The preventive effect of the Nordic hamstring curl in male amateur soccer players: the differences in hamstring injury incidence between subgroups at risk and optimization of tailored training programs

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"ONDERGETEKENDE

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bevestigt hierbij dat de onderhavige verhandeling mag worden geraadpleegd en vrij mag worden gefotokopieerd. Bij het citeren moet steeds de titel en de auteur van de verhandeling worden vermeld."

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SAMENVATTING

Doelstelling: Hamstring blessures zijn de meest voorkomende spier blessures in voetbal, 12-16% van alle blessures. Excentrische oefeningen zijn effectief gebleken voor het verlagen van de hamstring blessure incidentie voor een totale populatie maar niet is niet onderzocht voor specifieke subgroepen. Het doel van de studie was het bepalen van het effect van de risico factoren: leeftijd, hamstring flexibiliteit, eerdere hamstring blessure en veldpositie, op de hamstring blessure incidentie na een interventie programma met de Nordic hamstring curl (NHC) bij mannelijke amateur voetballers.

Methode: Mannelijke amateur voetballers, 18 tot 40 jaar, spelend in de Nederlandse Eerste Klasse werden geïncludeerd. Gegevens met betrekking tot leeftijd, eerdere hamstring blessures en veldpositie werden verzameld. Hamstring flexibiliteit werd gemeten met de Sit-and-Reach Test. De interventie groep volgde een programma van 13 weken met de NHC, de controle groep volgde het eigen programma. Associaties tussen subgroepen in de "risico zone" en "niet risico zone" werden bepaald met Pearson's X^2 toets.

Resultaten: 329 spelers werden geïncludeerd in de interventie groep en 293 in de controle groep. Gedurende het jaar 2013 werden 22 hamstring blessures gerapporteerd. De interventie toont een significant effect van 0,031 voor spelers in de risicozone door veldpositie verdediger. Tussen de subgroepen, leeftijd, hamstring flexibiliteit, eerdere hamstring blessure en veldpositie middenvelder en aanvaller, in de "risico zone" en "niet risico zone" in de interventie groep werden geen verschillen in Odds ratio's gezien.

Conclusie: Excentrische hamstring training met de NHC is effectief bevonden voor spelers in de "risico zone" door veldpositie verdediger. De NHC moet worden toegevoegd aan het training programma voor verdedigers om het aantal hamstring blessures te verminderen.

Klinische relevantie: Inzicht in risicofactoren kan informatie geven met betrekking tot spelers in de risicozone voor hamstring blessures en kan trainers en medische staf helpen om een speler-specifiek training programma te ontwerpen om blessure preventie te optimaliseren.

ABSTRACT

Aim: Hamstring injuries are the most prevalent injuries in soccer, 12-16% of all injuries. Eccentric exercises are shown effective to reduce the hamstring injury incidence in a total population but no research on specific subgroups is done. The aim of this study was to determine the effect of the risk factors: age, hamstring flexibility, prior hamstring injury and the position in field on the hamstring injury incidence after an intervention program with the Nordic hamstring curl exercise (NHC) in male amateur soccer players.

Methods: Male amateur soccer players, aged 18-40 years, participating in the Dutch "First Class" eligible. Information on age, prior hamstring injuries and playing position was collected. Hamstring flexibility was measured using the Sit-and-Reach Test. The intervention group followed a 13-week intervention with the NHC. Associations between subgroups "at risk" and "not at risk" were analyzed using Pearson's chi square test.

Results: 329 players were included in intervention group and 299 in the control group. During the year 2013, 22 hamstring injuries were reported. The intervention showed a significant effect for being at risk by playing position defender compared to being at risk in the control group of 0,031. No difference in Odds ratios (OR) of subgroups, age, hamstring flexibility, prior hamstring injury and playing position midfielder and attacker, "at risk" and "not at risk" in the intervention group were shown.

Conclusion: Eccentric hamstring training using the NHC is effective in players at risk by playing position 'defender'. Nordic hamstring curl exercises must be included in the training program of players with playing position defender for prevention from hamstring injuries.

Clinical Relevance: An overview of risk factors can give information on soccer players being "at risk" for hamstring injuries and help trainers and medical staff to develop a training program tailored to each individual player optimizing injury prevention.

Keywords: hamstring injury, risk factor, Nordic hamstring curl, eccentric exercise, prevention, age, flexibility, prior injury, playing position, subgroup

INTRODUCTION

Field soccer is one of the most popular sports and has over 240 million amateur and professional player's worldwide[1]. In the Netherlands, more than 1.2 million soccer players were registered during season 2012/2013[2]. Over 650.000 soccer injuries are reported every year, which counts for 19% of all sports injuries.

Hamstring injuries are the most prevalent muscle injuries in soccer, accounting for 12 – 16% of all injuries within this sport. Also 12 – 30 % of these players will have a re-injury of the undergone hamstring injury within the same soccer season[3-4]. The definition of a hamstring injury, accepted by the International Federation of the Football Association (FIFA) was formulated by Fuller et al. in 2006: "Any acute-occurring physical complaint in the region of the posterior thigh sustained during sports activities, irrespective of the need for medical attention or time loss from sporting activities"[5]. This definition is used as a framework for further research.

The majority of the hamstring injuries in soccer are the sprint-type injuries[1,3-4]. These injuries occur in the late swing phase when the bi-articular hamstring muscle reaches maximum eccentric contraction and must deal with high forces in order to decelerate the knee extension[4,6]. For that reason, the high hamstring injury incidence in soccer is caused by actions such as short distance high speed running and stopping[3].

The last decade, a trend is seen towards injury prevention strategies to decrease the hamstring injury incidence in soccer. Because most injuries occur in the eccentric phase of movement, a development of eccentric training of the hamstring muscles is investigated in literature. Brockett et al. (2001) developed an eccentric hamstring strength training exercise, the Nordic hamstring curl (NHC)[7]. This exercise has been shown to increase the eccentric strength in the hamstring muscles in male professional soccer players[8].

Injury preventive effects of interventions on eccentric hamstring training have been shown conflicting in systematic reviews. A Cochrane review of Goldman et al. (2010) on the preventive effect of interventions on hamstring injuries showed insufficient evidence to draw conclusions[9]. Main problems in the included studies were small sample sizes and poor compliance to exercise programs[9-11]. In 2012, a randomized controlled trial (RCT) by Petersen et al. showed a significant decrease of the number of hamstring injuries in male amateur and professional soccer players after a 10-week training program with the NHC[10].

The Nordic hamstring curl has been shown to decrease the hamstring injury rate significantly for a total population of players but no research based on subgroups is done. The player's age, hamstring flexibility, previous hamstring injuries and playing position in field, have shown to be risk factors for obtaining a hamstring injury during soccer activities[11-12].

However, the influence of age, hamstring flexibility, playing position in field and previous hamstring injuries on the hamstring injury incidence after a training program with the NHC is still unknown compared to players not at risk by these factors. Besides, if the effect of the NHC exercise is evaluated in groups based on risk factors, a start of a player tailored exercise program can be made to prevent from injuries and specific from hamstring injuries.

Therefore, the aim of this study is to determine the effect of the risk factors: a soccer player's age, hamstring flexibility, a prior hamstring injury and the position in field on the hamstring injury incidence after an intervention program with the NHC exercise in male amateur soccer players compared to players at risk in the control group and players not at risk in the intervention group.

METHODS

Design

The present study was a secondary analysis of the Hamstring Prevention Injury Strategies (HIPS) study, which was a cluster-randomized controlled trial on the prevention of hamstring injuries in male amateur soccer players[13.] This trial was approved by the medical ethics committee of the University Medical Center Utrecht (File number 12-575/C) and implemented in collaboration with the Royal Dutch Football Association (KNVB). The HIPS study procedure was carried out as described by Van der Horst et al.[13].

Participants

All Dutch soccer teams, participating in four districts (i.e. West 1, West 2, South 1 and East), of the first class ("Eerste klasse") amateur field soccer were eligible for this trial. Clubs were informed about the study purpose at information meetings organized by the research team. At these meetings, teams were invited to participate and team staff members were asked if they would collect data for the study. Soccer players in the included teams were eligible if they were aged 18 to 40 years. Players who joined a team after the start of the study were excluded from participation. Before participating in the study, informed consent was written by the individual players of a participating team.

Sample size calculation

The available sample size of the HIPS study was used in this study. For a chi square test with α 0.05 and an effect size of 0.5, a total of 52 players must be included to each research group. Taken the chance of players lost to follow up into account, a correction of 7% must be made[10,14]. Taken this into account a total of 56 players must be included in the analyses.

Intervention: the Nordic Hamstring curl exercise

The intervention program consisted of the NHC exercise, an exercise to improve the eccentric strength of the hamstring muscles. The NHC exercise is a partner exercise. The first player sits down on his knees while another player keeps the first player's ankles to the ground. The first player bends forward keeping his hips and back straight and slows the moving process down by using the hamstring muscles. If the player is no longer able to slow the moving process down by the hamstring muscles, arms are used to catch up the body on the floor and the player goes back to the start position[7]. For the purpose of the present study, the intervention program was supervised by the team coach or medical staff and is carried out just before cooling down, because this moment has shown the best effect on reduction of fatigue of eccentric hamstring strength[15].

The exercises were done at increasing level to avoid muscle soreness, constructive phase weeks 1-5. The following eight weeks, maintenance phase weeks 6-13, the exercise intensity is stable. Participants were informed on the possibility of Delayed Onset Muscle Soreness (DOMS), a known side effect of eccentric exercises[5].

Procedure

Participants were clustered at team level before randomization to prevent contamination bias between individuals within a team[16]. Allocation to team number was done by computer generated random assignment, before an equal number of teams were allocated to the intervention and control group by using an online research randomizer[17]. Information bias was tried to avoid by pre-randomization, so the control group was not aware of the intervention procedure.

The intervention started after the winter break of the season 2012-2013, 3 -5 weeks before start of the second half of the season. Staff members of the teams in the intervention group were instructed to start the regular training programs and add the NHC exercise program during 13-weeks as described before. Teams in the control group followed their regular training programs en received no further information. Players who were injured at the start of intervention could start the intervention after they were fully recovered for one week. Injuries as a result of the NHC exercise had to be reported to the researchers by the team medical staff.

Data collection

Baseline player characteristics

At baseline, player characteristics were collected using a questionnaire. The characteristics concerned age at start of the study, playing position in field, i.e. goal keeper, defender, midfielder and attacker, and amount of hamstring injuries in the past 12 months (year 2012).

Hamstring flexibility

The Sit-and-Reach test (SRT) is a widely used tool to evaluate the hamstring flexibility. The SRT has good criterion validity (R^2 = 0.86) compared to the passive straight leg raise which is seen as the golden standard[19]. All clubs received a Sit-and-Reach Box to perform the hamstring flexibility measurements at baseline. The club medical staff was instructed how to perform the SRT. Participants were not allowed to perform a warming-up before the test. The protocol was used as described by the American academy of orthopedic surgeons[18]. SRT scores were recorded to the nearest 0.5 cm[13,19].

Hamstring injuries

During the year 2013, all hamstring injuries were recorded by the club medical staff on a hamstring injury registration form. Hamstring injuries during the 13-week intervention period were excluded from analyses because there was yet no definite effect of the intervention and including these hamstring injuries may had caused bias. Recurrent injuries were recorded but excluded from analyses.

Statistical analyses

All statistical analyses were performed using SPSS 21.0 for windows. Participants, who were lost to follow up, were analyzed by intention to treat.

In case of more than 1% of missing cases for the variables age and hamstring flexibility, multiple imputation was used to complete the data.

Descriptive statistics at baseline
Descriptive statistics were used to describe the player characteristics age and hamstring flexibility (mean and standard deviations) and prior hamstring injuries and playing position in field (% of group total) at baseline. Comparability between intervention and control group at baseline was analyzed by independent samples t-test or nonparametric equivalents.

Determination of cutoff points for risk factors
To determine if patients were at risk, a cutoff point for categories "at risk" and "not at risk" had to be stated for dividing players into subgroups. The cutoff point for the age group as "at risk" was seen as the mean plus one standard deviation. The cutoff point for the flexibility group as "at risk" was seen as the mean minus one standard deviation[20-21.] If a soccer player obtained one or more hamstring injuries in 2012, the player was placed in the group for "at risk" by prior hamstring injury. Soccer players with playing position of defender, midfielder and attacker were seen also placed in the group "at risk" by their playing position[20-21].

Hamstring injury incidence
Overall hamstring injury incidence of the HIPS study is expressed in absolute hamstring injury incidence. Pearson chi square test was used to show the effect of the NHC on the hamstring injury incidence in intervention group compared to the control group. Odds ratio (OR) was used to compare the effect size to the subgroup analyses.

Determination of effect in subgroups
Associations for subgroups "at risk" by, age, hamstring flexibility, prior hamstring injury and playing position defender, midfielder and attacker, between hamstring injury incidence and intervention or control group were analyzed using Pearson chi-square test. Associations for subgroups "not at risk" by, age, hamstring flexibility, no prior hamstring injury and playing position goalkeeper, between hamstring injury incidence and intervention or control group, were analyzed using Pearson chi square test too[22]. If the assumptions of Pearson chi square test were not met, Fisher exact test was used. Cramer's V was used to determine the power of the associations found by Pearson chi square test. Zero means no association and one means excellent association.

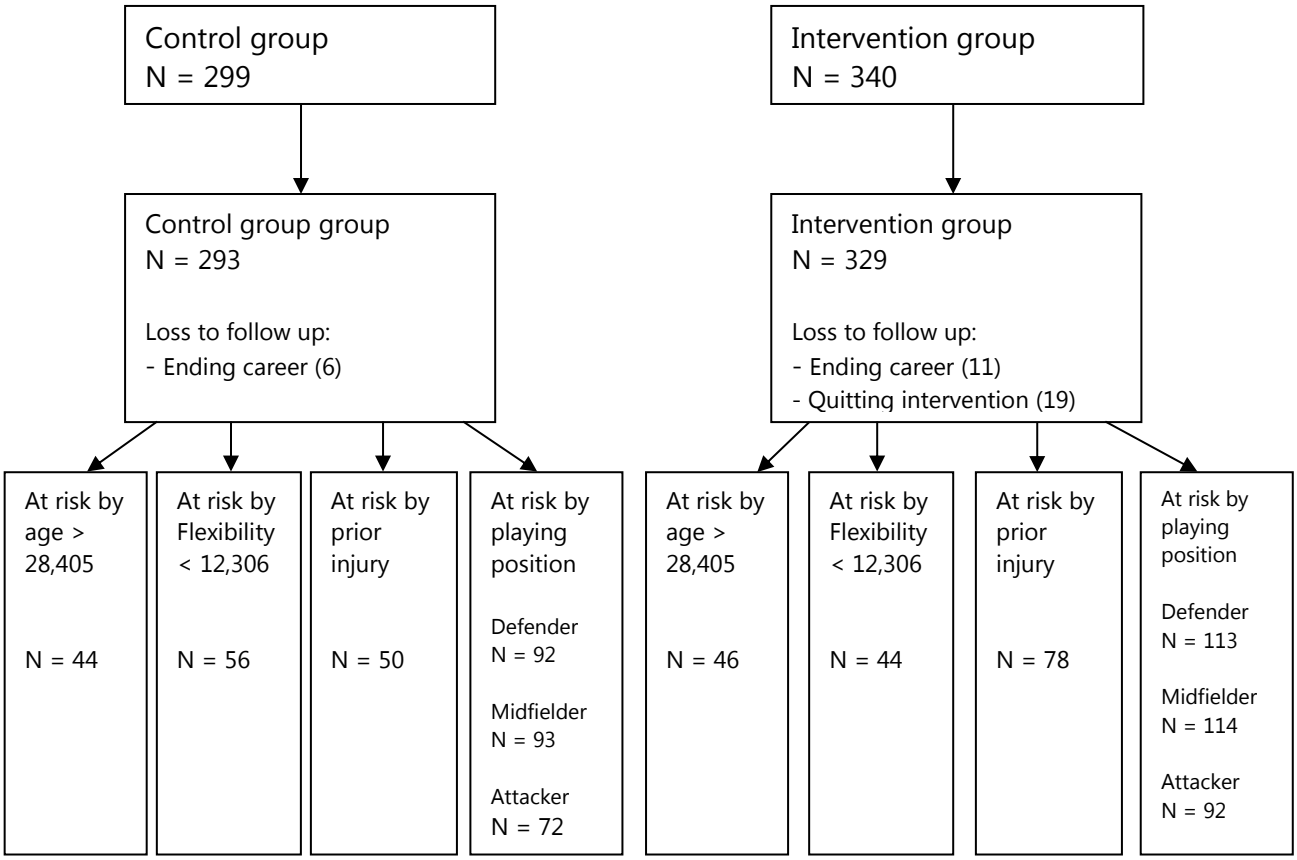
Comparison of subgroups by size of effect

ORs of all associations were determined to compare the OR of the subgroups of players "at risk" to the subgroups for players "not at risk".

RESULTS

After randomization, five teams (three in the intervention group and two in the control group) withdrew from the study before start of the intervention. During the study period seventeen players were lost to follow up because of career ending (eleven in the intervention group and six in the control group). One team of nineteen players quitted the intervention halfway. Finally, 293 players from sixteen teams were included to the control group and 329 players from nineteen teams were included to the intervention group. A flowchart of the inclusion process is shown in figure 1.

Figure 1: Flowchart of inclusion process



Baseline characteristics were similar at start of the study for both the intervention and control group. A clinical difference was seen in the prior hamstring injury rates, but no statistical difference was reached so they were assumed comparable. Baseline characteristics are shown in table 1.

Table 1: Baseline characteristics

	Control	Intervention	Significance
Age (years), mean and sd	24,35 +/- 3,598	24,69 + 4,207	0,281
Flexibility (cm), mean and sd	21,22 +/- 8,830	21,01 +/- 8,809	0,767
Prior injury, n (%)	50 (20,5%)	78 (25,5%)	0,313
Position in field n (%)			
• **Attacker**	72 (27.5%)	92 (28.8%)	0,718
• **Midfielder**	93 (35.5%)	114 (35.7%)	0,952
• **Defender**	92 (35.1%)	113 (35.4%)	0,938
• **Goalkeeper**	25 (9.5%)	35 (11.0%)	0,574

Percentages expressed in % of the total amount of players included in the intervention or control group. Significance level with α of 0.05.

Determination of risk factors

Players were at risk by age if their age at start of the study was higher than 28,41 years (24,51 + 3,90). Players were "at risk" by flexibility if their hamstring flexibility was lower than 12,31 cm (21,12 – 8,81). The overall means of age and flexibility were used to determine the cutoff point for the "at risk" analyses because no difference at baseline between the groups was shown. All players were divided into groups for being "at risk" or "not at risk" by age, flexibility, prior injury or playing position. The distribution of risk factors among the players is shown in figure 1.

Hamstring injury incidence

The overall hamstring injury incidence after an intervention with the NHC exercise was significantly lower for the intervention group (seven injuries) than for the control group (fifteen injuries). This is expressed in an OR of 0.223.

All hamstring injury cases during the year 2013 are shown in table 2. The cases are expressed in risk factors by the earlier mentioned cutoff points. "At risk" by prior injury was seen in three cases in the intervention group and two cases in the control group. "At risk" by age was seen in two cases in the intervention group versus one in the control group. For flexibility, one case in the intervention group versus three cases in control group were "at risk". Ten out of 22 cases were "at risk" by one of these risk factors. For playing position in field, all players were at risk by position attacker, midfielder or defender.

Table 2: hamstring injury cases expressed in risk factors

Case	Prior injury	Age	Flexibility	Position in field	Intervention/ control
1	No	No	**Yes**	**Defender**	1
2	**Yes**	**Yes**	No	**defender**	1
3	**Yes**	No	No	**Midfielder**	1
4	No	No	No	**Defender**	1
5	No	No	No	**Defender**	1
6	**Yes**	No	No	**Midfielder**	1
7	No	**Yes**	No	**Defender**	1
8	**Yes**	No	**Yes**	**Midfielder**	0
9	-	No	No	**Midfielder**	0
10	No	No	No	**Defender**	0
11	-	No	No	**-**	0
12	No	No	No	**Midfielder/ Defender/ Forwarder**	0
13	No	No	No	**Midfielder**	0
14	No	**Yes**	No	**Defender**	0
15	No	No	**Yes**	**Defender**	0
16	No	No	No	**Defender**	0
17	No	No	No	**Midfielder**	0
18	**Yes**	No	No	**Forwarder**	0
19	-	No	**Yes**	**-**	0
20	No	No	No	**Defender/ Midfielder**	0
21	-	No	No	**Forwarder**	0
22	-	No	No	**Defender/ Midfielder**	0

Yes/highlighted= at risk, No = not at risk, - = no data available, 1 = intervention group, 0 = control group

Determination of effect size in players at risk

Results for the chi square test for players "at risk" are shown in table 3. A significant effect of NHC exercise is seen in players at risk by playing position defender. A trend towards a significant positive effect is seen in flexibility, prior hamstring injury and playing position midfield and playing position attacker. Although, no associations were shown (Cramer's V). Odds ratios of the subgroups of the "at risk" analyses are comparable to the odds ratio of the total effect of the intervention with the NHC.

Table 3: Association between hamstring injury incidence and type of intervention sorted by risk factor

	Hamstring Injury	**Intervention group**	**Control group**	**Pearson chi square (P)/ Fisher's exact test (FE)**	**Cramer's V**	**Odds ratio**
Flexibility	No	56 (98,2%)	41 (93,2%)	0,315 (FE)	0,129	0,244
	Yes	1 (1,8%)	3 (6,8%)			
Age	No	42 (95,5%)	45 (97,8%)	0,612 (FE)	0,066	2,143
	Yes	2 (4,5%)	1 (2,2%)			
Prior hamstring injury	No	77 (98,7%)	48 (96,0%)	0,560 (FE)	0,088	0,312
	Yes	1 (1,3%)	2 (4,0%)			
Defender	No	110 (97,3%)	83 (91,2%)	**0,031 (P)**	0,151	0,252
	Yes	3 (2,7%)	9 (9,8%)			
Midfielder	No	111 (97,4%)	86 (92,5%)	0,117 (FE)	0,114	0,332
	Yes	3 (2,6%)	7 (7,5%)			
Attacker	No	92 (100,0%)	69 (95,8%)	0.083 (FE)	0,154	-
	Yes	0 (0,0%)	3 (4,2%)			

Results for the chi square test for players " not at risk" are shown in table 4. A significant positive effect was seen for players "not at risk" by flexibility and age. In players with a prior hamstring injury, a trend towards a significant effect is seen. Goalkeepers did not have any injuries at all. Notwithstanding the significant results, no associations were found (Cramer's V.) Odds ratios were comparable to the odds ratios of the " at risk" subgroup analyses.

Table 4: Association between hamstring injury incidence and type of intervention by players not at risk for a risk factor

	Hamstring Injury	**Intervention group**	**Control group**	**Pearson chi square (P)/ Fisher's exact test (FE)**	**Cramer's V**	**Odds ratio**
Flexibility	No	266 (98,2%)	233 (94,3%)	**0,021 (P)**	0,102	0,313
	Yes	5 (1,8%)	14 (5,7%)			
Age	No	280 (98,6%)	229 (93,5%)	**0,002 (P)**	0,134	0,204
	Yes	4 (1,4%)	16 (6,5%)			
Prior hamstring injury	No	223 (97,8%)	184 (94,8%)	0,101 (P)	0,080	0,413
	Yes	5 (2,2%)	10 (5,2%)			
Goalkeeper	No	35 (100,0%)	25 (100,0%)	-	-	-
	Yes	0 (0,0%)	0 (0,0%)			

DISCUSSION

The aim of this study is to determine the effect of the risk factors: a soccer player's age, hamstring flexibility, a prior hamstring injury and the playing position in field on the hamstring injury incidence after an intervention program with the NHC exercise compared to players "at risk" in the control group and players "not at risk" in the intervention group.

As hypothesized, eccentric training with the NHC is effective in reducing hamstring injuries for players with playing position defender compared to players "at risk" by playing position defender in the control group based on Pearson chi square test. The same results are shown in players "not at risk" for age or flexibility.

Comparing odds ratios for hamstring injury incidence in the intervention group versus control group, no difference can be seen in for players "at risk" and players "not at risk" by flexibility (0,244 vs. 0,313) and a prior hamstring injury (0,088 vs. 0,080). The odds ratios of the subgroup analysis were comparable to the odds ratio of the HIPS study (0,233) and the overall effect of the NHC eccentric training in the intervention group versus the control group.

Despite the fact that no other risk factors showed a significant effect of the NHC, a trend towards a preventive effect was seen in players at risk by hamstring flexibility (1.8% vs. 6.8%), a prior hamstring (1.3% vs. 4.0%), playing position midfielder (2.6% vs. 7.5%) and playing position attacker (7.5% vs. 2.6%). Odds ratios of the non-significant subgroup analyses were comparable to the HIPS odds ratios, so research on larger samples of players may have higher odds ratios.

The present paper is the first study with subgroup analyses based on the influence of eccentric hamstring training with the NHC on risk factors in prevention of hamstring injuries in male soccer players. Only one RCT by Petersen et al conducted a subgroup analysis for prior hamstring injuries and showed a significantly lower recurrence hamstring injury rate after an intervention with the NHC[10]. In contrast, previous reviews are based on the identification of risk factors in obtaining hamstring injuries during soccer. Despite the fact that only playing position defender was found as significantly being at risk for hamstring injuries, in literature more evidence in risk factors for obtaining hamstring injuries is seen. In meta-analysis of risk factors for hamstring muscle strain injuries, a higher age and prior hamstring injury are significantly associated with a higher hamstring injury incidence in soccer in high quality RCTs[12]. Soccer players of older age, above 23 years old, are at increased risk of sustaining a hamstring injury with a RR of 2.46[3,23-24]. Likewise, a prior hamstring injury is found significantly a risk factor for hamstring injuries with a RR of 2.68[3,23]. A systematic review of risk factor for hamstring injuries in male soccer players shows age, hamstring flexibility and prior hamstring injury as significant risk factors[11]. An older age, above 25 years

old, is shown as a risk factor by a hazard ratio of 1.1[25]. Low hamstring flexibility is a significant risk factor in[21]. A Prior hamstring injury is a risk factor for obtaining a hamstring injury with an OR of 2.62[23], a hazard ratio of 3.2[25] and an OR of 11.6 in multi-variate analysis[3]. All these analysis identified risk factors but studies showing intervention effects were excluded from analyses. The only conclusion based on comparison with the literature is that player with a prior injury did benefit from eccentric hamstring training. However, this subgroup showed a lower RR than the effect of the total study too.

Methodological considerations

By establishing the methodological approach of this study, choices are made to prevent from bias and increase the reliability of the study based on previous research.
At first, regarding to the literature, the only option to determine the cutoff point of a risk factor for age is the use of the mean plus one standard deviation. This overall used cutoff method may not be the right method for all sorts of studies. In a lot of sports, like soccer, a cutoff point based on physical functioning is used to make a shifting between younger and older players. In soccer under 23 years is regarded as junior by the FIFA and above 23 as senior level. The cutoff point for being at risk by age in this study was 28,405 years old by start of the study. Similarly, the cutoff point method for hamstring flexibility must be discussed. The mean Sit-and-Reach test score of the soccer players in this study was 21.120 cm, which is seen as far below average compared to 31.0 cm which is seen as normal in athletes. The lower hamstring flexibility in soccer players compared to athletes in other sports is widely known. In conclusion, for a better estimation of being at risk by hamstring flexibility or age, a cutoff point based on etiology must be used.

Second, multiple imputation is used in this study to replace the missing data for hamstring flexibility and age at start of the study. Multiple imputation is seen as the most valid method to replace data because calculations are based on the other available data in the database. Before imputation the number of missing for age was 4.8% and for hamstring flexibility 17.9%. After imputation only 0.5% of the data for age and hamstring flexibility was missing, so all reported hamstring injuries can be used in analysis.

An explanation for the discrepancy between the results of this study and the risk factors identified in literature may be caused by the fact that this study had a limitation influencing the subgroup analyses. This limitation was the small amount of hamstring injuries in this study. During the year 2013, only 23 hamstring injuries occurred, compared to 67 hamstring injuries in the RCT of Petersen et al. 2012 in a sample of 942 players[10]. The lower amount of hamstring injuries made it difficult to conduct proper subgroup-analyses for risk groups. A factor that might cause the low hamstring injury incidence is the awareness of the effect of the preventive effect of eccentric hamstring muscle training in soccer players by the club medical staff (i.e. doctor, physical therapist, movement scientist) and by earlier studies on the

NHC and "The 11"[25].

A major strength supporting the results is present in this study. Compliance to the eccentric hamstring exercise training using the NHC in the intervention group was higher than 90%. The execution of the NHC exercise must not be doubted because the club trainers and medical staff watched an instruction DVD. The compliance of the intervention group enlarges the impact of the study results.

Clinical relevance en interpretation

In clinical practice, an overview of subgroups "at risk" can give information on soccer players being at risk for hamstring injuries. Awareness of subgroups "at risk" can help trainers and medical staff to make a training program tailored to each individual player optimizing injury prevention.

Recommendations for future research

In future research the focus must be on larger samples and higher amounts of hamstring injuries to make subgroup-analyses by risk factors more convincing. Above all, cutoff points based on etiology must be used instead of statistical cutoff points. In case of more significant risk factors for reducing hamstring injury incidence a regression model can be used to determine interaction between risk factors. Similarly, factors as injury severity, training exposure, match exposure and injury recovery time can be taken into account. If exposure time is recorded well, survival analysis can be used to determine hazard ratios.

CONCLUSION

This study shows that eccentric hamstring training using the Nordic hamstring curl is effective in players at risk by playing position 'defender'. Odds ratios of subgroups "at risk" by age, flexibility, prior hamstring injury, playing position attacker and playing position midfield are comparable to the overall hamstring injury incidence odds ratios of the HIPS study. Nordic hamstring curl exercises must be included in the training program of players with playing position defender for prevention from hamstring injuries.

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