does not necessarily mean that those players sustain a new hamstring and not having had a previous injury is no guarantee that those players will not sustain a primary hamstring injury.[9] This necessitates assessment of a player's injury history and a more sensitive analysis of the impact of the previous injury and present complaints of the hamstring muscle in players with and without previous hamstring injury.

While there are no markers to detect early stages of hamstring injuries,[9] pain and soreness during and after (sport-specific) exercises, pain and soreness during daily activities, and fear of (re-) injury are associated with musculoskeletal injuries.[14,15] The Hamstring Outcome Score (HaOS) might be useful for identifying players with these symptoms.

The HaOS has been used in research to evaluate complaints after rehabilitation and to classify soccer players as being at low or high risk of hamstring injury,[16,17] but it has not been studied in daily soccer practice. The HaOS was developed following the same principles as the extensively used and validated Hip And Groin Outcome Score (HAGOS), Foot and Ankle Outcome Scores (FAOS) and the Knee Osteoarthritis Outcome Score (KOOS) and assesses five domains: soreness, symptoms, pain, activities (sports), and quality of life.[18,19] The first four domains are relevant to daily life and to soccer and sport-specific tasks, while the domain quality of life measures fear of re-injury.

Players are conventionally classified as being at high risk of hamstring injury with a history of hamstring injury or a HaOS score of <80% and at low risk with a score >80%.[16] However, the probability of injury with a HaOS score of 80% and whether the score is associated with number of injuries in the past remain unclear. Therefore, the aims of this study were (1) to determine the association between the HaOS score and previous hamstring injury, (2) to determine the association between the HaOS score and new hamstring injuries, and (3) to determine whether the HaOS score, with or without previous hamstring injury, is a valuable prognostic factor in hamstring injuries in soccer players.

2. Methods

Data were collected in 2016–2017 in large cluster-randomized controlled trial (cluster RCT) investigating the preventive effect of a Bounding Exercise Program on hamstring injuries in adult male amateur soccer players.[20] This study was approved by the Medical Ethics Committee of the University Medical Center Utrecht (16-332C) and was registered in the Dutch Trial Registry (NTR6129).

Adult male amateur soccer players aged 18-45 years who played in the first-class amateur soccer league in the Netherlands were eligible for participation. Players with insufficient understanding of the Dutch language were excluded. All players eligible for inclusion received an information letter before the start of the cluster-RCT and signed an informed consent.

In this cluster RCT, 400 soccer players from 32 amateur soccer teams were prospectively followed up during an entire soccer season (2016-2017). Each player filled in a baseline questionnaire that included HaOS score and various player and demographic characteristics such as age, weight, height, years of soccer experience, and previous (hamstring) injuries. Self-reported information about (hamstring) injuries and match- and training exposure were collected weekly. If an injury was reported, the player sought medical attention and the characteristics of the injury were registered using questionnaires completed by the medical staff and player.[20]

The original HaOS was translated in Dutch[17] and consist of two parts. Part 1 consists of hamstring injury history. Part 2 is in line with the validated Dutch HAGOS and FAOS and consists of five dimensions: (1) Symptoms, (2) Soreness, (3) Pain, (4) Function, Activities of Daily Living and Sport, and (5) Quality of Life.[18,19] The questions were scored 0 to 4, from no complaints to maximum complaints.[16] The HaOS score can be calculated as an overall score and a score for each dimension. Scores were calculated as percentages of the maximum score, with a player with no complaints scoring 100%. Scores were calculated by 1-(score/maximum score) * 100%. A score of 80% or more was considered to indicate a low risk of hamstring injury and a score of less than 80% as being indicative of a high risk of hamstring injury.[16]

The association between the baseline HaOS score and hamstring injuries was studied in three separate analyses. First, we studied the association between the mean HaOS score and the number of injuries (categorized as: 0, 1, 2, 3 or more) in the season preceding baseline. Differences in means for each of the HaOS subdomains (Symptoms, Soreness, Pain, Activity, Quality of Life) and the total HaOS scale were tested with F-tests in separate ANOVAs. Second, we compared the mean HaOS subdomain and total scores between players who did and did not sustain a new hamstring injury. Confidence intervals for the differences in means were calculated. After the two preliminary analyses, we studied the baseline HaOS total score as a prognostic factor to predict occurrence of hamstring injury during the current season in our main analysis. We first fitted a univariable logistic regression model with hamstring injury as the outcome and baseline HaOS total score as the predictor. A second model was fitted that allowed the HaOS predictor effect to be non-linear via a restricted cubic spline (4 knots). A third bivariable logistic model was fitted with both HaOS total score and hamstring injuries in the previous season as the predictor. Our fourth and final allowed for interaction between the HaOS score and previous injuries. For the main analysis, data were missing for 44 HaOS total scores and were multiple imputed on the assumption that the data were missing at random[21] using aregImpute (rms R-package), which allows for non-linear effects of the imputation predictors via restricted cubic splines. All data were analysed with the statistical language and software program R, version.[22]

3. Results

All 400 players filled in the baseline questionnaire and responded to weekly questions regarding their soccer exposure and injuries. Of these players, 356 players (89%) completed all the questions of the baseline HaOS. At baseline, 103 players reported having sustained a hamstring injury in the previous season (2015–2016).

Table 1
Player characteristics.

	No new injury	New injury	No previous injury	Previous injury
Age	25.74 (4.20)	24.58 (6.03)	24.86 (4.74)	24.97 (4.24)
weight	78.99 (6.71)	78.73 (8.08)	78.92 (7.95)	78.85 (7.95)
length	183.60 (5.70)	184.06 (6.47)	184.45 (6.11)	183.24 (6.60)
Years of soccer experience	19.20 (4.75)	18.59 (4.63)	18.56 (4.69)	19.31 (4.29)

During the season 2016–2017, 57 of the 356 players sustained a hamstring injury verified by the medical staff and 24 of those 57 players had a hamstring injury in the previous season (2015–2016) (RR 1,79; 95% CI, 1.11–2.87). The players in the new injury and no new injury groups did not differ in age, height, weight and years of soccer experience (19.20 (4.57)/18.59 (4.63)), respectively. The players with and without a previous hamstring injury also did not differ on those characteristics (Table 1).

The first analysis indicated the association between the baseline HaOS and previous hamstring injuries. A higher number of previous hamstring injuries was associated with a lower HaOS total score and lower HaOS subdomain scores at baseline (Fig. 1). Between group analysis revealed significant differences between the injury and no-injury groups in mean total HaOS score ($F(3,351) = 17.44$, $p = 0{,}000$) and in mean HaOS subdomain scores (symptoms: $F(3,373) = 13.171$, $p = 0{,}000$; soreness: $F(3,368) = 6.999$, $p = 0{,}000$; pain: $F(3,367) = 10.458$, $p = 0{,}000$; activity: $F(3,368) = 8.209$, $p = 0{,}000$ and quality of life: $F(3,368) = 24.243$, $p = 0{,}000$). The HaOS total score ranged from 52.50% to 100% in the no previous injury group and from 29.69% to 100% in the previous injury group.

Secondly, differences in HaOS scores at baseline between players who did or did not sustain a new hamstring injury in the subsequent season are presented in Table 2. Again, there were significant differences in mean total HaOS score and mean subdomain scores between players in the injury and no-injury groups. Players with a new hamstring injury in the current season had significantly lower HaOS domain scores at baseline than did players who did not sustain a new hamstring injury in the current season (Table 2).

Thirdly, previous hamstring injury and the HaOS score as a prognostic factor was investigated. The performance of the logistic regression models that allowed the HaOS predictor effect to be non-linear via a restricted cubic spline and the model that allowed for an interaction between the HaOS was not materially different. We will therefore focus on the two simpler models.

Univariable logistic regression analysis with baseline HaOS score as the only predictor of hamstring injury in the current season resulted in a model (after imputation and pooling) with an area under the ROC curve of 0.672 and a Nagelkerke R^2 index of 0.075 (intercept: 1.27 (0.73), regression coefficient:-0.04 (0.01)). Adding the number of injuries sustained in the previous season as a predictor increased the fit of the model (Likelihood ratio test, Chi-square = 13.38, df = 1, $p < .001$). This bivariable logistic regression model had an area under the ROC curve of 0.690 and a Nagelkerke R^2 index of 0.131 (intercept: 0.04 (std err: 0.844), HaOS score coefficient:-0.03 (std err: 0.01) and sustained hamstring injuries: 0.56 (std err: 0.16)). Univariable logistic regression analysis with previous hamstring injuries showed an area under the ROC curve of 0.643 and Nagelkerke R^2 index of 0.103 (intercept -2.17 (0.18), regression coefficient: 0.71 (0.15)).

Fig. 2 visualizes the predicted risk (i.e. estimated probability of a player suffering a hamstring injury in the current season) as a function of the HaOS score only (left panel) and with number of sustained hamstring injuries in previous season added (right panel). For reference, we added a line that marks the cut-off (80%) below which players are traditionally classified as being at "high risk" of sustaining hamstring injury.[16] With this cut-off, the hamstring injury risk was approximately 11%, whereas players with one or two hamstring injuries in the previous season had a risk of 18% and 28%, respectively.

4. Discussion

This study investigated the value of the Hamstring Outcome Score (HaOS) measured at the start of the soccer season as a prognostic factor to predict hamstring injury in that season. Players who had sustained an injury in the previous season had lower HaOS total and subdomain scores than did players without a previous hamstring injury. Further, players who sustained a new hamstring injury had lower HaOS total and subdomain scores than did players who did not sustain a hamstring injury in the current season. The ability of the HaOS score to predict new hamstring injury changed depending on the number of hamstring injuries sustained in the previous season. The probability of a new hamstring injury increased from 11% with no previous hamstring injury, to 18% with one previous hamstring injury and 28% with two previous hamstring injuries.

As expected, players who had sustained hamstring injuries in the previous season had lower total HaOS score and subdomain scores, indicating that they experienced more severe symptoms, more soreness and pain, less function in sports, and lower quality of life.[12] A possible explanation for the high recurrence rate of hamstring injuries is a too early return to play.[23] Our data show that players with previous hamstring injuries that occurred between 2 and 12 months ago still had lower HaOS scores than players without previous hamstring injuries. This indicates that complaints and symptoms of the posterior side of the thigh may be long lasting. Although fibrosis after hamstring injury is reported not to be associated with a higher risk of recurrence and lower myoelectrical activity in the Biceps Femoris has yet to be determined as cause or result of hamstring injury, long-term structural changes might explain why players report symptoms and complaints 12 months after returning to competition.[24,25] Additionally, these structural changes, for example, non-functional scar tissue, lower myoelectrical activity, decreased fascicle length and pennation angle, are also associated with functional limitations as reduced flexibility, decreased sprint speed, and alterations in muscle tissue lengthening mechanics, biomechanics, and peak knee flexor torque, which may be related to an increased injury risk.[14,26–28]

Players who sustained a new hamstring injury had lower HaOS total and subdomain scores at baseline than players who did not sustain a new hamstring injury. Although there is no strong evidence for risk factors other than age and previous hamstring injuries, subdomains of the HaOS appeared to be associated with future hamstring injury.[13] To our knowledge, the association between primary hamstring injury and pain and soreness in relation to activity and quality of life has not been investigated, although experts in the field do mention 'no pain' as a criterion for a safe return to play and for preventing recurrent hamstring injury.[23] Thus lower HaOS total and subdomain scores at the start of a season might be associated with an increased probability of new hamstring injury during the season. Furthermore, the risk of hamstring injury increased with both lower HaOS scores and higher number of previous injuries. This finding underlines the earlier findings of the structural and functional changes after hamstring

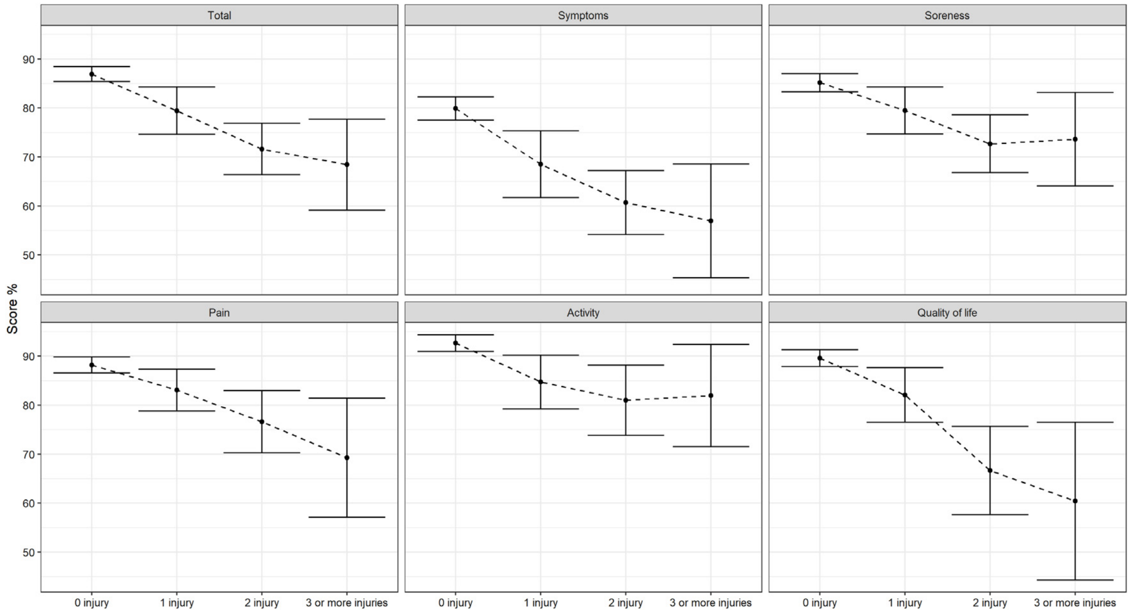

Fig. 1. Association between previous hamstring injuries and total HaOS score and HaOS subdomain scores. Averages with 95% (Wald) confidence intervals.

Table 2
HaOS scores (mean ± SD) of soccer players who did or did not sustain a hamstring injury in the current soccer season.

	Injury (n = 57)	No injury (N = 299)	Mean difference	Confidence intervals	P-values
Symptoms	65.45 (22.94)	78.22 (21.04)	12.77	6.65–18.89	0.000
Soreness	75.64 (16.56)	84.46 (16.45)	8.83	4.06–13.59	0.000
Pain	80.00 (18.01)	87.24 (14.35)	7.24	2.13–12.35	0.006
Activity	85.45 (17.37)	91.28 (16.04)	5.82	0.82–10.82	0.023
Quality of Life	78.41 (23.90)	87.50 (16.85)	9.09	2.38–15.80	0.009
Total HaOS	77.07 (16.31)	85.53 (13.78)	8.46	3.75–13.16	0.001

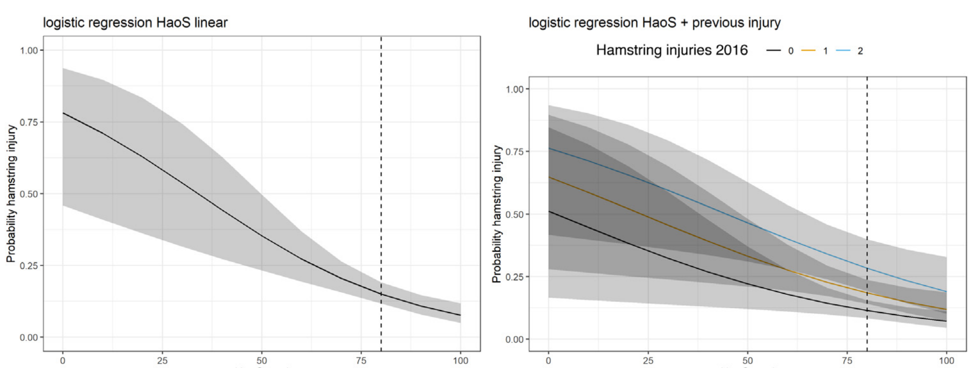

Fig. 2. Hamstring injury prediction plots based on logistic regression analysis.

injury. These changes may also be associated with discomfort during sport-specific activities and pain.[24,25,28]

Previous studies have used a HaOS cut-off score below 80% to classify players at high risk of hamstring injury. Our logistic regression models showed that with a cut-off score of 80%, the probability of sustaining a hamstring injury in one season increased with the number of hamstring injuries in the previous season, going from 11% with no previous injuries, to 18% with one previous injury, and 28% with two previous injuries. This risk increased with a lower score on the HaOS and the number of previous injuries. Although the HaOS score and previous injury have prognostic value, uncertainty around probability for new hamstring injury occurrence remains.[9] In the hamstring injury problem there are many (unknown) factors which may more or less, influence the probability of hamstring injury. In our study this is simplistically illustrated by our finding that a HaOS score of 0% combined with two previous hamstring injuries resulted in a probability of 76% of sustaining a new injury. It should be noted that in our dataset HaOS scores ranged from 29% to 100%, with 32 players (9%) having scores below 60%, 54 players (15%) having scores below 70%, and 98 players (28%) having scores below 80%.

Previous hamstring injuries have been recognized as risk factors for new hamstring injury. However, not every player with a history of hamstring injury gets reinjured, and no previous injury does not mean you are not at risk for hamstring injury. With the combination of number of previous injuries and the HaOS score, a first step towards the complex systems approach is set.[29] Multiple factors (or domains as measured by the HaOS) can interact in a certain way causing an increased risk or protect a player from injury.[29]

Up till now, we recommend that all players participate in hamstring injury prevention programs. In the future, it might be possible to target prevention programmes at those players at greatest risk. To be able to perform targeted prevention programmes, a number of studies and validated prediction models should be developed. Targeted prevention may be important because it might increase programme participation and compliance, which have been shown to increase the effectiveness of these interventions.[7,11]

This is the first study to investigate the association between the HaOS score and both previous and new hamstring injuries and to assess its prognostic value. The data for this study were collected prospectively during a large nationwide cluster-RCT that included 400 adult male soccer players.[20] This study is not without some limitations. The majority of the players (89%) filled in the HaOS at baseline and reported hamstring injuries weekly during one season. Unfortunately, the HaOS was only filled in at the start of the season, which might have led to missing valuable information during the season, especially right before the injury occurred. Previous hamstring injuries were registered retrospectively over a period of 12 months at the start of a new soccer season. This might have resulted in a recall bias, which could result in overestimation or underestimation of the number of previous hamstring injuries. While the current hamstring injuries were verified by the medical staff (physical therapist or sports masseur) of the teams, they were not confirmed with ultrasound or MRI.

To gain insight in individual changes in injury risk over time, future research could include longitudinal monitoring of symptoms with the HaOS. However, hamstring injuries are a multifactorial problem, and a multifactorial approach to their prevention and treatment is needed [30]. This hamstring injury model is a new step in targeted prevention, but other factors should be taken into account and tailored prevention programmes should be designed.

5. Conclusion

Amateur soccer players with a previous hamstring injury had lower HaOS total and subdomain scores than did non-injured players, as did players with new hamstring injuries in the current season. Thus HaOS scores and previous injuries appear to be prognostic factors for new hamstring injury.

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Conflict of interest

The authors declare that they have no conflicts of interest relevant to the content of this article.

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Appendix A. Supplementary data

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