

Prevention of Hamstring Injuries in Male Soccer Athletes

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ABSTRACT

Background: One of the most frequently injured muscle groups in soccer is the hamstring group. Soccer players have high rates of hamstring injury (HSI) due to frequent sprinting, changes in direction and similar high-risk activities. Such movements put immense stress on the hamstrings which can lead to injury. Over the last decade, at least four different HSI prevention programs and techniques have been explored in research. The purpose of this review is to assess the effectiveness of these methods.

Methods: Studies in this review were collected using multiple database searches of PubMed. A total of six studies were selected, all either randomized controlled trials (RCTs) or cluster-RCTs. The selected trials were from various soccer leagues in Denmark, Japan, the Netherlands, and the United States.

Results: The most prevalently studied method is the Nordic hamstring exercise (NHE). Studies that utilized the NHE, either as a stand-alone or within a program, reduced the risk of HSI by 15-71%. In addition, effective programs were characterized by progressively increasing the difficulty of exercises and high compliance rates.

Conclusion: Studies that utilized the NHE showed effectiveness in the prevention of hamstring injuries in male soccer athletes. Based on the limited research available, it is unclear whether adding other exercises to prevention programs further reduces injury risk. More research is needed to explore new and existing prevention methods in a variety of populations and regions.



KEYWORDS

Hamstring injury, Prevention, Exercise, Soccer

1 | INTRODUCTION

Soccer, also known as football, is regarded as one of the most popular sports in the world. Different soc-

cer competitions, premier leagues, and cups are held every year. Unfortunately, a soccer player sustains an average of two injuries per season. (1) Common soccer movements such as prolonged running, changes in acceleration, sprinting and kicking can all lead to injury. (2) Hamstring injuries are the most prevalent types of injury among all players ranging from youth to professional players. (3) It accounts for around 15-20% of all soccer injuries. (1, 4)

The hamstrings include the biceps femoris, semimembranosus and semitendinosus muscles, (5) which allow for knee flexion and hip extension. The most common type of hamstring injury is a muscle strain. (6) This occurs when one or more of the muscles tears, either partially or completely. Studies have shown that injury often occurs during the terminal swing phase. (7) Additionally, there are many factors that increase the risk of hamstring injuries., the most common of which are older age, fatigue, lack of flexibility, previous HSI, and muscle imbalance. (8,9)

Different hamstring injury prevention programs have been studied, tested, and implemented in various soccer leagues across the world. One major exercise used for building hamstring strength is the Nordic hamstring exercise (NHE, Fig. 2). (10) The NHE is part of both the 11 and 11+ FIFA prevention programs. It is a partnered exercise where the athlete kneels with their torso maintained upward, whilst the partner immobilizes the athlete's ankles and legs through pressure. The athlete tries to stay upright for as long as possible, maximizing the eccentric load on the hamstrings. The upper extremities are used to maintain balance. (10) Other exercises used to strengthen the hamstrings include bounding, lunges, and squats. (10, 11) These exercises are also seen in some HSI prevention programs.

Injuries have significant consequences on team performance. One study found injury rates to be associated with league ranking, performance in cups, and points per match. (12) A definitive method for preventing hamstring injury in soccer is necessary, as hamstring injuries have increased 4% annually from 2001 to 2016. (13) Some studies have had success with prevention programs, but evidence for a definitive method is limited.

(10, 14, 15) The aim of this review is to compare existing prevention programs to determine what factors make up effective interventions in the prevention of hamstring injuries.

2 | METHODS

The study examination process consisted of a general database search and review of the available studies. A primary search was conducted on PubMed. General searches were conducted with the key words 'hamstring injury', 'soccer injury', 'hamstring injury prevention' and 'soccer injury prevention'. Multiple searches were conducted over several months as part of the review process. Articles were included in the review if they were published between June 2011 and June 2021, reported data on hamstring injury incidence, and were randomized controlled trials (RCTs) or cluster-RCTs.

The characteristics examined in each selected study included age, location, compliance rate (%), study duration, intervention method and frequency of intervention. Any other factors that were not present across all selected studies or lacked clarity were excluded from the review and are briefly addressed in the discussion. The specific characteristics of individual prevention programs reviewed for this article include joint movements, types of movements, exercises, emphasized skills and whether a program increased in difficulty over the course of the study.

The study's effectiveness in preventing hamstring injury was quantified by the incidence rate ratio (IRR). The risk ratio was calculated by dividing the injury incidence in the intervention group (IG) by the injury incidence in the control group (CG). Injury incidence was calculated by the number of hamstring injuries per 1000 hours of soccer played. Some trials provided data for injury incidence and/or risk ratio. An IRR of less than 1 suggests a reduced risk of hamstring injury. An IRR close to or greater than 1 suggests minimal difference in risk of hamstring injury. A statistically significant risk reduction was determined by the provided confidence intervals and/or p-values ($p < .05$).

3 | RESULTS

All studies implemented HSI prevention programs. One study implemented the FIFA 11+ Program, which is also designed for the prevention of other lower body injuries. (14) Only data concerning the hamstrings were included in the review. A total of 56 studies were identified, and six studies were selected for the review. All six studies were RCTs, meaning that participants were randomly assigned to either the control or intervention group. Three were clustered RCTs. (10, 16, 17)

3.1 | Study Characteristics

The characteristics of selected studies are listed in Table 1. The selected studies reflected various regions, age groups, and competition levels. Three studies were conducted in the Netherlands, one in the United States, one in Denmark, and one in Japan. (10, 14-18). Ages were as young as 15 years old in Hasebe et al., which conducted its trial at the high school club level. (18) Another young age group was seen in Silvers-Granelli et al., at the collegiate level. (14) The remaining four studies consisted of adult amateur soccer players. (10, 15, 16, 17) Compliance was above average for most of the studies, with three reporting over 88%. (10, 15, 18) The trial period for all studies was one soccer season. The frequency of intervention was used was similar across studies with minor variations based on the time of season (1-3 times/week). Only van Beijsterveldt et al. did not specify the frequency of the intervention.(16)

3.2 | Prevention Programs

The review examined the Bounding Exercise Program, FIFA11+ Program, The11 Program, and the Nordic hamstring exercise. The joint movements, exercises, emphasized skills, and exercise progression were considered when comparing programs. Different exercises and joint movements will target different muscle groups and have varying effects, which can be compared for effectiveness. The emphasized skills can provide insight on what the main goal of the program was. The data for these

features is listed in Table 2 All six programs consisted of some eccentric exercises. The bounding exercise program (BEP) included walking, lunges, and drop lunges (weeks 1-6), all which incorporate concentric and eccentric movements. (17) It then continued with bounding exercises for the remainder of the study. (17) The 11 and FIFA11+ programs consisted of many of the same exercises. (14, 16) They included the sideways bench, NHE, single-leg stance, jumping and bounding. The FIFA11+ also had three levels of squat exercises and running exercises. The running exercises were conducted before and after the main strength exercises. (14, 16) van der Horst et al. and Petersen et al. both used the Nordic hamstring exercise as the main intervention. (10, 15)

The programs all made participants perform similar joint movements, despite the differences in exercises. Knee flexion was included in all six programs, as it is the main motion utilized in NHE, lunges, and other exercises. Other motions included hip flexion and extension, hip rotation, and knee extension. These movements were seen in exercises such as lunges, single-leg stance, and bounding. (10, 14-18) Petersen et al. only used the Nordic hamstring exercise, so knee flexion was the main joint movement of that intervention. (10)

There was great variation in the skills emphasized by each intervention program. There were two programs that mainly focused on the NHE emphasized technique, increasing hamstring resistance, and maintaining maximum eccentric load. (10, 15) The programs established by FIFA (The11, 11+) both emphasized a similar skillset, but the level of detail and difficulty was increased in the 11+ program. (14, 16) 11+ also included a focus on hamstring resistance, neuromuscular control, plyometrics, and agility. (14) The BEP mainly focused on increasing bounding distance and repetitions. (17)

All but one program (The11) had some level of progression in difficult throughout the study period (16). Progression consisted of increasing the number of session (per week), number of sets per session, the number of repetitions per set and/or the difficulty of the exercises. (10, 14-18) For instance, one of the exercises in the FIFA 11+ program is the bench, which is a static exercise where the player holds a plank position. However,

Study	Sample Size	Age	Location	Compliance	Study Duration	Frequency	Intervention	Player Level
Silvers-Granelli et al. (13), 2015	1525	18-23	United States	Moderate	1 season	3 times per week	FIFA 11+ Program	Collegiate
Petersen et al. (14), 2011	942	23.5 (avg)	Denmark	91%	1 season	1-3 times per week	Eccentric Training	Adult Amateur & Professional
van der Horst et al. (16), 2015	579	20-29	Netherlands	91%	1 season	1-2 times per week	NHE* only	Adult Amateur
van Beijsterveldt et al. (18), 2012	456	20-29	Netherlands	73%	1 season	Not listed	The11 Program	Adult Amateur
van de Hoef et al. (19), 2019	400	17-31	Netherlands	71%	1 season	2-3 times per week	BEP*	Adult Amateur
Hasebe et al. (20), 2020	259	15-18	Japan	88%	1 season	1-2 times per week	NHE* only	High School

*NHE: Nordic Hamstring Exercise, BEP: Bounding Exercise Program

TABLE 1 Study Characteristics

this exercise changes to a dynamic exercise (alternate legs) and then a modified version (one leg lift and hold) as the study progresses. (14)

3.3 | Study Effectiveness

Injury incidence and injury risk ratio (IRR) data are listed in Table 3. Van Beijsterveldt et al. found that its intervention increased hamstring injury risk (RR, 1.36). (16) The injury incidence (IR) was higher in the intervention group than the control group. This study also conducted trials for other lower extremity injuries. Data for only the hamstring group was calculated by multiplying the total injury incidence rate by the injury location.

Two studies had a minimal decrease in hamstring injury risk. Van de Hoef et al. had a 19% decrease in injury risk (RR, 0.81 [95% CI, 0.46-1.75]). (17) Hasebe et al. had a 15% decrease in injury risk (RR, 0.85, [95% CI,

0.26-4.97]). (18) In both studies, the IR values were similar, so there was a similar rate of injury in the two study groups. In Hasebe et al., the incidence rate for both the control and intervention groups were the lowest values of any study (CG, 0.104; IG, 0.088). (18)

Three had a significant decrease in hamstring injury risk. Silvers-Granelli et al. had a 63% decrease in injury risk (RR, 0.37 [95% CI, 0.21-0.63]; $P < .0001$). (14) Van der Horst et al. had a 69% decrease in injury risk (RR, 0.31 [95% CI, 0.11-0.72]; $P = .005$). (15) This study had the second-lowest incidence rate in its intervention group of any study (IR, 0.250). (15) Petersen et al. had a 71% decrease in injury risk (RR, 0.29 [95% CI, 0.15-0.57], $P < .001$). (10) It reported only 0.380 hamstring injuries per 1000 hours of soccer. (10)

Study	Joint Movements	Types of Exercises	Exercises	Emphasized Skills	Increased Difficulty
Silvers-Granelli et al. (13), 2015	Hip rotation, Knee flexion, Hip flexion, Trunk bending	Running, Strength, Eccentric, Plyometric, Balance	Running, The bench, Nordic hamstrings, Single-leg stance, Squats, Jumping, Bounding	Hip stability, Eccentric exercises, Hamstring resistance	Yes
Petersen et al. (14), 2011	Knee flexion	Eccentric	Nordic hamstrings	Hamstring resistance, Maximum Eccentric Load	Yes
van der Horst et al. (16), 2015	Knee flexion	Eccentric	Nordic hamstrings	Maximum eccentric load, Minimal concentric load	Yes
van Beijsterveldt et al. (18), 2012	Hip flexion, Hip extension, Knee flexion, Knee extension	Eccentric, Core stability, Plyometric	The bench, Nordic hamstrings, Single-leg stance, Jumping, Bounding	Hip stability, Eccentric exercises, Hamstring technique	No
van de Hoef et al. (19), 2019	Hip flexion, Hip extension, Knee flexion, Knee extension	Concentric, Eccentric, Plyometric	Walking lunges, Triplings, Drop lunges, Bounding	Increase bounding distance, Repetitions	Yes
Hasebe et al. (20), 2020	Knee flexion, Knee Extension	Eccentric	Nordic hamstrings	Isometric knee extension, Flexion strength, Flexibility	Yes

TABLE 2 Prevention Programs

4 | DISCUSSION

4.1 | General Findings

Each study examined several factors that could influence the risk of hamstring injury. Surprisingly, many of the factors did not have a significant impact. The age range was similar for most of the studies, around 20-31 years old. (10, 14-18) In Hasebe et al., the sample consisted high school players. (18) As a result, the age range was lower than in other studies. On the other hand, the other studies were conducted in adults at an amateur or professional level. Hasebe et al. may have had injury incidence rates that were significantly lower than in the other studies due to the younger age of the subjects

they studied. The control IR was 0.104, which is much lower than the second-lowest, 0.800. (15, 18) It had a 15% reduction (RR, 0.85 [95% CI, 0.26-4.97]), but the reported confidence interval suggests this was insignificant. (18)

Similarly, van de Hoef et al. had a 19% reduction in risk (RR, 0.81 [95% CI, 0.46-1.75]). (17) The subjects were adult amateur level players. The injury incidence for their control data was similar to other studies of the same age group. The reported confidence interval for van de Hoef et al. included 1, therefore the reduction was statistically insignificant.

Lack of compliance influencing a study's results was unlikely, as five out of six studies had a compliance rate of over 70%. (10, 15-18) The duration for all the re-

Study	Sample size (total players)	Injury Incidence*		IRR [95% CI]	p-value	Reduction
		Control	Intervention			
Silvers-Granelli et al. (13), 2015	1525	1.244	0.454	0.37 (0.21-0.63)	<.0001	63%
Petersen et al. (14), 2011	942	1.310	0.380	0.29 (0.15-0.57)	<.001	71%
van der Horst et al. (16), 2015	579	0.800	0.250	0.31 (0.11-0.72)	.005	69%
van Beijsterveldt et al. (18), 2012	456	1.300	1.766	1.36 (N/A**)	N/A**	N/A
van de Hoef et al. (19), 2019	400	1.390	1.120	0.81 (0.46-1.75)	N/A**	19%
Hasebe et al. (20), 2020	259	0.104	0.088	0.85 (0.26-4.97)	.83	15%

*Measured in hamstring injuries per 1000 hours of soccer.

**Data not provided

TABLE 3 Program Effectiveness

viewed studies was one soccer season, likely because they were RCTs. (10, 14-18) Cohort studies often last longer, as they track the progress of subjects over several years. Studies with significant reduction in risk increased the frequency of the intervention as time progressed.

4.2 | Successful Studies

Petersen et al., van der Horst et al., and Silvers-Granelli et al. were three studies with adult amateur level players. (10, 14, 15) They showed risk reduction over 62%. The reported p-values were below .05 for all three studies. (10, 14, 15) Based on the p-values, these three programs were effective in the prevention of HSI.

The design and implementation of a prevention program provides insight into what makes an effective intervention. Several trends were seen in the three effective programs, which reduced injury risk by as much as 71%. (10, 14, 15) Notably, all three programs utilized the Nordic hamstring exercise. Silvers-Granelli et al. included other exercises, such as flexibility exercises and other lower-leg movements as part of FIFA11+. (14) However, the intervention program used in Petersen et al., Hasebe et al., and van der Horst et al. only used the NHE. (10, 15, 18) A recent systematic review that ex-

plored NHE effectiveness found the intervention to significantly reduce injury risk. (19) It focused on examining the characteristics of studies and the details of NHE training protocols. However, the review focused exclusively on NHE-based interventions.

Successful programs also incorporated increased difficulty in the exercises. For example, the program used by Silvers-Granelli et al. included three variations for each exercise. (14) The exercises included several different joint movements, including hip rotation, knee flexion, hip flexion, and trunk bending. In van der Horst et al., the first five weeks were a build-up phase. During this phase, the number of sets and repetitions gradually increased every week. In contrast, the program utilized by van Beijsterveldt et al. The 11 did not increase difficulty throughout the trial. (16) As a result, this study did not have a build-up phase to the intervention. It reported the intervention to be ineffective in preventing HSI. (16)

4.3 | Limitations

The most significant limitation of the review was the limited research available. Many of the recent studies that investigate hamstring injuries assess strength characteristics rather than injury incidence rates. Consequently,

these studies could not be used in the review. This limits the ability to generalize the findings.

5 | CONCLUSION

The studies investigated in the review incorporated different programs, features, and exercises with the goal of preventing and reducing HSI. They all had different rates of success which were dependent upon several characteristics, most notably the intervention method. The studies that implemented the NHE intervention reduced injury risk by as much as 71%. Injury risk also decreased in studies that included progressively difficult exercises and high compliance. (10, 14-18)

More research is needed to better understand effective methods for HSI prevention. Specifically, more randomized controlled trials in a variety of soccer leagues across different divisions. It is important that hamstring injury be studied to reduce hamstring injury risk in soccer players.

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