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The Preventive Effect of the Nordic Hamstring Exercise on Hamstring Injuries in Amateur Soccer Players

A Randomized Controlled Trial

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Background: Hamstring injuries are the most common muscle injuries in soccer, and they have a high rate of recurrence. Eccentric hamstrings strength is recognized as an important modifiable risk factor. This led to the development of prevention exercises such as the nordic hamstring exercise (NHE). The effectiveness of the NHE on hamstring injury prevention has never been investigated in amateur soccer.

Purpose: To investigate the preventive effect of the NHE on the incidence and severity of hamstring injuries in male amateur soccer players.

Study Design: Randomized controlled trial; Level of evidence, 1.

Methods: Male amateur soccer players (age, mean \pm SD, 24.5 \pm 3.8 years) from 40 teams were randomly allocated to an intervention (n = 20 teams, 292 players) or control group (n = 20 teams, 287 players). The intervention group was instructed to perform 25 sessions of NHE in a 13-week period. Both the intervention and control groups performed regular soccer training and were followed for hamstring injury incidence and severity during the 2013 calendar year. At baseline, personal characteristics (eg, age, injury history, field position) were gathered from all participants via a questionnaire. Primary outcome was injury incidence. Secondary outcomes were injury severity and compliance with the intervention protocol.

Results: A total of 38 hamstring injuries were recorded, affecting 36 of 579 players (6.2%). The overall injury incidence rate was 0.7 (95% CI, 0.6-0.8) per 1000 player hours, 0.33 (95% CI, 0.25-0.46) in training, and 1.2 (95% CI, 0.82-1.94) in matches. Injury incidence rates were significantly different between the intervention (0.25; 95% CI, 0.19-0.35) and control groups (0.8; 95% CI, 0.61-1.15), $\chi^2(1, n = 579) = 7.865; P = .005$. The risk for hamstring injuries was reduced in the intervention group compared with the control group (odds ratio, 0.282; 95% CI, 0.110-0.721) and was statistically significant ($P = .005$). No statistically significant differences were identified between the intervention and control groups regarding injury severity. Compliance with the intervention protocol was 91%.

Conclusion: Incorporating the NHE protocol in regular amateur training significantly reduces hamstring injury incidence, but it does not reduce hamstring injury severity. Compliance with the intervention was excellent.

Keywords: hamstring injuries; soccer; injury prevention; eccentric strengthening; nordic hamstring exercise; nordic curl

Soccer is the most popular sport in the world, with more than 275 million participants.¹⁶ Unfortunately, research on sports injuries show high injury incidence rates for soccer, with male amateur soccer players being particularly prone to injury.^{9,10,12,35,38,43} Injury incidence rates of 20.4 to 36.9 injuries per 1000 match hours and 2.4 to 3.9 injuries per 1000 training hours have been reported in male amateur soccer.^{28,38,41}

Hamstring injuries are the most common soccer-related muscle injury.^{11,39,44} They account for 37% of all soccer muscle injuries, requiring extensive treatment and long rehabilitation periods.^{11,20,39,44} Recurrence rates for hamstring injuries remain high (12%-33%) despite preventive measures.^{20,21,23,44} Multiple potential risk factors for hamstring injuries have been reported, such as age, player position, previous hamstring injury, muscle architecture, fatigue, flexibility, core stability and strength.^{6,13,18,22,30,40}

The nordic hamstring exercise (NHE), or nordic curl, has been shown to be an effective tool to increase eccentric hamstring strength, developing higher maximal eccentric hamstring strength torques when compared with regular

hamstring curls.³¹ Previous studies on male professional soccer players have shown that adopting the NHE in regular training reduced hamstring injury incidence rates by 65% to 70%, with a particularly preventive effect in reducing recurrent injuries.^{1,33}

Male amateur soccer players form the largest subgroup of soccer players worldwide.^{9,35} Strategies to prevent hamstring injuries, such as the NHE, may reduce the incidence of hamstring injury, medical costs, and personal suffering of the injured player.^{26,29,33} Although previous studies in professional soccer have shown promising results, differences between professional and amateur soccer players in medical staff, level of play, training exposure, training intensity, and compliance to preventive measures have to be considered. Therefore, the findings for professional players cannot be extrapolated to amateur soccer players.

The aim of this study was to investigate the preventive effect of the NHE on the incidence and severity of hamstring injuries in male amateur soccer players.

METHODS

Study Setting

The present study was a cluster-randomized controlled trial, carried out in collaboration with the Royal Netherlands Football Association (KNVB). Soccer teams from 4 geographically separated districts playing in high-level amateur field soccer competition (KNVB Eerste Klasse) were invited to participate. These teams generally play 1 and sometimes 2 matches a week, with 2 or 3 training sessions per week. Dutch high-level amateur soccer teams generally have a physical therapist present at all matches and training. Occasionally, a sports massage therapist is present at matches and training, with a physical therapist available for additional consulting in case of any injury. The trial was approved by the medical ethics committee of the University Medical Centre Utrecht (file No. 12-575/C) and registered in the Dutch trial register (NTR3664) as the HIPS (Hamstring Injury Prevention Strategies) study. More detailed information is available in the study protocol.²⁴

Eligibility Criteria

Dutch male amateur soccer players aged 18 to 40 years were eligible for inclusion. Players who joined a participating team after the start of the trial were not included. All players were informed using an information letter and asked to give their informed consent before the start of this study. Players unwilling to do so were excluded from the trial.

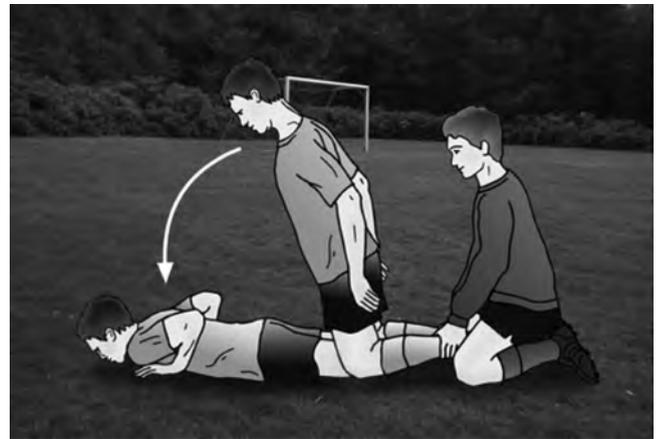


Figure 1. The nordic hamstring exercise (adapted from Petersen et al³³).

Randomization Procedure

Soccer teams were used as the unit of cluster to avoid the risk of bias if individuals were randomized to the intervention program. After computer-generated random assignment of team numbers, an equal number of teams were randomized to the control or intervention group by an online research randomizer (<http://www.randomizer.org>).

Intervention

Nordic Hamstring Exercise. The NHE, also referred to as the nordic curl, is designed to improve eccentric strength of the hamstring muscles.³¹ The exercise is performed in pairs (Figure 1; see also the Video Supplement).³³

Players start in a kneeling position, with the torso from the knees upward held rigid and straight. The training partner ensures that the player's feet are in contact with the ground throughout the exercise by applying pressure to the player's heels/lower legs. The player then lowers his upper body to the ground, as slowly as possible to maximize loading in the eccentric phase. Hands and arms are used to break his forward fall and to push him back up after the chest has touched the ground, to minimize loading in the concentric phase.³¹

Exercise Procedures. For the purpose of the present study, the exercise was supervised by the team coach or medical staff (eg, physical therapist and/or sport masseur). Exercises took place immediately after the completion of normal training, as recommended by Small et al,³⁶ before cooling down. After the winter break in the 2012-2013 season (last 2 weeks in December), all teams started their normal training program about 3 to 5 weeks before the

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TABLE 1
Nordic Hamstring Exercise Protocol

Wk	Frequency, per wk	No. of Sets per Training	Repetitions per Set
1	1	2	5
2	2	2	6
3	2	3	6
4	2	3	6, 7, 8
5	2	3	8, 9, 10
6-13	2	3	10, 9, 8

competition restarted (the season runs from July to May), which is typical for amateur soccer competition in Western Europe. The intervention (Table 1) started with a buildup phase (weeks 1-5) during preparation for competition and a maintenance phase (weeks 6-13) during competition.^{1,33}

Instructions. Players in the intervention group were instructed to perform 25 sessions of the NHE during the first 13 weeks after the winter break. Players were informed about the possibility of delayed-onset muscle soreness (DOMS), a known side effect of eccentric exercises.³¹ Players who were injured at the start of the intervention could start the protocol week 1 after full recovery. Specific instructions were provided for players who sustained an injury during the intervention period that limited performing the NHE. Players sustaining an injury within the first 5 weeks of the intervention period were instructed to restart the program after full recovery. The program had to be restarted from 1 week back in the program from where the player was when he sustained his injury. Players sustaining an injury between week 6 and week 13 of the intervention period were instructed to restart the program from week 4.

Data Collection

Baseline Characteristics. Before the start of the intervention, all players completed a questionnaire to record baseline characteristics: date of birth, weight, height, nationality, years of experience as a soccer player, leg dominance, field position, preventive measures taken (eg, taping, bandages, thermal pants, muscle strengthening exercises or stretching), and other injuries incurred before the start of the study (in particular, hamstring injuries and anterior cruciate ligament injuries).

Hamstring Injuries. The medical staff of participating teams were responsible for registering all hamstring injuries for a full calendar year (2013). A hamstring injury was defined as any physical complaint affecting the posterior side of the upper leg irrespective of the need for medical attention or time loss from soccer activities.¹⁹ All hamstring injuries were registered on a special form, and a so-called recovery form was completed when the player was fully recovered. Data were being collected on the epidemiology (location, type, and duration of the injury) and etiology (including intrinsic and extrinsic factors; eg, injury history and field condition) of the hamstring injury and information on residual complaints and tertiary prevention.

Exposure and Compliance. The number of times that a player performed the NHE protocol (intervention group), the number and duration (in minutes) of training sessions (both group and individual training) followed, and the number and duration (in minutes) of matches played were recorded weekly for 1 year by the team coach, using a computer-based registration form. Coaches also recorded reasons why players did not attend training or matches (eg, sickness, hamstring injury, other injuries, individual training, training elsewhere, or other) per individual player.

The research team had regular contact (by telephone, email, or visits) with team coaches and players with a view to encourage compliance and data registration. In addition, newsletters, evaluation meetings, and a website designed for this specific study were also used to stimulate participation and compliance. The intervention teams were monitored with regard to implementation and performance of the NHE and other self-initiated preventive strategies for hamstring injuries (eg, core stability, plyometric exercises). The control teams were monitored with regard to self-initiated preventive measures for hamstring injuries, specifically the NHE.

Outcomes

The primary outcome of this study was hamstring injury incidence. Injury incidence was reported in absolute numbers as well as an injury incidence rate for number of injuries per 1000 player hours in both matches and training.¹⁹ Secondary outcomes were injury severity and compliance with the intervention protocol. Injury severity was defined as the number of days that elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection.¹⁹ Injury severity was also classified in subcategories as slight (0 days), minimal (1-3 days), mild (4-7 days), moderate (8-28 days), severe (>28 days), and career ending.¹⁹

Statistical Methods

The quantitative data were analyzed using SPSS version 21.0 (IBM Corp). Significance was set at .05 for all statistical tests. Descriptive statistics (means and standard deviations) were used to describe baseline characteristics and exposure data. Hamstring injury incidence was analyzed based on an intention-to-treat basis. Injury incidence was only calculated from players whose full training and match exposure during all 52 weeks of the study were registered.

No effect of the intervention was expected until full completion of the NHE protocol. Therefore, the periods before (weeks 1-13) and after (weeks 14-52) full completion of the NHE protocol were separately analyzed. To assess the effect of the intervention on injury incidence and injury severity, chi-square tests were used for categorical variables and *t* tests for continuous variables. Odds ratios and relative risks were calculated to quantify associations between intervention and injury risk.

Compliance with the intervention was calculated on the basis of information provided by the team coaches. As the protocol consisted of 25 sessions, compliance was calculated

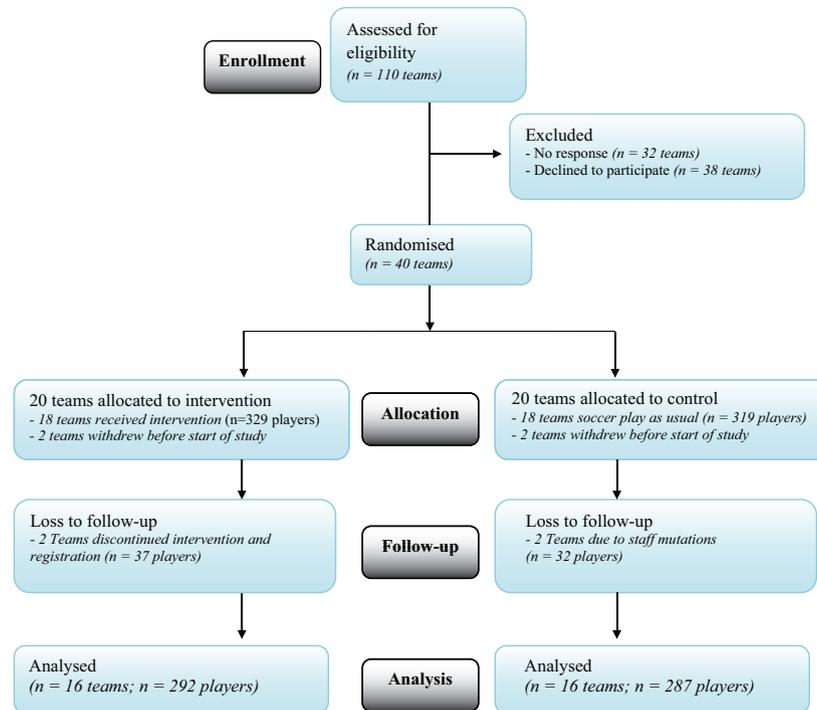


Figure 2. Flowchart of study population.

per team as follows: (amount of NHE sessions) / 25 × 100 = % compliance.

RESULTS

A total of 110 soccer teams from 4 soccer districts were asked to participate in this study. The 40 included teams were randomized by club to the intervention and control groups. Four teams (2 intervention and 2 control teams) withdrew participation before the start of the study because the medical staff was not able to perform baseline measurements as instructed. Another 2 teams from the control group were lost to follow-up because of trainer and/or medical staff replacements during the study period, and 2 teams from the intervention group were lost to follow-up because of unwillingness to continue the intervention and injury registration owing to players' complaints about DOMS. Players from 32 teams completed the study: 16 teams in the intervention group ($n = 292$ players) and 16 teams in the control group ($n = 287$ players). Figure 2 shows selection and allocation of players.

Baseline characteristics of all players included in the study are summarized by allocated group in Table 2. No statistically significant differences in baseline characteristics were found between the intervention and control groups.

Exposure

During the study period, players in the study had an average exposure of 92.9 (77.2-108.6) hours. The mean training and match exposure were 58.4 (41-75.8) hours and 34.5 (20.5-48.5) hours, respectively. There were no significant

differences between match or training exposure between the intervention and control groups (Table 3).

Hamstring Injury Characteristics

During the registration period, 36 initial hamstring injuries were recorded in 579 players (6.2%) (Table 3). The overall injury rate for both groups was 0.7 (95% CI, 0.6-0.8) per 1000 player hours, 0.33 (95% CI, 0.25-0.46) in training and 1.2 (95% CI, 0.82-1.94) in matches. Most injuries occurred during matches when compared with training (23 vs 11, respectively); other injuries occurred during warming up ($n = 1$) or were not reported ($n = 1$). No statistically significant differences were found regarding field position (defenders, 36%; midfielders, 32%; attackers, 32%). No hamstring injuries were recorded for goalkeepers. Members of team medical staff reported player acceleration as the most frequent cause (53%), more than the player decelerating (15%), shooting (6%), slipping (3%), cutting (9%), and overstretching the knee (3%) and other (21%).

Effects of the Intervention on Injury Incidence

Eleven hamstring injuries (31%) were recorded in the intervention group and 25 (69%) in the control group. Five of the 11 hamstring injuries (45%) in the intervention group and 7 of 25 hamstring injuries (28%) in the control group occurred within the 13-week intervention period. At the end of the 13-week intervention period, there was no statistical significant difference ($P = .427$) in hamstring injury incidence between the intervention and control groups (odds ratio, 0.628; 95% CI, 0.197-1.999).

TABLE 2
Baseline Characteristics of Soccer Players in Intervention and Control Groups^a

	Intervention Group (n = 292)	Control Group (n = 287)
Age, y	24.5 ± 3.6	24.6 ± 4.1
Height, cm	183.4 ± 6.4	183.5 ± 6.4
Weight, kg	77.6 ± 7.8	78.4 ± 8.2
Body mass index, kg/m ²	23.1 ± 1.7	23.3 ± 1.8
Dutch nationality	91 (263)	94 (243)
Soccer experience, y	17.8 ± 4.0	18.3 ± 4.6
Leg dominance		
Right leg	70 (203)	68 (174)
Left leg	21 (60)	20 (52)
Two-legged	7 (19)	12 (31)
Field position		
Forwarder	28 (80)	27 (69)
Midfielder	35 (101)	36 (92)
Defender	35 (102)	36 (92)
Goalkeeper	11 (31)	10 (25)
Preventive measures taken		
Taping/bandages	1 (3)	0 (0)
Thermal pants	15 (43)	24 (50)
Strengthening exercises	15 (42)	13 (34)
Stretching	26 (76)	32 (81)
Hamstring injury in previous year	24 (69)	20 (47)
Other soccer injuries in previous year	60 (174)	57 (144)
History of anterior cruciate ligament surgery	5 (13)	5 (11)

^aValues are presented in mean ± SD or percentage (No.).

TABLE 3
Comparison of the Intervention and Control Groups^a

	Intervention Group	Control Group
Exposure per player, h		
Total	90.5 ± 15.4	96.6 ± 16.0
Matches	34.0 ± 13.8	35.1 ± 14.3
Training	56.5 ± 17.0	61.5 ± 17.7
Hamstring injuries ^b	11	25
Before end of intervention period (wk 1-13)	5	7
After end of intervention period (wk 13-52) ^b	6	18
Soccer absenteeism due to hamstring injuries	31 ± 15	28 ± 19
Injuries by hamstring injury severity ^c		
Slight (0 d)	0	1
Minimal (1-3 d)	0	1
Mild (4-7 d)	0	2
Moderate (8-28 d)	4	5
Severe (>28 d)	2	9

^aValues are presented in mean ± SD or No.

^bSignificantly different between the intervention and control groups ($P < .05$).

^cAfter the end of the intervention period (weeks 13-52).

After the intervention period, 18 hamstring injuries (72%) were recorded in the control group and 6 (55%) in the intervention group, showing a significant difference in hamstring injuries between both groups, $\chi^2(1, n = 579) = 7.865, P = .005$. Risk for injuries was reduced in the intervention group after performing the NHE protocol (relative risk, 3.384; 95% CI, 1.362-8.409) (odds ratio, 0.282; 95% CI, 0.110-0.721) and was statistically significant ($P = .005$).

Effects of the Intervention on Injury Severity

After the intervention period, players in the intervention and control groups were absent from soccer play for an average (\pm SD) of 31 ± 15 days and 28 ± 19 days, respectively. The difference in injury severity between the intervention and control groups was not statistically significant: $t(22) = .374, P = .342$.

Compliance

Two teams did not fully report compliance with the intervention protocol owing to loss to follow-up. The compliance of intervention teams to the protocol was 91%. Reasons for not achieving full compliance with the intervention protocol were players complaining about DOMS and not having 2 training activities because of midweek matches or other activities. DOMS were mainly reported in the first weeks (buildup phase) of the NHE protocol. None of the teams in the control group performed a NHE protocol comparable with the intervention program.

DISCUSSION

This cluster-randomized controlled trial evaluated the preventive effect of the NHE on the incidence and severity of hamstring injuries in male amateur soccer players. The results show that performing the NHE protocol in regular amateur soccer training results in a reduced risk of hamstring injury in male amateur soccer players. The NHE protocol did not reduce hamstring injury severity.

The effectiveness of eccentric strengthening for hamstring injury prevention can be explained from previous biomechanical analyses. Hamstring ruptures typically occur in the latter part of the swing phase during sprinting.^{4,5,34} In this phase, where the hamstrings are (sub-)maximally stretched because of hip flexion and knee extension, the hamstring muscles have to decelerate knee extension (ie, performing an eccentric contraction in a lengthened position).^{4,5} The higher the sprinting velocity, the greater these forces are.^{4,5} The risk of hamstring injury during high-speed running is associated with inadequate eccentric strength of the hamstrings.^{7,8,32}

Effective injury prevention via eccentric strengthening of the hamstring muscles has been demonstrated before, mainly in professional soccer.^{1,2,33} Askling et al² showed significant hamstring injury incidence reduction in a subgroup of professional soccer players performing additional hamstring strength training with eccentric overload compared with a control group performing training as usual. Arnason et al¹ and Petersen et al³³ also investigated the preventive effect of eccentric strengthening on hamstring injury incidence in a much larger study population of professional soccer players. Although a preventive effect was found, these studies were mainly conducted on professional players. Additionally, the biggest effect was found for recurrent hamstring injuries as defined by Fuller et al.¹⁹ The present study did record recurrent hamstring injuries following the same definition.¹⁹ However, since there were only 2 recurrent injuries recorded, both from the same player, recurrent injuries were not included in the analyses, and effects were thus not specified for recurrent injuries as previously done.

This study focused on male amateur adult soccer players and was characterized by the large study population (40 amateur teams). Other strengths of this study are the tailored intervention design specific for amateur soccer and the high compliance with the intervention protocol (91%) compared with similar exercise-based intervention studies.^{14,25,41}

Some methodological issues should be considered. This study could have been limited by information bias, as participants were not blinded within the study. Unfortunately, it is usually impossible to achieve and maintain blinding in exercise-based field studies. Athletes are taking part in the intervention and know what measures were performed, and we did not produce a sham intervention for blinding purposes.³ Second, in view of the expected large number of hamstring injuries in this study, it was not feasible to verify injury diagnosis by an independent medical doctor, including appropriate additional diagnostic imaging (eg, magnetic resonance imaging, ultrasound). The adopted definition of hamstring injury was similar to that used in previous research and in accordance with the consensus statement on injury definitions in studies of soccer.^{1,2,19,33} Although guidelines from the consensus statement have been generally adopted in studies of soccer injuries, no subclassifications on hamstring injury type or hamstring injury location can be provided without thorough medical assessment (preferably including magnetic resonance imaging). Therefore, a specifically designed hamstring injury registration form was used to verify the hamstring injury and exclude other potential conditions for posterior upper leg pain (eg, referred pain or adductor-related injuries). When the distribution of hamstring injury severity is judged in our study population, significantly more moderate and severe injuries are reported than slight, minimal, or mild injuries. Underreporting of slight, minimal, or mild injuries could have led to lower overall hamstring injury incidence rates, although hamstring injury incidence rates in this study were similar to incidence rates described in a similar population by van Beijsterveldt et al,³⁹ reporting hamstring injury incidence rates of 1.5 per 1000 player hours. Additionally, medical staff of participating teams were specifically instructed on the adopted hamstring injury definition, and regular contact was established to encourage compliance to hamstring injury registration.

Previous studies, as well as the consensus statement of Fuller et al,¹⁹ have stated that injury incidence rates should be reported as the number of injuries per 1000 hours of soccer play. Although the present study intended to monitor exposure of every included player, this study had some data loss regarding exposure, owing to coach and player replacements. Exposure was therefore calculated only from data of players whose exposure had been reported for a full year. It should be considered that for studies on hamstring injuries, it is not the amount of hours of soccer play (exposure) that might be crucial but, rather, match or training intensity. Biomechanical analyses have shown that the hamstring muscle is particularly prone to injury during high-intensity movements in soccer, such as accelerating, high-speed running, and cutting.^{4,5,7,8,32} Subsequently, as stated by Petersen et al,³³ this would require registration of individual activity and intensity by GPS (global positioning system), biomechanical analyses, video, and so forth. From these registration methods, only high-risk activities should be registered as exposure. Unfortunately, this approach was not feasible in the current trial. Because all participating clubs played at the

same performance level, had approximately similar training and match exposure, and were randomized by an independent randomizer, we assumed similar intensity regarding both training and matches.

Injury prevention is an essential part of sports participation to reduce sports injuries, direct and indirect medical costs, and personal suffering of the injured player.¹⁵ The NHE has proven to be an effective preventive measure for hamstring injuries in soccer.^{1,33} Unfortunately, positive outcomes from intervention studies do not necessarily lead to subsequent prevention of injuries.⁴² Interventions can prevent injuries only when they are adopted and used by the intended end users.¹⁷ The present field study was conducted in collaboration with the Royal Netherlands Football Association, team coaches, team medical staff, and team players. This collaboration, as well as the specific parameters and buildup of the intervention protocol, should provide a basis for implementation of the NHE in soccer training for Dutch amateur teams. Policy makers and football associations should continue to make a joint effort to ensure and investigate implementation of injury preventive strategies such as the NHE to make injury prevention truly work.

As stated by Klügl et al,²⁷ there is a lack of research on implementation and effectiveness of injury preventive strategies in a real-world context. This knowledge is essential, as positive study outcomes do not directly translate into injury prevention. Future research should therefore focus on pitfalls and opportunities on implementation of eccentric strengthening as an injury preventive strategy in soccer. Additionally, studies with longer follow-up should be performed to analyze the long-term effects of NHE and effectiveness on recurrent injuries in an amateur population.

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A Video Supplement for this article is available in the online version or at <http://ajsm.sagepub.com/supplemental>.

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