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Determining the role of Nordic hamstring exercises in preventing hamstring injuries in soccer players: A narrative review

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Abstract
The most prevalent injury sustained by soccer players involves a hamstring strain or injury. These injuries have been observed in both contact and non-contact sports such as soccer, football, baseball, and cricket, but they can also be found in the general population due to overstretching or sudden muscle pull during daily activities, in soccer alone, the literature reports 15–50% of hamstring injuries, making it the sport with the highest rate of hamstring injuries. Long-term treatment and rehabilitation periods, combined with a high financial burden on players, cause them to miss games and, in some cases, retire from sports at the earliest. Despite of wide-ranging treatments, rehabilitation, and the preventive procedures the risk of recurrence of hamstring injuries remains significantly high. Nordic hamstring exercises (NHE) or Nordic curls are aimed at improving eccentric strength in the hamstring muscles, which is known to be a significant modifiable risk factor in hamstring injury prevention. Numerous studies have examined the effectiveness of Nordic hamstring exercises/curls as a preventative measure to lower the incidence of hamstring injuries in athletes participating in other sports and soccer players. The Nordic Hamstring Exercises (NHE) were incorporated into the FIFA '11' injury prevention program in 2003 and enhanced to develop the FIFA '11+' in 2006 with the aim of reducing hamstring injuries in soccer players. As a matter of fact, the desire to write a paper on this topic is to emphasize the role of Nordic hamstring exercises (NHE) as a preventive measure to lower the incidence of hamstring strains in soccer players and other athletes.

Keywords: Hamstring injuries, Nordic hamstring exercises, Soccer players, Eccentric strength, risk, injury prevention.

Introduction
A prevalent subtype of injury, contributing for 12% of all injuries, is hamstring injury, A club with a 25-player squad typically encounters 5-6 hamstring injuries every season, which is related to more than 80 days of football-related activity (training or games) missed due to an injury [1]. Compared to quadriceps muscle injuries, hamstring injuries are 2.5 times more prevalent [2]. A study examined the Elite Clubs of the Union of European Football Associations (UEFA) over a 13-year period. The findings show that since 2001, hamstring injuries have increased in training by around 4% year while remaining relatively steady in games [3]. Hamstring injuries are still common despite the identification of various intrinsic and extrinsic risk factors [4-8]. Even with preventive measures, hamstring injuries recur at a high rate of 12-33% [9-11]. It is important to note that hamstring injuries are still on the rise regardless the fact that the implementation of hamstring preventive programs has expanded dramatically in recent years [3]. This should not come as a surprise considering that recent increases in training and competition intensity have likely surpassed the improvement in hamstring preventive measures [3]. The overall cost of muscle injuries for professional football clubs could be very high [12, 13]. In a study Eliakim *et al*. demonstrated that an English premier league (EPL) team loses an average of £45 million sterling per season due to injury-related performance decline [14].

2. Injury mechanism

Games requiring sprinting, cutting movements, speed efforts, and vigorous stretching tend to result in injuries to the hamstring group of muscles, which is made up of the biceps femoris (BF), semimembranosus (SM), and semitendinosus (ST) muscle bellies [15-22]. The hamstring muscle complex is engaged throughout the biomechanics of running from the beginning of the mid-swing phase to at the end of the stance phase [15, 23, 24]. The biceps femoris BF is the muscle that elongates the most during that event, approximately 12% of its rest length [21, 25-28]. During the same phase, the SM is the flexor muscle that generates the most significant strength peak and absorbs most of the power production [21, 25-28]. Because of these elements, the BF and SM injuries are significantly different [22, 29, 30]. The SM injury mechanism is mostly based on overproduction of strength/power, whereas the BF injury mechanism is primarily based on overstretching [22, 29, 30]. Both ST and BF exhibit peak eccentric activity during the swing phase of running [28, 31, 32]. Schuermans *et al*. suggest that because the ST is activated more than the BF and SM during strength activities, it has the highest strength production activity [33]. Even with this, ST is the hamstring complex muscle with the lowest injury incidence, ranging from 5 to 6% [34-36]. Because of its significant tendonous component, ST which serves as protection against indirect injuries, there may be an explanation for the low injury incidence [29, 30, 34, 37, 38].

2.1 Risk Factors for hamstring injuries

According to Brukner *et al*. and Bisciotti *et al*., hamstring injury risk factors are classified as "primary injury risk factors" (i.e., risk factors that are primarily responsible for the first lesion) and "recurrent injury risk factors" (i.e., the risk that can cause a reinjury). In addition to the two above categories, some injury risk factors will be described as "Modifiable" and "Non-Modifiable factors" The latter are referred to as "bivalent injury risk factors" [39, 40].

2.2 Modifiable and Non-Modifiable injury risk factors

Age, prior injuries other than hamstring-related, history of hamstring injury, Size of the hamstring injury, level of competition, and the most recent soccer matches are the main non-modifiable factors injury risk factors that cannot be changed [1, 11, 34, 41-48]. In contrast, modifiable risk factors include the Hamstring Muscle Strength Imbalance Profile, Inadequate Rehabilitation Programs, and Change in Optimal Muscle Length [41, 49-54].

2.3 Bivalent injury risk factors

These include fatigue, inadequate warm-up, pelvic muscle coordination, and loss of flexibility, hamstring weakness, and training mistakes [35, 52, 55-65].

3. Hamstring injury prevention programs:

The two components of the hamstring injury prevention program are primary prevention and secondary prevention. Primary prevention (PP) is a preventive approach used to stop a first muscle injury, whereas secondary prevention (SP) is an approach used to prevent recurrences of the same muscle group after one or more lesions [66]. With a tendency to recurrence and significant impairment, preventing a first-time hamstring injury is highly essential [67]. Consequently, numerous preventative measures for hamstring injuries have been created and evaluated, including proprioceptive balance training, massage, instruction, functional training, sport-specific drills, stretchings and Strengthenings exercises [68-77]. It is widely acknowledged that eccentric muscle training can prevent hamstring injuries and has superior outcomes to concentric training in reducing their high prevalence [78-81].

3.1 Nordic Hamstring exercises

Nordic hamstring exercises (NHE), formerly referred to as Russian hamstring exercises, is an Eccentric exercise that is commonly used in Hamstring strain injuries (HSI)reduction programs [78, 82, 83]. This exercise requires the participant to bend their upper body as slowly as they can towards a prone position while kneeling on a soft cushion with their ankles firmly grasped by the instructor/ therapist or strapped to a firm surface (Fig 1 & 2). As the participant tries to defy gravity and falls forward, their instructor/therapist presses on their heels and lower legs. They control their descent into the prone position by eccentrically contracting their hamstring muscles [78]. Preliminary research from the Oslo Sports Trauma Research Center (OSTRC) indicates that this exercise may be able to prevent certain hamstring strains, and they developed a method for evaluating the exercise's efficiency [18, 79]. Mjolsnes *et al*. found that after just 10 weeks of training, the NH exercise significantly increased the production of eccentric torque [77]. Van Der Horst *et al*. (2015) examined whether the NHE could reduce the risk of hamstring injuries in amateur soccer players, and they found that only 38 out of the 579 participants in this randomized controlled trial encountered hamstring injuries. Comparing the intervention group to the control group, the intervention group had a lower risk of hamstring injuries [84]. This study's intervention involved 25 NHE sessions spread out over a 13-week period [84]. In a systematic review and meta-analysis of 8459 athletes, van *et al*. discovered that NHE reduces hamstring injury rates across multiple sports in different athletes by up to 51% [85]. In a similar study, Al Attar, *et al.* noticed that when used in an injury prevention program in soccer players, NHE reduced hamstring injury rates by up to 51% in the intervention group [86].

Fig 1: Starting position for Nordic Hamstring exercises

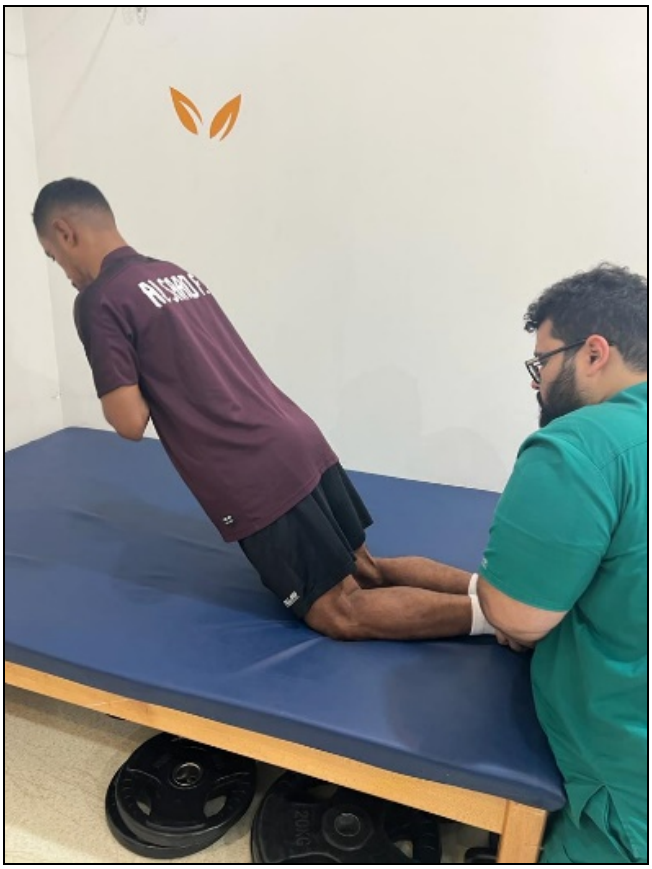

Fig 2: Lowering the upper body towards prone position with the ankles firmly grasped by the instructor/ therapist.

4. The Influence of Nordic hamstring exercise intervention on eccentric strength and adaptations in muscle architecture

The NHE has been shown to improve hamstring architectural and strength adaptations [87]. Opar *et al.* demonstrates important architectural aspects of the biceps femoris (BF), describing that longer fascicles reduce the risk of injury due to overlengthening during eccentric actions [88]. When combined with eccentric hamstring strength, increasing fascicle length appears to have the potential to lower the risk of hamstring strains [87]. According to Medeiros, *et al.* NHE training has the potential to increase the length of the biceps femoris long head fascicle as well as the eccentric strength of the knee flexors [89]. They discovered that NHE training increased knee flexor eccentric strength as measured using the isokinetic tests (0.68; 95% confidence interval, 0.29 to 1.06) and NHE tests (1.11; 95% confidence interval, 0.62 to 1.61) [89]. Fascicle length was also increased by NHE training with positive outcomes (0.97; 95% CI, 0.46 to 1.48) [89]. Similarly, while examining the effects of an 8-week low volume intervention of Nordic hamstring curl program in elite youth soccer players, Siddle *et al.* found that Change of Direction (COD) performance in male youth soccer players improved significantly despite no significant changes in hamstring muscle architecture, eccentric knee flexion (KF) strength, or linear sprint times [90].

5. Exercises training volume

The specific dosage of these exercises has not yet been determined, but studies showing higher compliance rate with NHE resulted to a greater reduction in hamstring strains. Medeiros *et al.* noticed that an 8-week NHE program performed eccentrically once weekly did not result in increased hamstring strength in football players [91]. In contrast, another study with twenty female football players found a significant improvement in NHE performance (22%) after 10 weeks of once-weekly training [92]. Addressing the ongoing discussion about the precise amount of exercise needed to prevent the occurrence of hamstring injuries has proven challenging due to divergent findings from various trial-conducting methodologies and methods of measuring pre- and post-intervention results. In a study conducted by Presland *et al.*, they compared the effects of a two-week standardized period of eccentric NHE training followed by four weeks of high or low volume training on twenty recreationally active males [93]. They discovered that both low and high volume NHE training stimulated increases in Biceps femoris Long Head (BFLH) fascicle length and eccentric knee flexor strength, but when training was discontinued, architectural adaptations returned to baseline [93]. In another trial, Ribeiro *et al.* discovered that a short-term NHE training program (4 weeks; 8 training sessions) minimizes multiple hamstring injury risk factors in physically active young adults [94]. In the study by van der horst *et al.*, the intervention group was directed to complete 25 sessions (1-2 per week) of NHE over a 13-week period [84]. They found that incorporating the NHE protocol into regular amateur training significantly lowers the incidence of hamstring injuries [84]. Age, gender, level of participation, sport-specific needs, and a history of prior hamstring injuries all have a significant impact on training volume.

6. Role of Nordic hamstring exercises in preventing hamstring injuries

The studies invariably demonstrate that a modifiable risk factor in reducing hamstring strains in soccer players is a decrease in hamstring muscle strength. As a result, incorporating Nordic hamstring exercises or Nordic curls into an injury prevention program has proven to be very effective. Keeping in mind the inexpensive nature of these exercises, which do not require any special equipment or more human intervention to perform, they have been successfully adopted by many elite soccer clubs around the world. Al Attar *et al.* performed a meta-analysis of meta-analysis in 2019 to examine the injury prevention program for soccer that is provided by the Federation International de Football Association (FIFA) and includes NHE. They discovered a reduction of 34% for all injuries (RR = 0.66 [0.60-0.73]), and a reduction of 29% for all lower limb injuries (RR = 0.71 [0.63-0.81]) [95].

6.1 How prevalent is NHE awareness and implementation as an injury prevention program among elite and semi-elite soccer players?

A survey was conducted by Al Attar *et al.* in 2012 to determine the awareness, implementation, and opinion of the NHE's effectiveness in reducing hamstring injuries among professional and semi-professional soccer players and coaches [96]. 812 players and coaches (88.3% male, 11.7% female) participated in this survey. 395 of them (48.6%) were aware of the NHE, and 355(43.7%) implemented it in their practice [96]. This survey found that those who were using NHE believed it to be effective in reducing hamstring injuries, but more research and education are required to inculcate soccer players and coaches about the importance of the NHE and its ability to prevent hamstring injuries as well as to promote and use it internationally [96]. This survey showed that while the soccer players and coaches who used the NHE in this study had generally positive attitudes and highly

regarded its effectiveness, their opinions on how well it prevented hamstring injuries varied [96]. More than half of the participants were not only unaware of NHE's potential to lower hamstring injuries, but also did not use it in their training sessions as part of an injury prevention program.

6.2 Adherence to Nordic hamstring curls is an important factor in reducing hamstring injuries in soccer players

Injury prevention Programs must be followed consistently to be effective, but the most difficult challenge for soccer players is to adhere to NHE. The exercise's eccentric nature places tremendous stress on the muscle fibers, which can cause significant pain and fatigue for several days after the session. In a Systematic Review and Meta-Analyses, Ripley *et al*. investigated the effects of intervention compliance, consistency, and modality on preventing hamstring injuries in athletes [97]. They discovered that compliance of more than 50.1% and consistent performance with < 3 weeks/session had a beneficial influence on HSI incidence [97]. This study additionally found that a compliance rate of > 75.1% increased the preventive affect by 139%, indicating the necessity for practitioners to adopt interventions that may result in a compliance rate of > 75.1% [97]. They further stated that training compliance correlates with intervention effectiveness, with more compliance resulting into higher effectiveness [97]. Due to its eccentric nature, NHE primarily activates these fibers and, if performed correctly and consistently with adherence to a well-designed program, can reduce the risk of these problems in soccer players.

7. Conclusion

There is enormous evidence that NHE are very effective in reducing the rate of hamstring injuries in soccer players. Since weak hamstring muscle strength is a risk factor that can be modified and contributes to the development of hamstring strains, injury prevention programs that focus on hamstring strengthening have been shown to be effective, especially for strains that occur at the distal part of the biceps femoris.

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