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Preventive Effect of Eccentric Training on Acute Hamstring Injuries in Men's Soccer

A Cluster-Randomized Controlled Trial

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Background: The incidence of acute hamstring injuries is high in several sports, including the different forms of football.

Purpose: The authors investigated the preventive effect of eccentric strengthening of the hamstring muscles using the Nordic hamstring exercise compared with no additional hamstring exercise on the rate of acute hamstring injuries in male soccer players.

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

Methods: Fifty Danish male professional and amateur soccer teams (942 players) were allocated to an intervention group (461 players) or a control group (481 players). Players in the intervention group conducted a 10-week progressive eccentric training program followed by a weekly seasonal program, whereas players in the control group followed their usual training program. The main outcome measures were numbers of overall, new, and recurrent acute hamstring injuries during 1 full soccer season.

Results: Fifty-two acute hamstring injuries in the control group compared with 15 injuries in the intervention group were registered. Comparing intervention versus the control group, overall acute hamstring injury rates per 100 player seasons were 3.8 versus 13.1 (adjusted rate ratio [RR], 0.293; 95% confidence interval [CI], 0.150-0.572; $P < .001$). New injury rates per 100 player seasons were 3.1 versus 8.1 (RR, 0.410; 95% CI, 0.180-0.933; $P = .034$), whereas recurrent injury rates per 100 player seasons were 7.1 versus 45.8 (RR, 0.137; 95% CI, 0.037-0.509; $P = .003$). Number needed to treat [NNT] to prevent 1 acute hamstring injury (new or recurrent) is 13 (95% CI, 9-23) players. The NNT to prevent 1 new injury is 25 (95% CI, 15-72) players, and NNT to prevent 1 recurrent injury is 3 (95% CI, 2-6) players.

Conclusion: In male professional and amateur soccer players, additional eccentric hamstring exercise decreased the rate of overall, new, and recurrent acute hamstring injuries.

Keywords: hamstring; strain; prevention; eccentric training

Worldwide, more than 15 million adults play amateur soccer in registered clubs and more than 100 000 soccer players are professionals.[15] A significant number of players experience injuries with subsequent pain, disability, and financial costs.[29] Hamstring muscle injury is the most prevalent injury in soccer, accounting for 12% to 16% of all injuries.[2,11,34] The incidence of hamstring injuries is 0.5 to 1.5 injuries per 1000 hours of soccer exposure (match and training).[2,12,19] In addition to the high incidence, a common problem concerning this injury is the high risk of recurrence. A recurrence rate of 22% within the first 2 months after the index injury has been reported, and in Danish professional soccer, 25% of players with a hamstring injury sustain a recurrent injury in the following season.[19,26]

The functions of the hamstring muscles are hip extension and knee flexion. However, the requirements of the hamstrings in terms of force, velocity, and power are limited during walking and jogging compared with during sprinting.[28] This is consistent with neuromusculoskeletal models showing that peak hamstring stretch and force occur during the late swing phase of the running gait cycle and that force increases significantly with speed.[8,32] The majority of hamstring injuries in soccer occur while players are running or sprinting,[2,34] and these injuries seem to occur in the late swing phase, where the hamstring muscles generate tension while lengthening (eccentric

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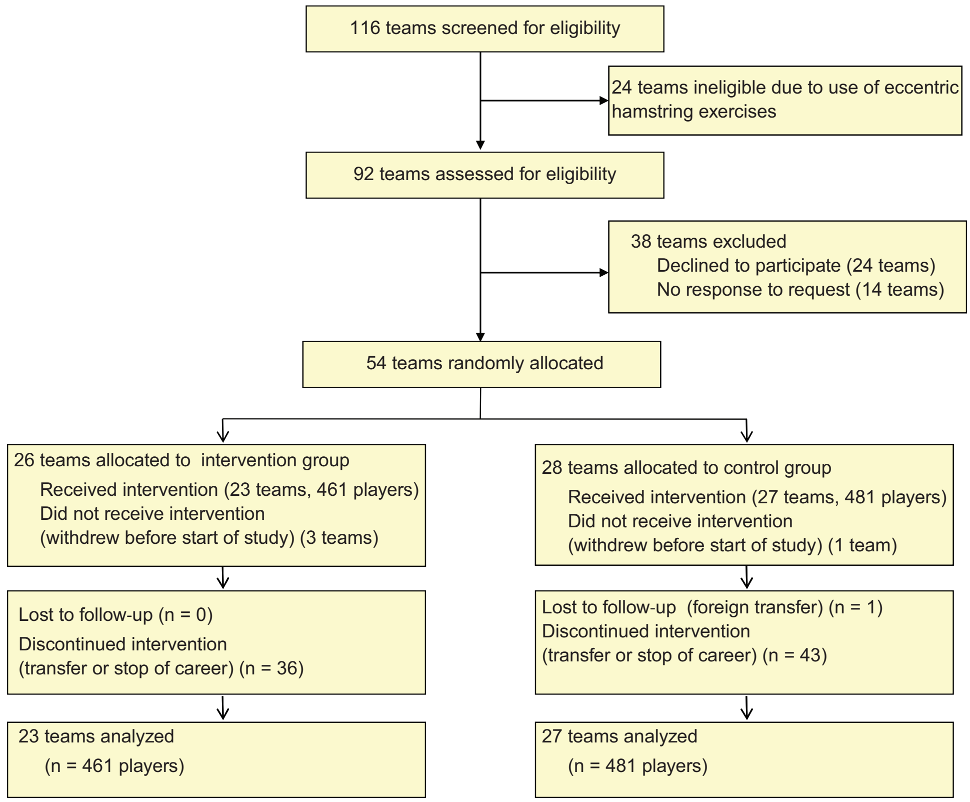

Figure 1. Flow of participants through the trial.

contraction) to decelerate knee extension.[20,28] Increasing the eccentric strength of the hamstring muscles, performed by lengthening the hamstring muscle complex while it is loaded and contracting, has therefore been proposed as a method to prevent hamstring injuries.[7,10,31]

Brockett et al[7] used a simple eccentric hamstring strength training exercise that has been further developed by Mjølsnes et al[22] and is known as the "Nordic hamstring exercise." This exercise, which can be done in the field without the use of any equipment, has been shown to increase the eccentric strength in the hamstring muscles in male professional soccer players.[22]

However, contradictory results of the effect of eccentric hamstring strength training on hamstring injuries have been found.[1,4,14,17] Pooled results for the 3 existing studies that have used a randomized controlled design[4,14,17] (n = 287) have shown substantial heterogeneity between the results of the studies ($I^2 = 62\%$) and no statistically significant difference between intervention and control groups (risk ratio, 0.83; 95% confidence interval [CI], 0.26-2.65).[18] However, these studies had an insufficient sample size or unsatisfactory compliance with the intervention. Rigorously conducted and sufficiently powered randomized controlled trials are therefore warranted to determine the effects of, for instance, eccentric hamstring muscle strengthening on the rate of acute hamstring injuries.[18,25] Therefore, we designed the first cluster-randomized controlled trial with an adequate sample size to test whether a 10-week training program using the Nordic hamstring exercise could lower the incidence of new and recurrent acute hamstring injuries in the subsequent soccer season, and cause less severe hamstring injuries compared with no additional hamstring exercise.

MATERIALS AND METHODS

Participants

A total of 116 men's soccer teams play in the top 5 Danish soccer divisions. Players in division 1 are full-time professionals, whereas players in division 2 are professionals or semiprofessionals. Players in divisions 3 through 5 are amateurs. All 116 teams were contacted and informed about the project. As depicted in Figure 1, 24 teams were ineligible because they already used eccentric hamstring exercises.

Of the remaining 92 teams, 54 accepted and 24 declined to participate in the trial. Fourteen teams did not respond to repeated requests. Players of the first-team squads were included after giving written informed consent. Players who joined a team after the start of the trial were not included. Included players who left a team before the end of the trial were not excluded. However, these players only contributed to the analysis in proportion to their participation time.

The trial was revised and approved by the Regional Ethics Committee (H-A-2007-0062) and was registered with the Danish Data Protection Agency (2007-41-0275) and ClinicalTrials.gov (NCT00557050).

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Randomization

To reduce potential confounding attributable to different exposure times and playing intensity, all participating teams were stratified according to playing level before they were randomized. Because of the organization of the Danish soccer divisions, all divisions below the second-best division are divided according to geographical location. Therefore, teams from the 3 lowest divisions were further stratified according to geographic location before the randomization procedure. We found it necessary to cluster-randomize using teams as the unit of cluster, because of the risk of contamination of the intervention program if individual randomization was used.

An independent research assistant did the randomization procedure by drawing a sealed, opaque envelope containing a team name followed by drawing another sealed, opaque envelope containing the allocation group (intervention or control) for that particular team. The numbers of envelopes containing the allocation group were adjusted to match the number of teams in the particular stratification level and, in cases of an unequal number of teams, the envelopes were adjusted to 1 extra envelope to secure the 1:1 ratio of intervention and control teams.

The procedure was done in December 2007 to ensure that the coaches involved were informed regarding the allocation before the start of the 2008 season. In this manner the coaches in the intervention teams were able to incorporate the Nordic hamstring exercise in the preparation and planning of the training sessions for the upcoming season.

Players in the teams were not informed about the project and group allocation until they started their first training session in 2008. This was decided because a considerable number of players are known to transfer between clubs in December.

Blinding

The trial was conducted as an open trial. Consequently, the person responsible for the day-to-day running of the project, medical staff within the teams, and all players were aware of group allocation.

Study Period

The playing season in Denmark starts in July or August and ends in June in the following year. In the 6- to 8-week preseason period from June to July/August, most teams are having a vacation for 2 to 3 weeks. The playing season includes a midseason competition break from December to March that divides the first and second halves of the playing season. In this midseason break, most teams have a vacation for 2 to 3 weeks.

The 10-week intervention program was introduced in the midseason break because this is the only time of the year in which this unaccustomed exercise does not conflict with the competitive season. The injury registration began when the participating teams started their first training session in 2008 (January/February) and ended when the teams ended their last training session in 2008 (December). Hence, the injury registration period consisted of the midseason break and second half of the 2007-2008 playing season combined with the preseason and first half of the 2008-2009 playing season, which equals all risk periods during a full 12-month season.

The trial was conducted between January 7, 2008, and December 12, 2008, with follow-up of the last injury until January 14, 2009.

Baseline and Injury Registration

When the participating teams started their first training session in 2008, all players (n = 942) reported baseline information using a report form in accordance with the recommendation from the Injury Consensus Group under the auspices of the FIFA (Fédération Internationale de Football Association) Medical Assessment and Research Centre.[16] The data included in the analysis were playing position, age, and details of hamstring injuries during the last 12 months.

The team's physiotherapist or medical staff were given standardized instructions regarding injury definition and collected details of all hamstring injuries in the period from the first training session in 2008 until the team ended their last session in 2008. A standardized injury registration form designed for this trial was used. The injury type was registered so that contusion injuries could be excluded. Furthermore, the time until the injured player returned to full participation was registered for all players who had time-loss injuries, that is, for players who missed 1 or more training sessions or matches. Recurrence of already recorded injuries in the registration period was not included to avoid recording the same injury more than once. All teams were contacted by e-mail on a monthly basis during the entire registration period to encourage the responsible personnel to register all acute hamstring injuries. To further increase the compliance of injury registration, all injured players were offered a free ultrasound examination of the injured thigh within 7 days. Ultrasound examination was not used to verify the clinical diagnosis because a great number of "characteristic" hamstring injuries are known to be undetectable with this imaging modality.[9] Therefore it was decided in advance not to use the results of the ultrasound examinations in the data analysis.

Intervention

All teams in the intervention and control groups followed their usual training program. In addition, the teams in the intervention group performed 27 sessions of the Nordic hamstring exercise in a 10-week period during the midseason break (Figure 2). The Nordic hamstring exercise is a partner exercise. The athlete starts in a kneeling position, with his torso from the knees upward held rigid and straight. A training partner applies pressure to the athlete's heels/lower legs to ensure that the feet stay in contact with the ground throughout the movement. The athlete then attempts to resist a forward-falling motion using his hamstring muscles to maximize loading in the eccentric phase. The participants were asked to brake the forward fall for as long as possible using the hamstrings. The athletes were asked to use their

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TABLE 1
Training Protocol for the Nordic Hamstring Exercise

Week	Sessions Per Week	Sets and Repetitions
1	1	2 × 5
2	2	2 × 6
3	3	3 × 6-8
4	3	3 × 8-10
5-10	3	3 sets, 12-10-8 reps
10+	1	3 sets, 12-10-8 reps

arms and hands to buffer the fall, let the chest touch the surface, and immediately get back to the starting position by pushing with their hands to minimize loading in the concentric phase.[22] The exercise was conducted during regular training sessions and players were supervised by their (physical) coach, who was informed about the exercise orally and had received written descriptions and illustrations of the exercise. The team coaches decided when the exercise was performed during the training session but they were advised not to use the Nordic hamstring exercise before a proper warm-up program. The teams followed the training protocol presented in Table 1. After the start of the second half of the 2007-2008 playing season (spring 2008), the exercise was conducted once a week with 3 sets of 12, 10, and 8 repetitions, respectively. However, the exercise was not conducted during the vacation period in the preseason (2-3 weeks). Compliance of the training program and adverse effects were registered for each team on a weekly basis by contact with the coaches during the 10-week training period.

Definitions

The outcome of interest was the occurrence of an acute hamstring injury. In accordance with the general injury definition and recommendation by FIFA, a hamstring injury was defined as any acute-occurring physical complaint in the region of the posterior thigh sustained during a soccer match or training, irrespective of the need for medical attention or time loss from soccer activities.[16] An injury was recorded as a new injury unless an injured player had reported a similar injury at the same site at baseline, that is, during the 12-month period prior to the trial. In the latter case, the injury was recorded as a recurrent injury. Recurrence after an already recorded injury was not registered.

A player was defined as injured until he returned to full participation in team training and was available for match selection. The medical staff, in consultation with the player, assessed when an injured player could return to full participation and be available for match selection. For players with time-loss injuries, the number of days that elapsed from the date of injury (day 0) to the date of the player's return to full participation was used to calculate the injury severity.

Statistical Analysis

The incidence of hamstring injuries in Danish professional soccer was estimated at 14% based on data from Danish

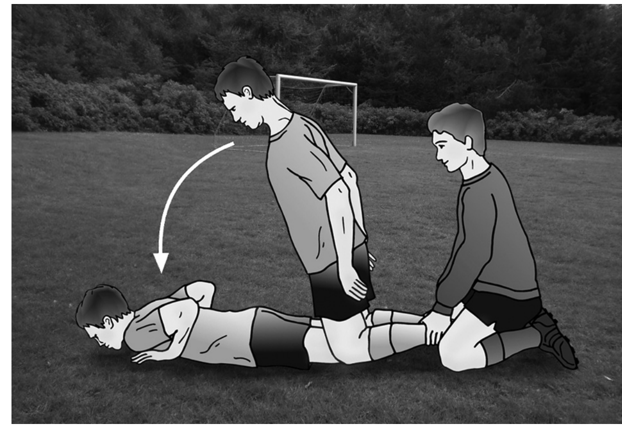

Figure 2. The Nordic hamstring exercise.

men's professional soccer teams.[26] We estimated that the cluster effects for club randomization gave an inflation factor of 1.19 based on a mean cluster size of 20 and an intracluster correlation coefficient (ρ) of 0.01.[13] To achieve 80% power with a significance level of 5% to detect a relative risk reduction of 50% and a dropout rate of 20%, a sample size of 428 players in each group was needed. Our aim was to include a total of 1000 players in 50 teams.

We used cluster-specific statistical methods because clubs, and not players, were randomized. Data were entered into a Microsoft Excel 2007 (Microsoft, Redmond, Washington) spreadsheet and were analyzed with the SAS software version 9.1 (SAS Institute Inc, Cary, North Carolina).

An injured player was not excluded from the trial because he was still at risk of sustaining an injury to the same or opposite thigh. However, recurrence of already recorded injuries was not included in the data collection and hence not analyzed.

Number needed to treat (NNT) was estimated by comparing the proportion of injured players in the intervention and control groups. The injury rates in the 2 groups were then compared using Poisson regression analysis. Here the number of injuries in a given player is assumed to follow a Poisson distribution. The mean in this distribution is given by the product of injury rate and time at risk. The injury rate is allowed to depend on covariates, while time at risk is calculated as the number of days the player participated in the study minus the number of days he was injured. This analysis appropriately takes into account the fact that not all players had complete follow-up and that injured players were not at risk of injury in the period of rehabilitation. Results of the Poisson regression analysis are given as rate ratios. Because of the clustering in data, parameters were estimated using "generalized estimating equations" that account for intrateam correlation of the injury risk.[27] Age, previous injury, and competition level are known risk factors of sustaining a hamstring injury.[3,34] Thus, in further analysis, the initial model was adjusted for the players' age, competition level, and a covariate indicating whether the players had had a previous hamstring injury. This analysis was conducted to avoid the possibility

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TABLE 2
Characteristics of the Cohort at the Beginning of the Trial[a]

Characteristic	Intervention Group (n = 461)	Control Group (n = 481)	*P* Value
Position			
Goalkeeper	38 (8.2)	41 (8.5)	.88
Defender	134 (29.1)	139 (28.9)	.95
Midfielder	147 (31.9)	143 (29.7)	.47
Forward	76 (16.5)	77 (16.0)	.84
Alternating	66 (14.3)	81 (16.8)	.29
Age in years, mean (SD)	23.0 (4.0)	23.5 (4.0)	.75
Previous hamstring injury[b]	49 (10.6)	54 (11.2)	.77
Matches played per team, mean (SD)	29.5 (0.90)	29.5 (1.16)	.81

[a]Values are expressed as number (%) unless stated otherwise. SD, standard deviation.
[b]Within 1 year before the trial.

of bias caused by small differences between the 2 groups in the distribution of their background characteristics. We then compared the injury rates in the 10-week midseason period in a Poisson regression analysis restricted to injuries and time at risk in that period. We also compared the rate of new injuries between the 2 groups. This was done by comparing the number of injuries and time at risk only in players who did not have a previous injury. To compare the risk of recurrence, we restricted the data to players who had a hamstring injury in the season before the trial. In a Poisson regression model, we then explored how the recurrence rate varied between groups. Finally, we compared the 2 groups with respect to the length of time players were injured. This was done in a regression model with age as an additional covariate. Intrateam correlation was taken into account in a so-called mixed model by allowing residual terms in players from the same team to be correlated.

The level of significance was set at $P < .05$.

RESULTS

Fifty-four teams accepted and 24 teams declined to participate in the trial. The decliners were teams from all geographical locations and competition levels. A total of 54 teams were included and randomly assigned to an intervention group (26 teams) or a control group (28 teams). Of the 54 teams that originally were enrolled in the trial, 4 teams withdrew before inclusion of individual players. It was therefore not possible to include data concerning these 4 teams in the analyses. Three of the teams that withdrew were assigned to the intervention group and 1 team was assigned to the control group. Hence, the intervention and control groups consisted of 23 teams (461 players) and 27 teams (481 players), respectively. Fifty-six players in 3 teams in the intervention group were professionals (division 1 or 2) whereas 405 players in 20 teams were amateurs (divisions 3-5). The corresponding numbers in the control group were 62 professional players in 3 teams and 419 amateur players in 24 teams). Figure 1 shows the trial profile. Baseline characteristics of the groups were similar (Table 2) and the distribution of professional and amateur teams in the 2 groups were not significantly different ($P = .91$).

The mean injury registration period for the 50 teams was 318 days (range, 283-341 days).

The total number of dropouts was 79 (8%) players (36 players from the intervention group and 43 players from the control group corresponding to 8% and 9%, respectively). All dropouts occurred in the preseason period. Reasons for dropping out were transfer or stop of active career. None ended their active career because of a hamstring injury.

The teams in the intervention group performed a mean of 91% of the 27 intended training sessions (mean, 24.6; standard deviation [SD], 2.3; range, 18-27 sessions).

A total of 67 acute hamstring injuries (44 new and 23 recurrent injuries) in 67 players were registered, with 15 injuries in the intervention group (12 new and 3 recurrent injuries) and 52 injuries in the control group (32 new and 20 recurrent injuries) (Table 3). Nine of 15 (60%) injuries in the intervention group occurred within the 10-week training period, whereas the corresponding number in the control group was 12 of 52 (23%) injuries. Controls showed a higher injury rate in the preseason period (adjusted rate ratio [RR], 1.76; 95% CI, 0.54-5.67) but this effect was not statistically significant ($P = .35$).

No injuries occurred during conduction of the Nordic hamstring exercise.

Recurrent injuries occurred 2 to 20 months (median, 12 months) after the index injury. Comparing intervention versus control groups (Table 3), overall hamstring injury rates were significantly lower in the intervention group (RR, 0.293; 95% CI, 0.150-0.572; $P < .001$). This difference was based on both significantly lower injury rates regarding new injuries (RR, 0.410; 95% CI, 0.180-0.933; $P = .034$) and recurrent injuries (RR, 0.137; 95% CI, 0.037-0.509; $P = .003$). The NNT to prevent 1 overall hamstring injury, be it a new or recurrent injury, is 13 (95% CI, 9-23) players. The NNT to prevent 1 new injury is 25 (95% CI, 15-72) players and NNT to prevent 1 recurrent injury is 3 (95% CI, 2-6) players.

Injury severity in the 2 groups was assessed by days of absence from soccer. In the intervention group, the 15 injuries resulted in a total of 454 days absence from soccer (mean, 30.3; SD, 18.3; median, 22; range, 7-64 days per

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TABLE 3
Acute Hamstring Injuries in Intervention Versus Control Groups[a]

Injury Type	Allocation Group	No. of Injuries	Player Seasons at Risk	Injury Rate Per 100 Player Seasons	NNT (95% CI)	Unadjusted Rate Ratio (95% CI)	Adjusted Rate Ratio (95% CI)	P Value
Total	Intervention (n = 461)	15	390	3.8	13 (9-23)	0.292 (0.136-0.631)	0.293[b] (0.150-0.572)	<.001
	Control (n = 481)	52	396	13.1				
New	Intervention (n = 461)	12	348	3.1	25 (15-72)	0.380 (0.150-0.965)	0.410[c] (0.180-0.933)	.034
	Control (n = 481)	32	352	8.1				
Recurrent[d]	Intervention (n = 49)	3	42.0	7.1	3 (2-6)	0.156 (0.046-0.525)	0.137[c] (0.037-0.509)	.003
	Control (n = 54)	20	43.7	45.8				

[a]NNT, number needed to treat; CI, confidence interval.
[b]Rate ratio adjusted for age of players, competition level, and previous injury.
[c]Rate ratio adjusted for age of players and competition level.
[d]Recurrence of injuries sustained in the 12-month period prior to the trial.

injury). Of 52 injuries in the control group, 51 could be evaluated according to severity. These 51 injuries resulted in a total of 1344 days' absence from soccer (mean, 26.4; SD, 19.5; median, 21; range, 4-89 days per injury). Injury severity for the single player in the control group with missing data was estimated to 0 days in the Poisson analysis in order to use a conservative approach. After adjustment for age, the mean injury period in the control group was 8.2 days shorter than in the intervention group, but this difference was not statistically significant ($P = .16$).

Eccentric exercise is known to result in delayed-onset muscle soreness.[22] Delayed-onset muscle soreness was reported by most players in the intervention group during the first weeks of the training program. Besides this, no adverse events were reported.

DISCUSSION

This is the first cluster-randomized controlled trial documenting that it is possible to reduce the incidence of hamstring injuries in professional and amateur soccer significantly by completing a training program that focuses on increasing eccentric hamstring muscle strength. The training program is able to reduce the injury rate of new injuries by more than 60% and an important clinical finding of this trial is that the intervention is highly effective in reducing the rate of recurrent injuries, which was reduced by approximately 85%. No beneficial effect on the severity of hamstring injuries when completing the training program was documented.

Methodologic Considerations

Strengths of this trial are the use of a randomized design and the inclusion of a large number of participants. In contrast to other studies concerning hamstring injury prevention,[14,17] the team compliance of the intervention was very good, with an average of 91% of the intended training sessions performed during the 10-week midseason period. However, compliance of the intervention after the first 10 weeks was not recorded, which is a limitation of the present trial. The use of a clear injury definition that made injury registration independent of a clinical assessment, combined with the regular contact to the participating teams, presumably resulted in a minimum of missed injuries and is considered a strength of the trial.

Another strength is to exclude recurrence of already recorded injuries. The risk of recurrence after a hamstring injury is high, and it has been shown in Australian Rules football that more than one-third of all recurrent hamstring injuries occur in the first week after the final rehabilitation day.[19,24,26] Recording recurrent injuries of an already recorded injury would have tended to magnify the difference between groups and thereby could have resulted in a false significant difference. By restricting the injury registration to new injuries only, we avoided overestimating the effect of the intervention.

Blinding of a nonpharmacologic trial can be difficult to achieve.[5,6] We did not find it possible to introduce a convincing sham training program that could have led the players in the control group to believe that they performed a hamstring injury preventive exercise. The fact that this trial was conducted as an open study with no blinding of the study participants is a limitation that potentially introduced bias. However, Wood et al[33] have shown that the use of an objective outcome, defined as an outcome that cannot be influenced by investigators' judgment, minimizes the risk of introducing bias attributable to group allocation in open studies. The outcome of interest in the present trial was acute events. Most likely an acute injury cannot be neglected by a player in the belief that he is protected from injuries because of the exercise program. Injuries were registered and reported by the medical personnel within the teams and the person responsible for the day-to-day running of the project therefore had no influence on injury reporting. Hence, we consider the injury reporting an objective outcome, and do not believe that this issue has biased the results notable. Furthermore, all analyses were conducted blinded to allocation groups.

In this trial, we reported the number of injuries independent of exposure time, which is a limitation of the trial because of potential dissimilar exposure in the 2 groups.

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However, exposure time in general is not synonymous with time at risk for incurring an injury. First of all, the generally used term "1000 exposure hours" is not similar in a division 1 and a division 5 team as quality and intensity of soccer play depends on the competition level.[23] Secondly, various "soccer exposures," for instance recovery training, technical training, and strength training, do not imply a risk of incurring an acute hamstring injury. Therefore, a detailed evaluation of exposure would not only involve individual registration of playing/training time but also include registration of individual activity and intensity by GPS (global positioning system), video, heart rate monitoring, and so forth. Then only high-risk activities (high-speed running or sprinting) should be registered as risk exposure. This approach is not feasible in a large-scale randomized controlled trial such as the present trial. Instead, we stratified all participating teams according to competition level (5 levels) before they were randomized. This procedure sought to ensure that teams within each stratification layer in the intervention group and control group had approximately the same exposure time at a similar intensity regarding both training and match play.

The majority of injuries (9 of 15) in the intervention group occurred in the 10-week training period in the preseason, whereas 12 of 52 injuries in the control group occurred in the same period. Since the amount of injuries in the 2 groups were similar in the first period of the study, it seems that players in the intervention group were not at increased risk of injury during the training period, and that they had to complete a number of training sessions to gain the injury preventive effect.

Generalizability of Results

The results of this trial are in accordance with the quasi-experimental study by Arnason et al,[1] who reported a 65% lower injury incidence in a group of athletes completing a training program consisting of warm-up stretching, flexibility training, and the Nordic hamstring exercise compared with warm-up stretching and flexibility training alone. This indicates that the preventive effect is solely a result of the Nordic hamstring exercise. In general, the lack of effect of stretching before exercise on muscle injury prevention has been shown.[30] These findings might be attributable to the fact that eccentric training, and not stretching, alters the mechanical properties of the hamstrings.[7,21]

In this study, 50 of 116 teams from the 5 best competition levels participated. The reasons given by the teams for declining participation in the trial were primarily a fear of low compliance with the training intervention because they were uncertain about their head coach for the upcoming season. Other reasons were concerns about the amount of time demanded by the training program and fears that participating in the trial would diminish the players' concentration on the impending soccer season. These issues reflect some of the problems concerning scientific studies in elite sports. Even though decliners theoretically may differ with regard to fitness and training levels, we do not believe that this has influenced the results of this trial. We are therefore convinced that the findings in this trial are valid for male professional and amateur soccer players. Whether the results can be generalized to women, other age groups, or to other sports is not known.

Future Implications

The perspective of this trial is that future recommendations concerning hamstring injury prevention in soccer should focus on eccentric strengthening of the hamstring muscles. The fact that the Nordic hamstring exercise is easy to perform, is not a big time-consumer, and can be done without the use of any additional equipment allows the exercise to be implemented as a general exercise in most soccer training programs. However, some coaches might only want to use the exercise for players at particularly high risk of sustaining a hamstring injury and not for the entire squad. In that case, the present hamstring exercise program can be highly recommended, since the preventive effect is particularly good in players with previous hamstring injuries.

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REFERENCES

1. Arnason A, Andersen TE, Holme I, Engebretsen L, Bahr R. Prevention of hamstring strains in elite soccer: an intervention study. *Scand J Med Sci Sports*. 2008;18:40-48.
2. Arnason A, Gudmundsson A, Dahl HA, Johannsson E. Soccer injuries in Iceland. *Scand J Med Sci Sports*. 1996;6:40-45.
3. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. *Am J Sports Med*. 2004;32:5S-16S.
4. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scand J Med Sci Sports*. 2003;13:244-250.
5. Boutron I, Moher D, Altman DG, Schulz KF, Ravaud P. Extending the CONSORT statement to randomized trials of nonpharmacologic treatment: explanation and elaboration. *Ann Intern Med*. 2008;148:295-309.
6. Boutron I, Tubach F, Giraudeau B, Ravaud P. Blinding was judged more difficult to achieve and maintain in nonpharmacologic than pharmacologic trials. *J Clin Epidemiol*. 2004;57:543-550.
7. Brockett CL, Morgan DL, Proske U. Human hamstring muscles adapt to eccentric exercise by changing optimum length. *Med Sci Sports Exerc*. 2001;33:783-790.
8. Chumanov ES, Heiderscheit BC, Thelen DG. The effect of speed and influence of individual muscles on hamstring mechanics during the swing phase of sprinting. *J Biomech*. 2007;40:3555-3562.
9. Connell DA, Schneider-Kolsky ME, Hoving JL, et al. Longitudinal study comparing sonographic and MRI assessments of acute and healing hamstring injuries. *AJR Am J Roentgenol*. 2004;183:975-984.
10. Croisier JL. Factors associated with recurrent hamstring injuries. *Sports Med*. 2004;34:681-695.

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11. Ekstrand J, Hagglund M, Walden M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med*. 2011;45:553-558.
12. Ekstrand J, Timpka T, Hagglund M. Risk of injury in elite football played on artificial turf versus natural grass: a prospective two-cohort study. *Br J Sports Med*. 2006;40:975-980.
13. Emery CA. Considering cluster analysis in sport medicine and injury prevention research. *Clin J Sport Med*. 2007;17:211-214.
14. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. *Am J Sports Med*. 2008;36:1052-1060.
15. Fédération Internationale de Football Association (FIFA). FIFA Big Count 2006: 270 million people active in football. http://www.fifa.com/mm/document/fifafacts/bcoffsurv/bigcount.statspackage_7024.pdf. Accessed November 26, 2009.
16. Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scand J Med Sci Sports*. 2006;16:83-92.
17. Gabbe BJ, Branson R, Bennell KL. A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian football. *J Sci Med Sport*. 2006;9:103-109.
18. Goldman EF, Jones DE. Interventions for preventing hamstring injuries. *Cochrane Database Syst Rev*. 2010;(1):CD006782.
19. Hagglund M, Walden M, Ekstrand J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *Br J Sports Med*. 2006;40:767-772.
20. Heiderscheit BC, Hoerth DM, Chumanov ES, Swanson SC, Thelen BJ, Thelen DG. Identifying the time of occurrence of a hamstring strain injury during treadmill running: a case study. *Clin Biomech (Bristol, Avon)*. 2005;20:1072-1078.
21. Magnusson SP, Simonsen EB, Aagaard P, Dyhre-Poulsen P, McHugh MP, Kjaer M. Mechanical and physical responses to stretching with and without preisometric contraction in human skeletal muscle. *Arch Phys Med Rehabil*. 1996;77:373-378.
22. Mjolsnes R, Arnason A, Osthagen T, Raastad T, Bahr R. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. *Scand J Med Sci Sports*. 2004;14:311-317.
23. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci*. 2003;21:519-528.
24. Orchard J, Best TM. The management of muscle strain injuries: an early return versus the risk of recurrence. *Clin J Sport Med*. 2002;12:3-5.
25. Petersen J, Holmich P. Evidence based prevention of hamstring injuries in sport. *Br J Sports Med*. 2005;39:319-323.
26. Petersen J, Thorborg K, Nielsen MB, Holmich P. Acute hamstring injuries in Danish elite football: a 12-month prospective registration study among 374 players. *Scand J Med Sci Sports*. 2010;20:588-592.
27. Pickles A. Generalized estimating equations. In: Armitage P, Colton T, eds. *Encyklopedia of Biostatistics*. 2nd ed. Chichester, UK: John Wiley & Sons; 2005;2074-2085.
28. Schache AG, Wrigley TV, Baker R, Pandy MG. Biomechanical response to hamstring muscle strain injury. *Gait Posture*. 2009;29:332-338.
29. Schmikli SL, Backx FJ, Kemler HJ, van Mechelen W. National survey on sports injuries in the Netherlands: target populations for sports injury prevention programs. *Clin J Sport Med*. 2009;19:101-106.
30. Shrier I. Stretching before exercise does not reduce the risk of local muscle injury: a critical review of the clinical and basic science literature. *Clin J Sport Med*. 1999;9:221-227.
31. Stanton P, Purdham C. Hamstring injuries in sprinting: the role of eccentric exercise. *J Orthop Sports Phys Ther*. 1989;10:343-349.
32. Thelen DG, Chumanov ES, Best TM, Swanson SC, Heiderscheit BC. Simulation of biceps femoris musculotendon mechanics during the swing phase of sprinting. *Med Sci Sports Exerc*. 2005;37:1931-1938.
33. Wood L, Egger M, Gluud LL, et al. Empirical evidence of bias in treatment effect estimates in controlled trials with different interventions and outcomes: meta-epidemiological study. *BMJ*. 2008;336:601-605.
34. Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A. The Football Association Medical Research Programme: an audit of injuries in professional football–analysis of hamstring injuries. *Br J Sports Med*. 2004;38:36-41.

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