Effects of Implementing Nordic Hamstring Exercises for Semi-professional Soccer Players in Akershus, Norway

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ABSTRACT

Background and Purpose: Hamstring injuries are common in sports with sprinting demands, kicking, and sudden accelerations. Rehabilitation programs aimed at the prevention of future hamstring injuries have been recommended. This study examined if Nordic hamstring (NH) exercises decreased injury rates, increased sprinting speed, and increased hamstring and quadriceps muscle strength among semi-professional soccer players. **Methods:** A convenience sample of level 3 and 4 male soccer players from Norway (ages 18-39) participated in the study. Participants were randomly divided into either a control group (usual warm-up exercises) or a NH group (usual warm-up plus NH exercises). Injury data was collected on 119 players for 10 months. Twenty-seven participants were evaluated twice over the same period on sprint speed, eccentric and isometric hamstring strength, and concentric hamstring and quadriceps strength. Independent t-tests compared changes in strength and speed between the control and NH groups. Paired t-tests analyzed within group changes. Statistical significance was set at $P \leq 0.05$. **Findings:** There was a significant difference in the number of injuries between the control (6 injuries) and NH (zero injuries) groups. No significant changes in strength or sprint speed were found between the groups. The NH group experienced a statistically significant decrease in speed, during the first 10 m of sprint testing. In addition, both groups had a significant decline in the eccentric total work of the hamstrings. **Clinical Relevance:** Incorporation of NH exercise protocol into regular practice sessions may be effective in reducing the number of hamstring injuries in soccer players.

Key Words: hamstring strains, muscle injury, physical therapy, eccentric training

INTRODUCTION

Hamstring muscle strains and injuries are common among high school, college, and professional athletes, especially in sports with sprinting demands, kicking, and sudden accelerations.[1-10] Sports with a high number of hamstring injuries included sprinting (11-29%),[6,9] Australian Rules football (15%-23%),[6,7,9,11] general football (15%),[11] soccer (10%-47%),[6,7,9,11-18] and rugby (6%-15%).[7,11] Among soccer players, hamstring strains were reported as the most common injury.[16,18-22]

Injuries to the hamstrings have been attributed to both intrinsic and extrinsic risk factors. Extrinsic risk factors are characteristics within the environment, many of which are not in the athlete's control. The greatest risk factor for this type of injury is due to contact with an opponent, accounting for 44% to 47% of all injuries.[23] Intrinsic injuries, on the other hand, are characteristics within each athlete and may or may not be modifiable. The most commonly cited nonmodifiable risk factors included a previous hamstring injury,[4,6-8,11,22,23] older age,[4,6-8,11,23] gender (more common among males),[21] and ethnicity.[4,7] Modifiable risk factors were more numerous and included leg length asymmetries,[5,23] muscle strength deficits,[3,4,6,11,22-24] poor neuromuscular control,[11] lack of flexibility,[3,5-7,11,22-24] lack of warm-up,[5-7,11,22,24] imbalances between the quadriceps/hamstring musculature,[5-7,11,22,25] poor lumbo-pelvic strength and stability,[7,24] and fatigue.[3,5-7,22,24]

Several authors examined internal risk factors in great detail, especially those that were modifiable and could prevent future hamstring injuries. For soccer players in particular, a previous injury to the hamstring musculature was the greatest risk factor for development of a future hamstring injury.[12] Once a hamstring injury occurred, the player often suffered prolonged symptoms, a poor healing rate, and a high risk of reinjury (as great as 12%-33%).[1,2,4,8,13,15,16,20] Reinjuries were significantly more severe than first time occurrences, and have led to as many as 25 lost playing days (versus 7 lost days for a first time occurrence).[7] For the team and player, the costs associated with an injury varied and included missed training time, unavailability for matches, lost payment for the player, and even the end of a career.[6,8,9]

Given the variety of deficits that follow a hamstring injury, rehabilitation programs aimed at the prevention of future injuries were recommended for both the injured and noninjured athlete.[21] Common preventative interventions included stretching, strengthening (eccentric and concentric), correction of movement dysfunction, manual therapy, neuromuscular strategies, educational awareness, and general intervention programs (warm-up, aerobics, activity specific drills).[26] Results of the effectiveness of these interventions were mixed. Some authors reported no change in the incidence of hamstring strain with the use of stretching.[1,6,26] Other authors recommended improvements in active range of motion through both static stretching and strengthening regimes,[3,7,20] or stretching while a muscle is fatigued.[10] Manual therapy was found to possibly prevent injuries of leg muscles.[26] Balance training and warm up/cool down had no supportive evidence, or inconclusive evidence, for preventing leg injuries.[26] Strengthening exercises had varied results based on the type of exercise performed.[26] Several authors advocated for eccentric and concentric exercises for the hamstring musculature.[1,3,17] Other authors recommended eccentric exercise alone such as Yo-Yo curls (eccentric hamstring curls performed in a prone position)[17] or Nordic hamstring (NH) lowers (eccentric lowering of the upper body to the floor from a kneeling position, followed by a return to the starting position).[9,12] Finally, some authors recommended sport specific training drills to prevent hamstring injury.[10] In general, there was insufficient evidence from randomized controlled trials to draw definitive conclusions about the effectiveness of any intervention to prevent hamstring injuries.[26]

Nordic hamstring exercises, such as NH lowers, have had positive results among soccer players. Using these exercises, elite soccer players from Norway and Iceland reported decreased hamstring injuries,[6] maximal eccentric hamstring strength increases,[9] enhanced optimal lengthening of the hamstring musculature,[15] and improved ability of the hamstrings to progressively sustain loads.[24,25] Peak hamstring torque was shifted to a more extended knee angle position after training with NH exercises.[24] Clarke et al[24] postulated that since most hamstring strains occur during eccentric contraction of the hamstring muscles, increased torque in an extended knee position may reduce the occurrence of strains. While elite athletes are at the most risk, injury incidence may be impacted by level of play, exercise load, and standards of training.[27] High-level players are most often injured during matches, while low-level players are more often injured during training sessions.[27] Since most studies have been performed with professional athletes, the purpose of this study was to investigate whether NH exercises were beneficial to semi-professional athletes during training and the beginning of the soccer season, when most injuries occur as mentioned previously. Specifically, this study sought to determine if NH exercises decreased the number of hamstring injuries and increased hamstring and quadriceps muscle strength from pre-to midseason, among semi-professional soccer players in Norway. In addition, the authors were interested to see if any changes occurred in sprinting speed, since sprinting injuries are common in soccer, and increased sprinting speed was reported among eccentrically trained athletes.[17]

METHODS

Participants

Members of 10 adult level 3 and 4 (semi-professional) Norwegian soccer teams (ages 18-39) were recruited for the study. Coaches of the teams were given the exercise protocol and assisted with recruiting players. All coaches agreed to allow players who volunteered for the study to participate in the randomly selected exercise protocols.

Players were excluded from the study if they had a hamstring injury currently or in the last 6 months, or if they had other injuries (eg, knee injuries, surgeries, or hip or back complaints) that made them unable to perform the initial strength and sprint testing protocols. In addition, players who sustained hamstring injuries during the season were withdrawn from the strength and sprint test protocols if they were unable to continue with the NH or their usual warm-up exercises, or if they were unable to complete soccer practices or games for a period of two weeks. This was to ensure that the participants did not sustain any additional injury to the hamstring musculature due to the demands of the testing protocol. Injury data was collected on all participants regardless if they withdrew from the strength and sprint testing protocols. In our study, hamstring injury was defined as an athlete having posterior thigh pain, where direct contact with the thigh was excluded as the cause of the injury, and the injury resulted in missed match or practice time.

Procedures

Approval for the study was obtained through the Institutional Review Board for the Protection of Human Subjects at the authors' university, and the rights of all participants were protected. After obtaining informed consent, all participants completed a questionnaire consisting of demographic information, the number and type of previous injuries, the dates of these injuries, and amount of time they were unable to participate in any sporting events because of any injuries. A computer randomly divided players into two groups, a control group (usual warm-up exercises) and a NH group (usual warm-up plus NH exercises).

Members of both groups were scheduled to participate in (1) concentric, eccentric, and isometric hamstring strength testing using a Cybex 6000 (Lumex and Ronkonkoma, NY); (2) concentric quadriceps testing using the same machine; and (3) a 40-m sprint test. Participants were tested 3 times throughout the study: a pretest in December, retest in April (before competitive games started), and a final test in August (before the second half of the season started). Strength testing and the 40-m sprint were performed at the Norwegian University of Sports and Physical Education by volunteers who were trained in the testing protocol and blinded to group assignment. In addition, coaches and participants were instructed to inform the researchers of all injuries that occurred during the season every 14 days by documenting all injuries on an injury form.

Throughout the study, all exercises were performed as part of the players' usual soccer practice, under the direction of coaches (trained by the principle investigator) to make sure players were following the correct protocol and were consistently performing all exercises. The players in the control group participated in the team's usual warm-up exercises, while the players in the intervention group performed the usual warm-up exercises in addition to the NH-protocol exercises. Both groups practiced 3 days per week during preseason, and two days per week during the soccer season.

Testing Procedure

The pre-, beginning, and mid-season test procedures consisted of (1) a warm up, (2) sprint time testing, and (3) strength testing. The Cybex 6000 was used to test all muscles strengths (concentric, eccentric, and isometric). Test-retest correlation coefficients for all parameters of the Cybex 6000 were reported above 0.90.[28] Prior to participant testing, the Cybex 6000 was calibrated. All testing procedures, including the warm-up exercises, were carried out by two volunteers who were trained by the researchers. Testing of isometric and eccentric strength was carried out on the hamstrings only, since this was the primary muscle group being investigated in this study and because weaknesses in these types of contractions were found to contribute to hamstring injuries.[1,3,6] Concentric strength testing was examined for both the quadriceps and hamstring muscles.

A general warm-up consisting of jogging progressing to sprinting was performed to prepare the muscles for maximal effort in strength testing. Following the general warm-up, a specific warm-up for the hamstrings was completed. In a standing position, the participants were asked to alternately kick their right and left heel as close to their buttocks as possible in 3 sets of 20 repetitions. Between the sets, the participants did 10 repetitions of lifting their knees as close to their chest as possible. The participants then did 3 isometric stretches using the contract-relax method. Each stretch started with the participant pressing his heel to the ground with the knee in slight flexion. The stretch was held for 15 seconds and was within the participant's tolerance of pain.

Following completion of the warm-up exercises, participants started the testing protocol. Participants were tested for maximal sprint by performing three 40-m sprints, with the best of the 3 attempts being used for data analysis. Timing started when the participant released pressure on the front foot from the start mat, and was measured electronically in 10-m intervals up to 40 m. Next, the participants were strength tested using the Cybex 6000. Participants were tested on the right leg only, since all players were right leg dominant. Testing was initiated by positioning and fixating each participant's right leg in a seated position. The set-up for each participant was noted in the research protocol for replication during the retests in April and August.

First, concentric quadriceps and hamstring strength was measured. The participant did 3 voluntary hamstring and quadriceps contractions by flexing and extending the knee joint without rest between the contractions. The concentric strength tests for both the hamstring and quadriceps muscles were performed at a test velocity of 60°s^{-1}. Participants were given 4 warm-up repetitions, and then performed 3 maximal contractions. The best of these 3 trials was used for analyzing peak torque (PT), and the sum of all 3 trials was used for determining total work (TW). After a one minute rest, a test for isometric hamstring strength was performed with the knee at 20°, 40°, and 60° from full extension. Since the ability to increase hamstring strength in an extended knee position has been postulated to reduce the occurrence of hamstring injuries,[24] measurements moving toward full knee extension were selected for the study. Participants performed a 5 second maximal voluntary contraction, 3 times at each knee flexion angle, with a 30 second rest period between each contraction. The best of 3 trials was recorded. Next, eccentric hamstring strength was tested. Each participant was tested in a range from 20° to 60° of knee flexion, by resisting an elevating arm from the machine. The participants performed 3 maximal efforts using the best trial for PT and the sum of all 3 trials for TW. Finally, the ratio of the hamstrings (H) and quadriceps (Q) muscle groups was calculated using the formula Hecc/Qcon (ratio of eccentric hamstring strength to concentric quadriceps strength). This H/Q ratio is thought to be more functional for running as it compares the agonist/antagonist roles of the two muscle groups.[29]

The Training Program – Nordic Hamstring Exercises

The training sessions began with a general warm up for both groups (jogging and light sprinting), at which point the two groups split up. The control group performed general stretching, while the intervention group performed NH exercises (Table 1). Both groups came back together and participated in technical skills and soccer specific activities, followed by a cool-down consisting of either light stretching or jogging. Each training session lasted 90 minutes.

The NH protocol was divided into 3 different parts and included a self-stretch, a stretching exercise with a partner, and a strengthening exercise (NH lowers), also performed with a partner (Table 1). Practice tips were given to the participants and included using some type of soft material under the knees, trying to relax the ankles and calves during the exercises to avoid cramps, and following the suggested protocol (Table 2) to avoid overuse and possible injury. Sets and number of repetitions were gradually increased through the fourth week. Beginning in the fifth week, participants were encouraged to add speed and resistance to tolerance.

Data Analysis

Differences in strength (recorded by the Cybex 6000) and running speed (calculated during the 40-m sprint test) were collected for analysis at 3 testing sessions (pre-, beginning, and mid-soccer season). However, due to the limited number of participants who attended the second testing session (beginning of the soccer season), only data from the first (T1) and last (T3) testing sessions were used for data analysis. Data for number of injuries for both groups were collected every 14 days. Pearson Chi-square test of independence was performed to examine the relationship between group assignment and number of injuries prior to data collection (one year before the study) and during the 10 months of the study. Absolute risk reduction (AAR) was calculated using the formula AAR = control event rate - experiment event rate. Independent t-tests were used to compare changes in strength and speed from T1 to T3, between the control and NH groups. Paired T-tests with 95% confidence intervals were used to analyze within group changes. Data from participants who suffered an injury and did not participate in the sprint and strength testing sessions was included in the study for the number of injuries only. Data were analyzed using SPSS 18.0 and the significance level was set at 0.05.

RESULTS

One-hundred and forty-two players volunteered for this study (control group = 70, NH group = 72). During the study, there were 23 drop-outs: 11 of the players decided to stop playing soccer and 12 players were not able to continue due to moving for school and work opportunities; therefore, injury data was only collected on 119 participants. Of the 119 participants, 59 individuals were in the control group (18-29 years of age) and 60 players were in the NH group (20-36 years of age). All 119 participants completed injury forms whenever a hamstring injury occurred during both before

Table 1. Nordic Hamstring Exercises

Exercise	Instructions
Self-stretch	Use support from a partner or stationary object such as a chair or low table. The knee should be bent at the start, and the ankle relaxed (Figure 1). Press the heel against the ground for 5-10 seconds to activate the hamstring muscles, then relax and use your hand to extend your knee. Hold the stretch for about 20 seconds. If necessary, increase the distance between your legs and bend your hips little more, but keep your back straight. Stretch each thigh three times.
Partner stretch	Your partner raises your leg with the knee bent, until you feel the back of the thigh stretch (Figure 2). Hold this position for a few seconds before you press your leg towards your partners shoulder. Hold for 10 seconds. Then relax while your partner stretches firmly, but cautiously by leaning forward. Hold this position for 45 seconds. Stretch each thigh three times.
Nordic hamstring lowers	Your partner holds your legs stable. Lean slowly forward with a steady speed (Figure 3). Hold your back and hips straight. Try to resist with your hamstring muscles as long as possible, until you lose your balance and fall on your arms (Figure 4). As you get stronger, make the exercise more demanding by increasing speed in the beginning of the movement, even by being "pushed" by your partner. Let the chest touch the ground. Use your arms to push up immediately, until your hamstring muscles can take over the movement and pull you up to the starting position. Be careful in the beginning, use two sets with 5 reps, and increase slowly to 3 sets with 12 reps.

Figure 1. Self-stretch.

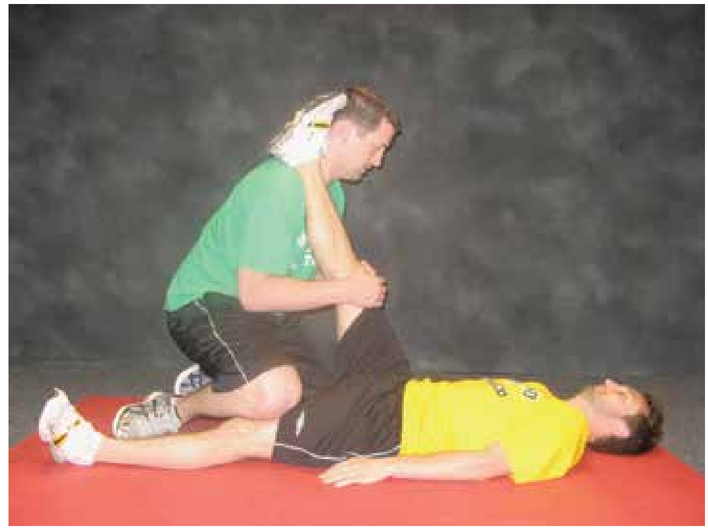

Figure 2. Partner stretch.

Figure 3. Beginning position for Nordic hamstring lowers.

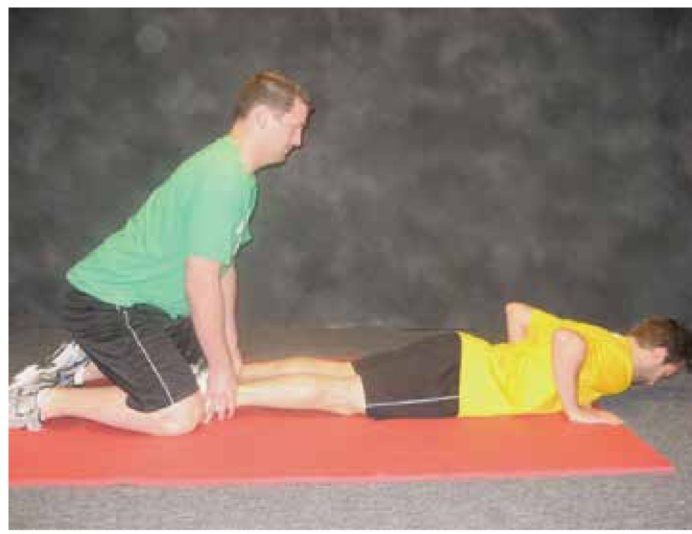

Figure 4. Ending position for Nordic hamstring lowers.

and during soccer season. However, injury sheets were only collected every 14 days. Of the 119 participants, only 27 (22.7%) completed the pre- and midseason testing: the remaining participants did not attend the training sessions due to injuries not related to the study, school and work responsibilities, unwillingness to drive to the testing session, or coaching requests. Therefore, the results for strength testing and sprint speed were analyzed using the means of 27 participants (control group = 11, NH group = 16). At the first session, the means of both groups were compared using independent T-tests for all outcome data. The two groups did not differ statistically on any measure (*P* = .072 to .999).

The number of injuries reported one year prior to (from the initial questionnaire) and during the study is shown in Table 3. There were no significant differences in the number of injuries between the groups during the 10 months prior to the study (X^2 (1) = .89, *P* = .345). However, during the 10-month study all of the injuries occurred in the control group (6 injuries), which was a statistically significant difference between the groups (X^2 (1) = 6.44, *P* = .010). Overall, there was a 10% AAR of sustaining a hamstring injury associated with participation in the NH exercise protocol, as calculated by the AAR formula mentioned previously.

For sprint testing, no statistically significant differences were found between the groups for any measure. Only one statistically significant difference was seen within each group: The NH group significantly increased their speed from 1.62 m/s to 1.65 m/s (Table 4), during the first 10 m of the sprint test (t(13) = 3.43, *P* = .005, *95% CI*: -0.040, -0.009). Cohen's effect size calculated this finding as a small effect (d = .04).

Results of all strength testing can be found in Table 5. There were no statistically significant differences between the groups in any measure. Within group changes revealed one statistically significant difference for both groups. The total work for eccentric hamstring contractions decreased for both the control (Mean T1 = 485.9, SD T1 = 189.7; Mean T3 = 439.5, SD T3 = 187.0) (t(7) = 3.18, *P* = .016, *95% CI*: 11.88, 80.87) and Nordic exercise (Mean T1 = 510.6, SD T1 = 87.2; Mean T3 = 460.6, SD T3 = 101.1)(t(12) = 2.68, *P* = .020, *95% CI*: 9.34, 90.65) groups. While Cohen's d revealed a small effect size for the control group (d = .025), a moderate effect was observed for the NH group (d = .529).

DISCUSSION

The purpose of this study was to investigate the effect of an NH exercise program

Table 2. Nordic Hamstring Strengthening Protocol

Week	Training Number	Sets/Repetitions	Comments
1	1	2/5	Straight upper body (with a slight bend in the hip) throughout the whole movement. Resist falling as long as possible. Fall on your arms, let the chest touch the surface and push up immediately, until your hamstring muscles can take over the movement.
2	2	2/6	Try to reduce the lowering speed more.
3	3	3/6-8	Gradually increased load. You can resist falling even longer, and for an increasing number of repetitions.
4	3	3/8-12	Full program: 12, 10, and 8 repetitions.
5	3	3/8-12	When you can control the movement in all repetitions, you can increase the load by allow more speed in the start phase. Additionally, you can have a partner give your shoulders a little push to increase the resistance.

Table 3. Occurrence of Hamstring Injuries

	Control Group	NH Group
Age (years)	18-29	20-36
2005	7*	11*
Injury Occurrences	February: 3 March: 2 September: 2	January: 3 February: 1 April: 2 June: 1 August: 2 September: 2
2006	6*	0*
Injury Occurrences	January: 2	February: 1 April: 1 September: 2

* Total number of injuries

combined with traditional training, versus traditional training alone, on hamstring and quadricep strength, sprinting speed, and number of hamstring injuries, in semi-professional soccer players. Our hypothesis was that the players, who participated in the NH exercises in addition to their usual training program, would experience a decreased number of hamstring injuries, improved sprinting speed, and increased hamstring and quadriceps strength compared to the control group who participated in a traditional training program.

In spite of the fact that the NH group had more risk factors for hamstring injuries, including older age, and a greater number of prior injuries, they did not experience any hamstring injuries during the study period. The control group, on the other hand, reported 6 injuries. This change was statistically significant as determined by the Pearson Chi-square test of independence. A similar decline in hamstring injuries, following eccentric training, was reported in a number of studies.[1,6-8,17] Most hamstring strains are thought to occur during eccentric activity of muscles.[6] Nordic hamstring exercises specifically targeted at eccentric training of the hamstring musculature may have resulted in a decrease in the numbers of hamstring strains.

With regard to sprint speed, no significant changes were observed between the groups. However, within group changes revealed a significant difference in the 10-m sprint speed in the NH group, which changed from 1.62 m/s to 1.65 m/s, meaning the participants were slower at the last testing session (Table 4). (A change of 0.03 m/s is above the standard error of measurement calculated at 0.018 m/s.[30]) This is in contrast to a study by Askling et al,[17] where significantly increased speed was observed for eccentrically trained participants on a 30-m test.[17] There are several reasons our NH group may have experienced these changes. First, NH exercises were performed at a slow rate and running is a high velocity activity. Several authors[9,10,17] have found that specificity of training is important for a carryover effect into functional activities. Theoretically, the NH exercises should be performed at high rates of speed in order to have an impact on running, which was not the case in this study. In the Askling et al study,[17] the participants used a fly-wheel to increase speed, followed by eccentric braking of the wheel at varying degrees of knee flexion, which more closely replicates the function of running/sprinting. Second, the players trained during the Askling et al[17] study reported delayed onset muscle soreness at the beginning of eccentric training exercises, which gradually decreased over the training period. During our study, the players and coaches may have avoided maximal participation in the training sessions if muscle soreness interfered with subsequent matches.

With regard to strength changes, no significant differences were found between or within the groups, for concentric measures of quadriceps strength. These results are similar to other studies that reported no changes in concentric peak torque.[9,15,24] Mjolsnes et al[9] hypothesized that this is due to training being activity specific. In order to increase concentric strength, concentric exercises focusing on the targeted muscle should be performed.[9] None of the exercises introduced in our study focused on quadriceps strengthening.

For isometric hamstring strength, no statistically significant changes were observed between or within the groups. In fact all isometric hamstring strength values declined for both groups from test session #1 to test session #3, with the exception of 20° of knee flexion in the NH group, which increased slightly from 138.0 Nm to 139.9 Nm (Table 5). Although this finding was not statistically significant, increased isometric strength of the hamstrings in an extended position was reported by previous authors.

Table 4. Mean Sprint Testing at Preseason (Test #1) and Midseason (Test #3)

Sprint Measurement	Control Group		NH Group	
	Test #1	Test #3	Test #1	Test #3
10-meter (s)	1.59 +*.055*	1.59 +*.066*	1.62 +*.055*	1.65 +*.054*
20-meter (s)	2.86 +*.099*	2.86 +*.113*	2.93 +*.084*	2.94 +*.086*
30-meter (s)	4.05 +*.150*	4.04 +*.177*	4.14 +*.119*	4.14 +*.142*
40-meter (s)	5.22 +*.201*	5.20 +*.239*	5.34 +*.158*	5.33 +*.155*

Abbreviations: s, seconds
Shaded areas = significant findings

Table 5. Mean Strength Testing at Preseason (Test #1) and Midseason (Test #3)

Strength Measurement	Control Group		NH Group	
	Test #1	Test #3	Test #1	Test #3
Concentric Quadriceps PT (Nm)	196.1 + *59.6*	182.7 + *64.6*	202.8 + *38.9*	203.9 +*30.9*
Concentric Quadriceps TW (J)	552.7 +*172.0*	502.1 +*182.7*	588.1 +*124.7*	570.1 +*88.0*
Concentric Hamstrings PT (Nm)	114.0 + *32.3*	110.1 + *42.3*	121.4 +*26.6*	118.0 +*20.4*
Concentric Hamstrings TW (J)	388.1 +*120.8*	371.7 +*146.8*	418.3 +*90.6*	396.1 +*69.1*
Isometric Hamstrings				
20° PT (Nm)	139.6 +*49.9*	131.7 +*65.1*	138.0 +*22.8*	139.9 +*33.7*
40° PT (Nm)	150.0 +*45.6*	141.5 +*51.6*	142.0 +*25.1*	139.6 +*25.1*
60° PT (Nm)	140.0 +*44.8*	134.3 +*47.3*	138.5 +*29.2*	135.4 +*23.2*
Eccentric Hamstrings PT (Nm)	156.3 + *46.0*	145.5 + *61.4*	150.4 + *20.5*	147.6 + *24.6*
Eccentric Hamstrings TW (J)	485.9 +*189.7*	439.5 +*187.0*	510.6 +*87.2*	460.6 +*101.2*
Hecc/Qcon PT	.80 + .08	.80 + .11	.74 + .13	.72 + .11
Hecc/Qcon TW	.88 + .16	.88 + .16	.87 + .19	.81 + .16

Abbreviations: PT, peak torque; Nm, Newton meters; TW, total work; J, Joules
Shaded areas = significant findings

Clark et al[24] reported that peak hamstring torque shifted to a more extended knee position after intervention training using NH lowers. The authors postulated that increasing peak torque in an extended position may reduce muscle damage due to eccentric contractions.[24] Hamstring injuries, in particular, occur during two points of running–the take-off segment of the support phase and the late forward swing phase. In the late swing-phase, the hamstrings are at the greatest length, contracting eccentrically to decelerate flexion of the thigh at the hip and extension of the lower leg at the knee.[5,6] During sprinting, the deceleration phase shortens, requiring the hamstrings to work even harder to compensate for the forward momentum.[9] Thus, increased peak torque in an extended position, seen in the participants in our NH group, may or may not have contributed to the decline in hamstring injuries seen among this group.

The last strength measure, eccentric hamstring strength, also resulted in no significant changes between the groups. However, there was a significant decline in eccentric TW of the hamstrings for both the control and NH groups (Table 5). The control group declined from 485.9 J during initial evaluation to 439.5 J at 6-month re-evaluation. The NH group experienced a similar decline, decreasing from 510.6 J to 460.6 J over the duration of the study. These findings are in contrast to other authors who reported increased eccentric hamstring strength following exercises targeted at eccentric hamstring training.[9,17] We can only postulate on the differences observed in this study. One theory is that participants may not have provided maximal effort during strength testing. Some of the participants experienced soreness in their hamstring muscles after the pretest, and to avoid this soreness again, may not have performed with maximal force at the next testing sessions. Some coaches were displeased that muscle soreness interfered with their players' ability to perform during practices and games. In fact, 5 players from one club were not allowed by their coach to complete the last strength test due to other players in the same club experiencing soreness and pain in their hamstring and groin after completing testing several days earlier. This soreness interfered with the tested participants' playing ability at a subsequent match. A second hypothesis may be attributed to motivation of the participants to complete the exercise protocol in which they were randomly assigned. Some participants may have heard that NH exercises were effective and could prevent them from sustaining hamstring injuries, thus leading to disappointment if not selected for the NH group. This may have changed motivation levels among control group members. On the other hand, there may have been participants who did not want to perform the NH exercises, and these individuals may not have been motivated to complete the NH protocol.

On a final note, the Hecc/Qcon ratio did not change significantly between or within groups during the duration of the study. The H/Q ratios above 0.6 are frequently cited as a goal to prevent hamstring injuries.[29] The mean Hecc/Qcon ratios for our participants ranged from 0.75 to 0.89 (see Table 5), which were well above the 0.6 goal and the average reported mean of 0.63 + 0.07.[29] However, H/Q averages in the 0.6 range may not account for joint angle or speed in the analysis.[29] As the knee moves to a more extended position (similar to how our participants were tested), Hecc/Qcon values have been reported above 1.00.[29] Since our participants had less muscle imbalance in the hamstrings and quadriceps to begin with, this could be a reason for the lack of changes in hamstring strength that we originally hypothesized would occur.

Limitations

There were several limitations to this study. First, of the 119 participants who volunteered and completed the injury data section of the study, only 27 were willing and able to complete the testing protocol, which limits the ability to generalize the findings. A second limitation was the use of self-report data as the basis to analyze injury rate. Although injury reports were collected every two weeks, players may or may not have remembered to complete the injury sheets in a timely fashion.

The lack of blinding of the participants may have also contributed to our findings. As mentioned previously, some participants may have wanted to be in a different group than they were randomly assigned to, leading to decreased motivation among these participants at both the practice sessions and during the testing protocol. In addition, the testing protocol always followed the same sequence, which may have led to a test order effect. Finally, a number of participants developed muscle soreness following the initial evaluation. Due to fear of missing upcoming playing time, or pressure from the coaches, participants may have given less than maximum effort on subsequent reevaluations, and even possibly during training sessions.

Future studies could examine injury rates over several years to see if the number of injuries remains lower among NH exercise participants. In addition, studies with a larger sample size are warranted. Participation rates should be available for both control and intervention groups to see if other variances contribute to the results. Another suggestion is to have participants perform strengthening exercises that incorporate both concentric and eccentric contractions and to perform the exercises at different speeds and different joint angles. Changes in speed and joint angle are a functional component of any running or sprinting activity. Finally, repeating this study with recreational soccer players, with athletes in other sports that involve similar muscle actions, and with different age groups, could also contribute to the body of literature on hamstring strengthening and injury prevention.

CONCLUSION

No significant changes in strength or sprinting speed were found between a control group (using traditional training) and an intervention group (using NH exercises), among semi-professional soccer players. There were several within group changes including a significant decline in speed among the NH group during the first 10 m of a 40-m sprint test. In addition, both the control and NH groups had a significant decline in the eccentric total work of the hamstring musculature. These results may be reflective of the training and testing protocols. Finally, there was a significant difference in the number of injuries in the intervention group (n = 0) compared to the control group (n = 6). However, we are not sure of why fewer injuries occurred in the intervention group since the remaining variables in the study were not statistically different between groups. The incorporation of the NH exercise protocol into regular practice sessions, therefore, may or may not be effective in reducing the number of acute hamstring injuries in soccer players. Based on the results of this study, further research with a more rigorous research design is recommended.

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