

## Prevention of hamstring strains in elite soccer: an intervention study

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The purpose was to test the effect of eccentric strength training and flexibility training on the incidence of hamstring strains in soccer. Hamstring strains and player exposure were registered prospectively during four consecutive soccer seasons (1999–2002) for 17–30 elite soccer teams from Iceland and Norway. The first two seasons were used as baseline, while intervention programs consisting of warm-up stretching, flexibility and/or eccentric strength training were introduced during the 2001 and 2002 seasons. During the intervention seasons, 48% of the teams selected to use the intervention programs. There was no difference in the incidence of hamstring strains between teams that used the flexibility training program and those

who did not [relative risk (RR) = 1.53,  $P = 0.22$ ], nor was there a difference compared with the baseline data (RR = 0.89,  $P = 0.75$ ). The incidence of hamstring strains was lower in teams who used the eccentric training program compared with teams that did not use the program (RR = 0.43,  $P = 0.01$ ), as well as compared with baseline data for the same intervention teams (RR = 0.42,  $P = 0.009$ ). Eccentric strength training with Nordic hamstring lowers combined with warm-up stretching appears to reduce the risk of hamstring strains, while no effect was detected from flexibility training alone. These results should be verified in randomized clinical trials.

Hamstring strains are common injuries in sports characterized by maximal sprinting, kicking and sudden accelerations like sprinting (Lysholm & Wiklander, 1987), Australian Rules football (Orchard et al., 1997; Orchard, 2001; Verrall et al., 2001, 2005), American football (Heiser et al., 1984) and soccer (Arnason et al., 1996, 2004b; Hawkins & Fuller, 1999; Woods et al., 2004). Hamstring strains usually cause significant time loss from competition and training (Bennell et al., 1998; Woods et al., 2004; Verrall et al., 2005).

Studies have shown that hamstring strains account for about 29% of injuries among sprinters (Lysholm & Wiklander, 1987) and 16–23% of injuries in Australian Rules football (Orchard et al., 1997; Orchard, 2001; Verrall et al., 2001). During recent years, the injury profile in soccer appears to have changed. Most studies conducted in the 1980s found that ankle sprains were the most common injury type, followed by knee sprains or hamstring strains (Ekstrand & Gillquist, 1983a; Lewin, 1989; Nielsen & Yde, 1989; Ekstrand & Tropp, 1990). The more recent studies indicate that the proportion of hamstring strains seems to have increased, and is now higher than for ankle sprains, accounting for 12–16% of all injuries (McGregor & Rae, 1995; Arnason et al., 1996, 2004b; Hawkins & Fuller, 1999; Hawkins

et al., 2001; Woods et al., 2004), with an incidence of 3.0–4.1 hamstring strains per 1000 h; of match play and 0.4–0.5 per 1000 h; of training (Arnason et al., 1996, 2004b). This may be a result of the game becoming more physically demanding, with higher speed and more intensive play than seen previously (Tumilty, 1993).

Despite the high incidence of hamstring strains in several popular sports, research on their causation and prevention is limited (Bahr & Holme, 2003). There is evidence showing that previous hamstring strains (Bennell et al., 1998; Orchard, 2001; Verrall et al., 2001; Arnason et al., 2004b) and age (Orchard, 2001; Verrall et al., 2001; Arnason et al., 2004b) are independent risk factors for new hamstring strains. Other factors, such as poor hamstring muscle flexibility (Jonhagen et al., 1994; Witvrouw et al., 2003), muscle fatigue (Mair et al., 1996) and insufficient warm-up (Safran et al., 1988), have also been suggested to predispose to hamstring strains, but the evidence for this is less convincing (Bahr & Holme, 2003; Arnason et al., 2004b). The effects of a specific flexibility training program to prevent hamstring strains in high-performance athletes have not been studied. The only intervention studies available on stretching to date are from military populations, where hamstring strains are rare, using a brief

warm-up stretching program to prevent lower extremity injuries in general (Hartig & Henderson, 1999; Pope et al., 2000).

Most hamstring strains occur during maximal sprinting activities (Nielsen & Yde, 1989; Arnason et al., 1996; Woods et al., 2004). EMG analyses during sprinting have shown that muscle activity is highest during the late swing phase, when the hamstring muscles work eccentrically to decelerate the forward movement of the leg, as well as during foot-strike, in the transition from eccentric to concentric muscle action (Mann, 1981; Jonhagen et al., 1996). It has therefore been postulated that eccentric overload could cause tearing in the muscle tendon unit (Garrett, 1990). Investigators have also suggested that inadequate muscle strength (Yamamoto, 1993; Jonhagen et al., 1994; Orchard et al., 1997), imbalance in the hamstring to quadriceps strength ratio (Yamamoto, 1993; Orchard et al., 1997; Croisier et al., 2002) or side-to-side imbalances (Yamamoto, 1993; Orchard et al., 1997) are risk factors for hamstring strains. However, the studies published to date on hamstring strength as a risk factor for strains have significant methodological limitations (Bahr & Holme, 2003).

Nevertheless, three recent studies have demonstrated the effectiveness of eccentric strength training for the hamstring muscles. Brockett et al. (2001) tested the effect of one acute bout of eccentric exercise in 10 subjects who were not involved in regular weight training. Askling et al. (2003) used Swedish elite soccer players to study the effects of a strength training exercise with eccentric overload for the hamstring muscles using a YoYo flywheel (YoYo Technology AB, Stockholm, Sweden) ergometer. Mjøl̄snes et al. (2004) examined the effects of a simple eccentric partner exercise, "Nordic hamstring lowers," and compared this to traditional hamstring curls in a group of Norwegian soccer player. The first study showed that the optimum angle for concentric hamstring torque generation increased. The two other studies demonstrated a remarkable increase in eccentric torque production after only 10 weeks of eccentric strength training. In the Swedish study they also pilot tested the effects of their eccentric training program on the risk of hamstring strains in 15 players with promising results (Askling et al., 2003). As hamstring strains are thought to occur through maximal eccentric muscle actions and low strength has been suggested as a risk factor for strains, we hypothesized that eccentric strength training could reduce the risk of hamstring strains.

Thus, the aims of this study were to test the effects of eccentric strength training and flexibility training on the risk of hamstring strains among elite soccer players.

## Methods

### Participants

Male soccer teams were recruited for the study from the Icelandic and Norwegian top leagues. The number of players varied from 18 to 24 players per team. Of the 20 teams that participated in the Icelandic elite league and first division, 17 agreed to participate in the study during the 1999 season, 15 during 2000, 16 during 2001, and 10 during 2002. Participation was based on the decision of the coach and team administration. The Norwegian elite league consists of 14 teams, and all of these participated in the study during the three competitive seasons from 2000 to 2002. However, in both countries two to three teams are promoted or relegated between divisions each year based on the results of the previous season. Therefore, from one season to the next there were some changes in the teams that were invited to participate in the study.

### Study design

Baseline data on hamstring strain incidence were recorded in Iceland during the 1999 and 2000 seasons, and in Norway during the 2000 season. As illustrated in Fig. 1, some or all components of a three-part prevention program were then introduced to the clubs in Norway and Iceland before the 2001 and 2002 seasons. The prevention programs were launched in meetings with club medical personnel 3 months before the start of each season. The teams were informed that the program components recommended were intended to reduce the rate of hamstring strains. All teams included in the study participated in a continuous injury registration protocol during the study period. However, the teams themselves selected whether they would take part in the intervention program. In this way, results from the intervention teams could be compared to the results from the baseline seasons (1999 and 2000) in Norway and Iceland, as well as to the control teams (teams that chose not to use the intervention program components during 2001 and 2002). At the beginning of the study, informed consent was obtained from the players.

### Prevention program

The program consisted of three exercise components; warm-up stretching, flexibility training and/or eccentric strength training. Warm-up stretching was prescribed as a standard component of the program throughout all intervention seasons in both countries (Fig. 1). The teams were asked to stretch the hamstring musculature using a contract-relax exercise before beginning sprinting or shooting exercises during warm-up before every single training session and game (Fig. 2). The purpose was to reach the player's maximal range

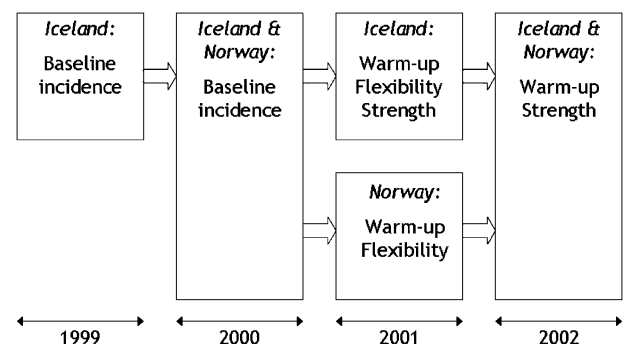
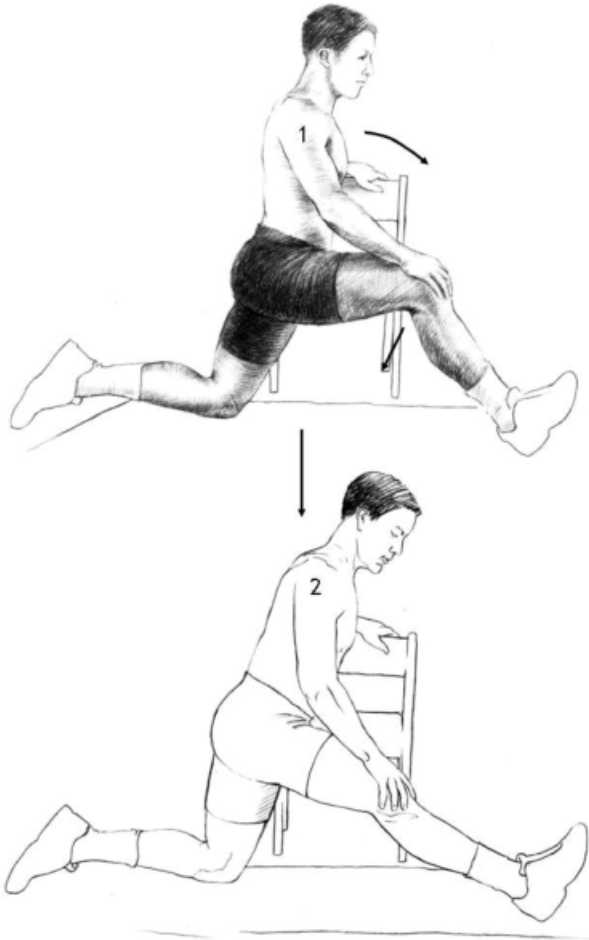
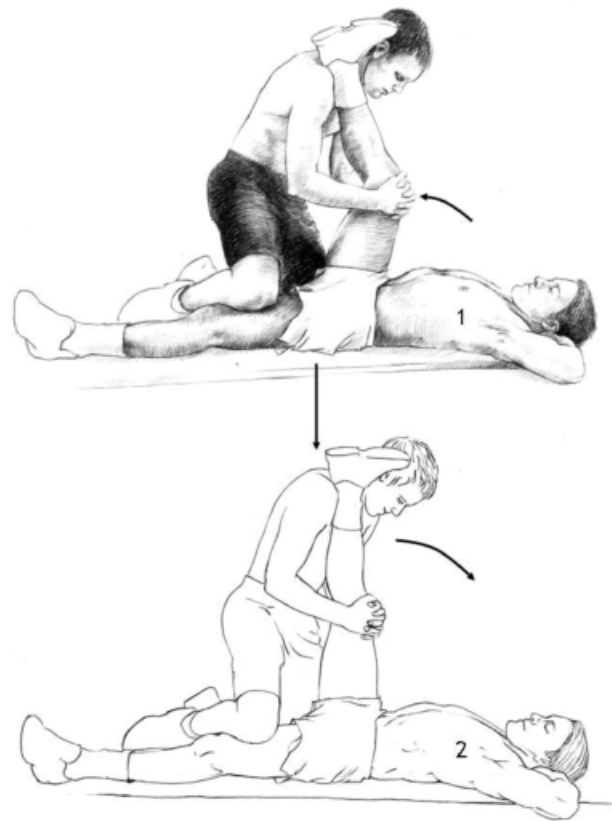


Fig. 1. Study design.



*Fig. 2.* Warm-up stretching exercise. The players were instructed as follows: “Use support, preferably from another player. Allow your ankle to relax. Press your heel against the ground for 5–10 s to activate the hamstring muscles, then relax and use your hand to straighten out your knee. Hold the stretch for about 20 s. If necessary, bend forward slightly at your hip until you feel the stretch in the hamstrings, but be sure to keep your back straight. Stretch each leg three times before every training session throughout the season.” Reproduced from Bahr and Mæhlum (2004) with permission from the publisher (©Lill-Ann Prøis & Gazette bok).

of motion, to prepare for maximal effort. The flexibility training program was prescribed for all teams in Norway and Iceland during the 2001 season (Fig. 1), and was based on a partner contract-relax stretching exercise (Fig. 3). The teams were asked to do this exercise after training three times per week during the preseason period and one to two times during the competitive season. The purpose of this program was to increase maximal range of motion through systematic stretching over time. The eccentric strength training program was prescribed for the Icelandic teams during the 2001 and 2002 seasons and for the Norwegian teams during the 2002 season (Fig. 1). The program was based on the Nordic hamstring lowers exercise (Fig. 4). After a 5-week introductory period with gradually increasing load, as described in detail by Mjølshes et al. (2004), the exercise prescription was three sets of 12, 10 and 8 repetitions, respectively. This program has been shown to increase eccentric hamstring strength (Mjølshes et al., 2004). The teams were asked to use the program during training three times per week during the



*Fig. 3.* Flexibility training program. The players were instructed as follows: “Your partner lifts your leg with the knee slightly bent, until you feel stretching on the posterior side of your thigh. Hold this position for a while before actively pressing your leg against your partner’s shoulder, so that your knee straightens out. Hold for 10 s. Then relax completely while your partner carefully stretches, by leaning forward. Hold that position for at least 45 s. It is important to relax your ankle to stretch the posterior side of the thigh, not the lower leg. Stretch each leg three times.” Reproduced from Bahr and Mæhlum (2004) with permission from the publisher (©Lill-Ann Prøis & Gazette bok).

preseason period, and one to two times per week during the competitive season. To be included in the intervention group, the teams must have used the program at least twice weekly during the preseason period and once per week during the competitive season.

#### Injury and exposure registration

Hamstring strains and exposure were recorded during the competitive season, which in Iceland lasts from mid-May until mid-September (4 months) and in Norway lasts from April to October (7 months). Hamstring strains were registered prospectively by the team’s physical therapists on a special form, which was collected by one of the authors on a monthly basis. This form included information about the location of the strain, former similar strains, and the exact diagnosis. During the same period, match and training exposure were also registered on a special form (Andersen et al., 2004; Arnason et al., 2004a, 2004b). Hamstring strains were recorded if they occurred during match play or organized training resulting from acute muscle actions, such as sprinting, shooting, accelerating or turning, while contact injuries (contusions) were not

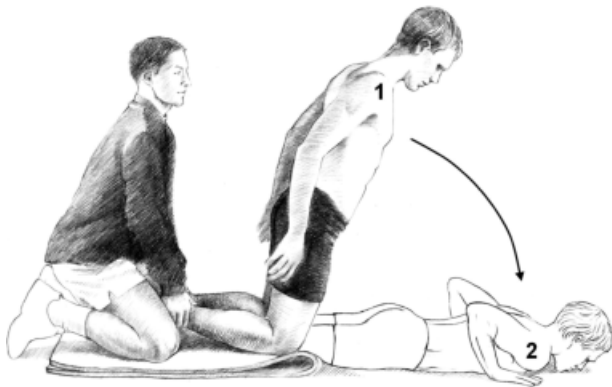


Fig. 4. Eccentric strength training (Nordic hamstring lowers). The players were instructed as follows: “This is a partner exercise, in which your partner stabilizes your legs. The goal is to hold as long as possible, to achieve maximum loading of the hamstrings during the eccentric stage. Lean forward in a smooth movement, keep your back and hips extended, and work at resisting the forward fall with your hamstring muscles as long as possible until you land on your hands. Touch down with your hands, go all the way down so that your chest touches the ground and forcefully push off into a kneeling position with minimal concentric load on the hamstring. Load is increased by attempting to withstand the forward fall longer. When you can withstand the whole range of motion for 12 repetitions, increase load by adding speed to the starting phase of the motion. Initial speed and load can also be increased further by having someone push you at the back of your shoulders.” Reproduced from Bahr and Mæhlum (2004) with permission from the publisher (©Lill-Ann Prøis & Gazette bok).

included. Hamstring strains were recorded based on the clinical assessment of team medical staff, and magnetic resonance imaging (MRI) examinations were not performed to verify the clinical diagnosis. A player was defined as injured if he was unable to participate in a match or a training session because of a hamstring strain that occurred in a soccer match or during training. The player was defined as injured until he was able to play a match or comply fully with all instructions given by the coach, including sprinting, turning, shooting and playing soccer at full tempo (Lewin, 1989; Arnason et al., 1996, 2004b, 2005). Injury severity was classified in categories according to the duration of absence as minor ( $\leq 7$  days), moderate (8–21 days) and severe ( $>21$  days). In addition to hamstring strains, all other acute injuries occurring during match play or organized training were also recorded. During the study period, the coaches or medical staff recorded player exposure during training, as well as their participation in the preventive program. Player exposure during matches was found from official records.

**Statistical methods**

Injury incidence ( $\pm$  standard error) was calculated as the number of hamstring strains per 1000 h of player exposure (match, training or total). Z tests were used to compare ratios (number of injuries/hours of exposure) between intervention and control groups, as well as between seasons. Fisher’s exact test was used to compare injury severity, as well as the proportion of recurrent injuries between intervention and control groups and between seasons.

Table 1. Exposure, number and incidence of hamstring strains in Iceland and Norway 1999–2002 (training and matches combined)

	No. of teams	Exposure (h)	Hamstring strains (N)	Incidence (strains/1000 h)
1999				
Iceland	17	33 258	30	$0.90 \pm 0.16$
2000				
Iceland	15	28 887	33	$1.14 \pm 0.20$
Norway	14	65 313	34	$0.52 \pm 0.09$
2001				
Iceland	16	36 193	26	$0.72 \pm 0.14$
Norway	14	74 306	33	$0.44 \pm 0.08$
2002				
Iceland	10	19 538	7	$0.36 \pm 0.14$
Norway	14	74 758	20	$0.27 \pm 0.06$

**Results**

**Baseline data**

The total incidence of acute time-loss injuries (all injury types included) was higher among the Icelandic teams ( $6.1 \pm 0.4$  and  $6.6 \pm 0.5$  per 1000 h of training and match combined during the 1999 and 2000 seasons, respectively) than among the Norwegian teams ( $3.9 \pm 0.2$ , during the 2000 season,  $P < 0.001$ ). A higher incidence of hamstring strains was also seen among the Icelandic soccer players than the Norwegian players ( $P < 0.035$ ) during the same period (Table 1). Hamstring strains constituted 15.9% of all acute injuries in Iceland and 13.4% of all acute injuries in Norway during the baseline period.

**Effect of flexibility training**

During the 2001 season, the Norwegian teams were asked to use warm-up stretching and the flexibility training program. Of the 14 teams that participated in the elite league, seven chose to use the intervention program. No significant difference was found in the incidence of hamstring strains between these teams and the seven teams that did not follow the intervention program [ $0.54 \pm 0.12$  vs  $0.35 \pm 0.10$ , relative risk (RR): 1.53, 95% confidence interval 0.76–3.08,  $P = 0.22$ ]. When comparing the severity distribution, there was significant difference in favor of the intervention teams (12% minor, 29% moderate, 59% severe) compared with the control teams (50% minor, 50% moderate, 0% severe;  $P = 0.006$  vs intervention), but not between the baseline (10% minor, 20% moderate, 70% severe) and intervention seasons ( $P = 0.85$  vs intervention) within the intervention teams. Furthermore, no difference was found in the incidence of hamstring strains between the intervention group and all teams the previous year ( $0.54 \pm 0.12$  vs  $0.52 \pm 0.09$ , RR: 1.03, 0.59–1.79,  $P = 0.91$ ), nor between the two seasons for the

intervention group only ( $0.54 \pm 0.12$  vs  $0.61 \pm 0.18$ , RR: 0.89, 0.42–1.85,  $P = 0.75$ ).

### Effect of eccentric strength training

During the 2001 season, eight teams in Iceland chose to use the full prevention program with warm-up stretching, eccentric strength training and flexibility training, while eight teams did not complete the program. During the 2002 season, five of 10 Icelandic teams and six of 14 Norwegian teams used the strength training program, as well as the warm-up stretching. No injuries were reported during eccentric strength training. The overall incidence of hamstring strains was 65% lower among the teams that used the eccentric strength training program, compared with the teams that did not use the program ( $0.22 \pm 0.06$  vs  $0.62 \pm 0.05$ , RR: 0.35, 95% confidence interval 0.19–0.62,  $P < 0.001$ ). When comparing the severity distribution, there was no difference between the intervention (27% minor, 64% moderate, 9% severe) and the control teams (36% minor, 50% moderate, 14% severe;  $P = 0.88$  vs intervention). The proportion of reinjuries was not different between the intervention (36%) and control teams (39%,  $P = 1.0$ ). The total incidence of hamstring strains was lower among the intervention teams than the teams that did not use the eccentric strength training program during the same seasons (control teams,  $P = 0.01$ ), as well as compared with the same intervention teams during the 1999 and 2000 baseline seasons ( $P = 0.009$ , Fig. 5). Injuries were more severe during the baseline season (29% minor, 21% moderate, 50% severe,  $P = 0.024$ ) than the intervention seasons within the intervention teams. The proportion of reinjuries was not different between the intervention (36%) and baseline seasons (54%,  $P = 0.47$ ) within the intervention teams. During matches, the rate of hamstring strains among the intervention teams was lower than among the control teams ( $P = 0.03$ ) and there was a similar trend during training ( $P = 0.07$ , Fig. 5). During training the rate of hamstring strains was also lower among the intervention teams than the same teams during the baseline season ( $P = 0.004$ , Fig. 5). However, during matches there was no significant difference in the rate of hamstring strains between the intervention teams and the same teams during the baseline seasons ( $P = 0.45$ , Fig. 5).

### Discussion

The main finding of the present study was that eccentric strength training with Nordic hamstring lowers combined with warm-up stretching seems to be effective in preventing hamstring strains in soccer.

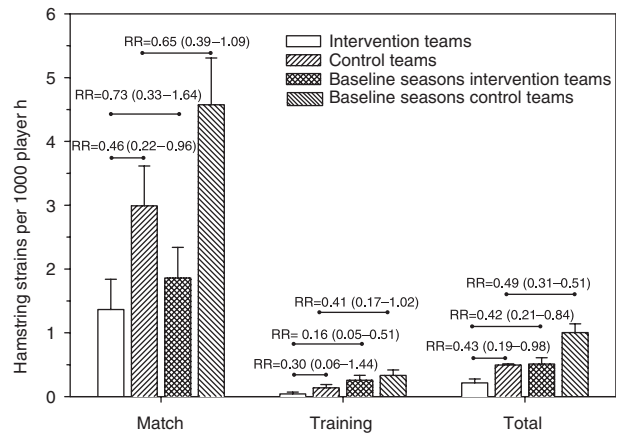


Fig. 5. Effect of eccentric strength training. Incidence ( $\pm$  SE) of hamstring strains in the Icelandic and the Norwegian league for four groups: (1) the intervention teams (Icelandic and Norwegian teams that completed the eccentric strength training program during the intervention seasons), (2) the control teams (the Icelandic and Norwegian teams that chose not to follow the strength training program during the intervention seasons), (3) the baseline season data for the intervention teams (the Icelandic and Norwegian intervention teams that participated during the baseline seasons 1999 and 2000), and (4) the baseline season data for the control teams (the Icelandic and Norwegian control teams that participated during the baseline seasons 1999 and 2000). In addition, the relative risk (RR) is shown with 95% confidence intervals.

In contrast, stretching during warm-up and flexibility training of the hamstrings group had no effect on the incidence of hamstring strains.

### Methodological considerations

The main limitation of this study is that it was not possible to use a randomized trial design. This study was performed on elite soccer teams and athletes at this level are not easily entered into randomized studies. Coaches use the training methods they believe will be most successful for their team. Therefore, during the 2001 preseason preparation period we asked all of the Icelandic teams to use the Nordic hamstring lowers exercise along with warm-up stretch and flexibility training, while the Norwegian teams were asked to use the warm-up stretch and the flexibility training. Although information meetings were held with coaches and team physical therapists in Iceland and the team physical therapists in Norway before the program was started both during the 2001 and 2002 preseason period and all of the Icelandic teams were visited by one of the authors to inform and correct the exercises during the preseason period in 2001, compliance with the program was only 48%. The coaches for the other teams decided not to use the program (39%) or used it only partly during the preseason

(13%). We are not aware of any systematic differences between teams that chose to use the training program and the teams that chose not to use it that would invalidate the results. Nevertheless, to account for potential systematic differences resulting from self-selection, we have also reported data comparing the injury rate during the previous season with the results during the intervention season within the intervention teams. These results are consistent with the overall analysis, showing a favorable effect after the introduction of the strength training program.

Another concern is that we could not control how much and how well the exercises were performed. Here we must rely on reports from coaches and team physical therapists. Coaches or their assistants recorded player training exposure on a special form, as well as when the warm-up stretch, flexibility training or eccentric strength training programs were performed. This information was collected by one of the authors once a month. Phone calls were also made to coaches and physical therapists to follow-up on the use of the programs. We also know that some players from teams that did not use the Nordic hamstring lower exercise as a team program used it individually. At least some of these players had a previous history of hamstring strains and believed this exercise could reduce their risk of recurrent strains. This may have reduced the incidence of hamstring strains among these teams and therefore diluted the difference observed between the teams that used the Nordic hamstring lowers exercise and those which did not.

Injury registration was performed prospectively on a standardized form by the team physical therapists. The registration forms were collected by one of the authors once a month, and frequent phone calls were made to reinforce the data collection procedures. In the Norwegian elite league, team physical therapists attended all matches and most training sessions, while in Iceland they were often only present during matches but usually not during training sessions. For this reason, it is possible that minor injuries, lasting for 1 or 2 days, were more likely to go unrecorded in Iceland, even if players were encouraged to contact the team physical therapist with every injury. Diagnoses were made clinically by team doctors and/or team physical therapists, and MRI exams were not performed to confirm the clinical diagnosis. Verrall et al. (2001) found that of 32 clinically diagnosed hamstring strains in Australian Rules football, 6 (19%) had a normal MRI scan. This means that it is likely that some of the clinically diagnosed hamstring strains in the present study could have another origin, or some of the strains registered with the shortest recovery time could be muscle cramps rather than true strains. Because of the relatively long

follow-up (4 years for some teams) coaches or physical therapists could be less motivated to record exposure and report injuries toward the end of the study. This may be the reason why only 10 Icelandic teams chose to participate during the final year. However, we are not aware of any differences in the recording of injuries between the intervention and control group. If anything, we would expect the intervention teams to be more likely to record injuries, which would mean that the intervention effect is underestimated.

Recurrent hamstring strains are common and have been shown to be an important risk factor for new hamstring strains (Arnason et al., 2004b). Because we only have information about previous hamstring strains among injured players, but not for all players, we were unable to assess whether there was a difference in the prevalence of previous hamstring strains between the intervention and control groups. However, when comparing the injury rate within the intervention teams between the baseline and the intervention seasons, there is less potential for such bias. On the other hand, no difference was found in the proportion of recurrent vs new injuries between the intervention and the control teams, nor between the baseline and the intervention season within the intervention teams.

The study did not include blinded outcome assessors. This was not possible, given that injuries were recorded by the team physical therapists, who of course knew whether their team used the prevention program or not.

#### Baseline data

When baseline data was collected, the proportion of hamstring strains (15.9% of acute injuries in Iceland and 13.4% in Norway) was in accordance with previous studies from Iceland (18.2%; Arnason et al., 1996) and studies from England (12% of all injuries; Hawkins & Fuller, 1999; Woods et al., 2004). During the baseline seasons, the total injury incidence was 38.4% higher in Iceland than in Norway and the incidence for hamstring strains was also 48.6% higher in Iceland. One reason for this could be a lower rate of recurrent injuries in Norway than in Iceland, possibly because the Norwegian physical therapists are present during most training sessions and are in a better position to follow-up injured players during training until they are fully recovered. The Norwegian season is also longer and training exposure higher than in Iceland, so the Norwegian players could be in better physical condition than the Icelandic players. This is also in accordance with previous studies, which have shown that players with a relatively higher training exposure incur significantly fewer injuries (Ekstrand et al., 1983; Arnason

et al., 2004b). Hamstring strength was not tested during the baseline period and only flexibility was tested among the Icelandic players. No correlation was found between hamstring flexibility and hamstring strains in the Icelandic players (Arnason et al., 2004b).

### Flexibility training

During the present study, flexibility training had no effect on the incidence of hamstring strains. To our knowledge there are no studies on soccer players or other elite athletes on the preventive effect of flexibility training on hamstring strains. However, one study on military basic trainees indicates a reduced number of lower limb overuse injuries after a period of hamstring stretching (Hartig & Henderson, 1999), while another military-based study found no effect of stretching (Pope et al., 2000). It should be noted that these studies were designed to examine the effect of general stretching on lower limb injuries in general, not a specific hamstring program on hamstring strain risk. Verrall et al. (2005) recently observed a reduction in the incidence of hamstring strains in Australian Rules football with a three-component prevention program, where stretching while fatigued was one of the components. The other factors in the program were sport-specific training drills and high-intensity anaerobic interval training. Thus, it is not possible to determine which of these factors are responsible for the observed effect. One study indicates that poor hamstring flexibility is a risk factor for hamstring strains (Witvrouw et al., 2003), but others do not support this finding (Ekstrand & Gillquist, 1983b; Arnason et al., 1996, 2004b; Watson, 2001). Thus, there is little or no evidence that flexibility training alone can prevent hamstring strains in soccer or other sports. The explanation may be that most hamstring strains occur during maximal sprinting, when hamstrings are not stretched toward their maximum range.

### Strength training

Several studies indicate that low hamstring strength is a risk factor for sustaining hamstring strains (Yamamoto, 1993; Jonhagen et al., 1994; Orchard et al., 1997). EMG studies have shown that activity is highest late in the swing phase and during heel-strike, when the hamstrings work eccentrically or transfer from eccentric to concentric muscle action (Mann, 1981; Jonhagen et al., 1996). It is assumed that most hamstring strains occur during eccentric muscle actions, when the muscle activity is highest (Garrett, 1990; Kaminski et al., 1998). It is well documented that strength training is mode specific (Tomberlin

et al., 1991; Highbie et al., 1996; Hortobagyi et al., 1996; Seger et al., 1998; Mjøl̄snes et al., 2004). Based on this it may be argued that, to be specific, strength training for the hamstring muscles should be eccentric. Although other type of strength training than Nordic hamstring lowers were not registered systematically by the teams, it is known that common training method for hamstring strength training in soccer players is traditional hamstring curls, an exercise that has been shown to be ineffective in increasing eccentric hamstring strength among elite athletes (Mjøl̄snes et al., 2004). In contrast, Mjøl̄snes et al. (2004) demonstrated the effectiveness of the Nordic hamstring lower exercise on eccentric strength. Therefore, it is not surprising that the present study indicates that eccentric strength training with Nordic hamstring lowers reduces the incidence of hamstring strains. Although Nordic hamstring lowers also has a concentric part, the exercise prescription focuses on the eccentric component. However, to avoid delayed onset muscle soreness it is important to follow the recommended exercise prescription with a gradual increase in training load when introducing a program of Nordic hamstring lowers (Mjøl̄snes et al., 2004). In the present study, none of the intervention teams that followed the prescribed progression complained about delayed onset muscle soreness. However, one team which used a much more aggressive training protocol, incurred considerable delayed onset muscle soreness and dropped out of the study. Injuries from the exercise itself have not been recorded in this study nor in the study by Mjøl̄snes et al. (2004), which means that from an injury perspective the exercise program appears to be safe in this player population. In their pilot study, Askling et al. (2003) found that eccentric strength training using the YoYo flywheel ergometer was effective in reducing the number of hamstring strains among soccer players. However, it should be pointed out that these results need to be confirmed in randomized-controlled trials, using an appropriate cohort of well-trained athletes.

In conclusion, an intervention program based on warm-up stretching combined with a simple eccentric partner exercise – Nordic hamstring lowers – seems to have reduced the incidence of hamstring strains in elite soccer players, while flexibility training alone did not appear to have any preventive effect. These results need to be confirmed in randomized-controlled trials, using an appropriate cohort of well-trained athletes.

### Perspectives

Hamstring strains are one of the most common types of injury in soccer, Australian Rules football,

American football and sprint. The recurrence rate of hamstring strains is also high. Therefore, preventive measures are important, but few studies are available in this field. Because most hamstring strains in soccer occur during maximal sprinting activities (Nielsen & Yde, 1989; Arnason et al., 1996; Woods et al., 2004) and eccentric overload in the late swing phase just before foot-strike could cause tearing in the muscle tendon unit (Garrett, 1990), eccentric strength training may be important to reduce the incidence of hamstring strains. Results from this study indicate that an eccentric strength training program with Nordic hamstring lowers could reduce the incidence of hamstring strains in elite soccer players. The Nordic hamstring exercise is a simple partner exercise, which can be easily integrated into the training program of soccer teams, as it can be performed in the field without special equipment. However, it is important to start slowly with few repetitions and sets, and follow the recommended prescription with a gradual increase in load and the number of repetitions. Injuries from the exercise itself have not been recorded in this study nor in the study by Mjøl̄snes

et al. (2004), which means that from an injury perspective the exercise program appears to be safe in this player population.

**Key words:** soccer, hamstring strains, prevention, Nordic hamstring, eccentric strength training.

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