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The effects of a training based on Nordic Hamstring and sprints exercises on measures of physical fitness and hamstring injury prevention in U19 male soccer players

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Abstract

This study analyzed the effects of a training program based on Nordic Hamstring and sprint exercises on physical performance and hamstring injuries in young male soccer players. Forty-nine U19 players were randomly assigned to a control (CG; n = 26) or experimental group (EG; n = 23). Linear sprint and with change of direction (COD) were assessed before and after a 14-week training period. Hamstring injuries that occurred throughout the intervention period were collected. Between-groups analysis revealed differences in linear sprint performance (p = 0.012-0.001) in favor of the EG. Pre-to-post performance increased significantly in the EG for 20 m (effect size [ES] = -0.56) and 30 m (ES = -0.62) sprints, but a significant reduction in some COD parameters was observed (ES = 0.45-0.57). In CG, only a significant reduction in COD with dominant leg performance was found (ES = 0.63). Significant differences in injury burden in favor of the EG was reported such as (27.87 [CG] vs 3.82 [EG] absence days/1,000 hours of exposure, rate ratio = 7.30, 95% CI 3.34-15.99). While injury incidence was not different between the EG and CG. These findings suggest that the training program implemented can improve sprint performance and reduce injury burden.

Keywords: hamstring; injury prevalence; velocity; football; performance.

Introduction

Soccer is a highly demanding team sport which requires execution of repetitive high-intensity actions (e.g., jumps, accelerations, changes of direction and sprints) to obtain adequate on-field performance (Chaouachi et al., 2014; Marcote-Pequeño et al., 2019; Trecroci, Duca, et al., 2020). These high demands are associated with muscle injuries (Raya-González, Suárez-Arrones, et al., 2020), in particular to the hamstring muscle complex (Raya-González, de Ste Croix, et al., 2020). This is due to the architecture of this complex muscle group and their implication in high intensity actions (Beato, Drust, et al., 2021). Considering injuries may negatively affect performance, club finances, and player health in soccer, it is essential that appropriate prevention strategies be implemented (Beato, Maroto-Izquierdo, et al., 2021). The purpose of improving physical fitness with soccer players is two-fold: to perform better during competitions (Castillo et al., 2020), and to reduce the risk of suffering injuries during training sessions and matches (Gabbett & Domrow, 2007). The implementation of some specific training programs is a key strategy for developing both of these aims simultaneously.

Resistance training programs have shown to be among the most effective methods to improve performance of high-intensity actions in soccer players (Silva et al., 2015); but the majority of resistance training programs are based on expensive equipment such as traditional (de Hoyo et al., 2016) or flywheel devices (Raya-González et al., 2021) making it difficult to implement at the amateur or youth level. Thus, practitioners have found time-efficient alternatives that could be applied without incurring additional costs, such as the Nordic Hamstring exercise (NHE). The NHE is an exercise where the athlete attempts to resist a forward-falling motion using their hamstrings to maximize loading in the eccentric phase without using additional equipment (Mjølsnes et al., 2004). Previous research has shown promising sport performance and injury prevention outcomes after the application of resistance training programs based on the NHE (Bautista et al., 2021; van Dyk et al., 2019). Specifically, a recent meta-analysis conducted by Bautista et al. (2021) showed that the NHE has a positive effect on eccentric strength of knee flexors (standardized change of mean difference: 0.83 [0.55-1.12]) and sprint performance (-0.04 sec [-0.08, -0.01]) in team sport players. Moreover, van Dyk et al. (2019) meta-analysis reported a positive effect of including the NHE exercise in injury prevention programs compared with controls on hamstring injuries, showing a reduction in the overall injury risk ratio of 0.49 (95% CI 0.32 to 0.74). However, Mendez-Villanueva et al. (2016)

reported that the NHE influenced only the short head of the biceps femoris and the semitendinosus muscle, so other exercises are necessary to complement training programs focused on the hamstring musculature (Oakley et al., 2018; Suarez-Arrones et al., 2021). Such training would allow soccer players to repeat several high-intensity actions, such as sprints, during matches with reduced chance of injury (Trecroci, Porcelli, et al., 2020).

Since sprinting is the predominant mechanism in hamstring injuries (Askling et al., 2007), one of the most common actions before a goal in professional soccer (Faude et al., 2012), and the only exercise that induces a sprint-specific hamstring muscles activation (Tillaar et al., 2017), it seems pertinent to include sprinting exercises in the preventive training programs (Beato, Drust, et al., 2021). Additionally, it has been observed that sprint training with moderate volume with or without change of direction does not induce neuromuscular or physiological changes 72 h post-exercise (Grazioli et al., 2020), favoring its inclusion in a specific soccer context. In this sense, Mendiguchia et al. (2020) applied a sprint training protocol with elite soccer players for 7 weeks obtaining improvements in sprint time over 5 and 20 m (effect size [from -0.77 to -0.58]). Similarly, Rey et al. (2017) increased the sprint performance over 10 and 30 m ($p < 0.001$) in amateur soccer players after a 6-week sprint training program. Finally, and related to youth soccer players, Venturelli et al., (2008) observed significant improvements in their sprint capacity over 20 m after 12 weeks of sprinting training. Although beneficial effects of this training methodology have been reported, previous research about its effects on injury prevention in soccer players are scarce. In this regard, Mendiguchia et al., (2019) suggested that an adequate and regular exposure to sprinting can reduce the likelihood of hamstring injuries; this is supported by research reporting positive changes in some muscle variables (e.g., biceps femoris' architecture) related to hamstring injury risk after sprint training programs (Mendiguchia et al., 2020). Additionally, soccer players that are prepared during training to support greater volumes of sprint distances in training and matches, can benefit from a protective effect against injury risk (Malone et al., 2018). However, to date no studies have analyzed the effect of this training on injury incidence so future studies on this topic are warranted.

Despite the promising evidence observed after the application of isolated NHE and sprint training programs, no investigations have studied their combined effects on physical performance and injury incidence and burden in soccer players. Therefore, the aim of this study was to analyze the effects of a training program based on NHE and sprint training on physical performance and hamstring injuries in U19 male soccer players. Based on previous studies (Mendiguchia et al., 2020; Rey et al., 2017), we hypothesize that this program would improve performance while reducing the incidence and burden of injuries in young soccer players.

Method

Experimental design

A randomized-controlled trial design was applied to analyze the effects of a combined NHE and sprint training program on selected measures of physical fitness and hamstring injury incidence and burden in U19 male soccer players. Before and after 14 weeks of training, linear sprint (i.e., over 10, 20 and 30 m distances) and change of direction (i.e., over 20 m distance with one change of direction) tests were carried out. In addition, hamstring injuries incidence and burden were registered. All tests were carried out in the afternoon (6–8 pm) on an artificial grass field where the team performed their usual training sessions (17–22º C, 60–70% humidity) and were supervised by the same strength and conditioning specialist. Likewise, players were instructed to take their last meal, not to drink any caffeinated beverages or to perform intense physical exercise 3 hours before the beginning of the tests.

Participants

Sixty-seven soccer players (age: 17.8 ± 0.8 years, height: 174.1 ± 0.5 cm, body mass: 67.8 ± 7.7 kg, body mass index: 22.3 ± 1.92 $kg \cdot m^{-2}$) voluntarily participated in the study. *A priori* power analysis with a type I error rate of 0.05 (alpha = 5%) and 90% statistical power (Beta) was computed. The analysis indicated that overall, 14 participants were sufficient to observe significant effects (Cohen's d = 0.90) for sprint time over 30 m. All participants played at the same soccer academy over the last 2 years. Their usual program consists of 3 training sessions (i.e., 50% technical- tactical drills, 40% small-sided and simulated games, and 10% injury-prevention drills) and a match on the weekend. Players were included in the study if they participated in at least 80% of training sessions (i.e., soccer and strength sessions) during the 14-week period and were not injured 2 months prior to the investigation commencing. Goalkeepers were excluded from the statistical analysis due to their special role in soccer practice. Participants were allocated to either the control group (CG, n = 34) or to the experimental group (EG, n = 27). Finally, 49 soccer players (i.e., CG, n = 26 and EG, n = 23) were included in the further analysis, since nine participants did not attend 80% of training and three of them were injured during the experimental period and did not complete the assessment sessions (Figure 1). All soccer players and their legal guardians were informed of the procedures, potential risks and benefits of the study and the legal guardians signed a written informed consent. The study was conducted according to the Declaration of Helsinki (2013), and the protocol was fully approved by ethics committee of ***for blinding purpose*** before recruitment.

Figure 1 near here, please

Procedures

During the 14-week intervention period, players performed their regular weekly in-season routine (Table 1), with the EG including the NHE and sprint training program once a week. This session was performed in the central session of each microcycle, at least 48 hours prior to a competitive game. Players' physical performances were assessed in a single testing session in the following order to minimize the accumulation of fatigue: 30 m linear sprint (SPR30) test and change of direction (COD) sprint tests with the dominant leg (CODd) or non-dominant leg (CODnd) performing the turn on the outside (Raya-González et al., 2021). For COD sprint, the dominant leg was considered as the one in which each player obtained the best result (Raya-González, Bishop, et al., 2020). All participants were already familiarized with all testing protocols due to the assessment routines at the club. Prior to the physical assessment, players undertook a 17-min standardized warm-up, consisting of 3 min of slow jogging, followed by 7 min of strolling locomotion and finishing with 7 min of progressive sprints and accelerations.

Table 1 near here, please

30 m linear sprint test. Soccer players completed two maximal 30 m linear sprints, with split times on 10 m (SPR10), 20 m (SPR20) and SPR30, and interspersed with a 120 s passive standing rest. Sprint performance was assessed using four pairs of photoelectric cells (Polifermo Light Radio, Microgate™, Bolzano, Italy) placed at 0, 10, 20 and 30 m. Players started each sprint 0.5 m before the first timing gate and initiated the sprint upon their own volition. The fastest time (in seconds) was considered for the subsequent analysis. The ICCs and the CVs for the sprint tests were 0.82 (0.54–0.91) and 4.7% (3.9–5.9) for SPR10, 0.77 (0.42–0.88) and 2.8% (2.4–3.6) for SPR20, and 0.85 (0.62–0.92) and 2.0% (1.7–2.5) for SPR30.

Change of direction sprint test. Participants were evaluated over a 20-m COD sprint test using two pairs of photoelectric cells (Polifermo Light Radio, Microgate™, Bolzano, Italy). Four maximum 10 + 10-m sprints with a COD turn of 90º (i.e., two trials of CODd and two trials of CODnd) were performed allowing two min of passive recovery between trials. Players started each sprint 0.5 m before the first timing gate and upon their own volition. The best time (in seconds) obtained with each leg was identified and was selected for the subsequent analysis, which was compared with the SPR20 to estimate the percentage mean of speed loss when executing the CODd or CODnd through the formula [DEC-CODd = (CODd – SPR20)/ SPR20) x 100; DEC-CODnd = (CODnd – SPR20)/SPR20) x 100] (Raya-González et al., 2021). The ICCs and the CVs for the COD test were 0.85 (0.62–0.92) and 1.8% (1.5–2.3) for CODd, 0.81 (0.51–0.90) and 1.9% (1.6–2.4) for CODnd.

Injuries: definitions and data collection

This study was conducted according to the key guidelines provided by the Union of European Football Associations (UEFA) for epidemiological research (Hägglund et al., 2005). In this regard, injury was defined as “an injury that occurred during a scheduled training session or match that caused absence from the next training session or match” (Hägglund et al., 2005) while burden was defined as “the numbers of days lost per 1,000 hours of exposure” (Bahr et al., 2017). On the other hand, the criteria used to consider the exposure was the following: “the time (in hours), both in training and match play, during which the player is in a position to suffer an injury, and incidence refers to the number of injuries sustained during practice, both in training and competition, for every 1,000 hours of exposure” (van Mechelen et al., 1992). Match play exposure was calculated when playing against teams from different clubs, and training sessions were considered those in which a coach directed physical activity carried out with the team. A player was considered fully recovered after a hamstring injury when he was given clearance by the medical staff to participate fully in team training and match play (Raya-González, de Ste Croix, et al., 2020).

Information relative to hamstring injuries was recorded by the strength and conditioning specialist of each team and supervised by the head fitness coach. The club's medical staff diagnosed all hamstring injuries and followed the evolution during the rehabilitation process (Raya-González, de Ste Croix, et al., 2020). Hamstring injuries were registered on a computerized standard report based on the instruction manuals created for the UEFA studies (Hägglund et al., 2005) and information about absence days, type of injury or moment of injury (i.e., training or match) were recorded. Attending to exposure, this time was registered daily individually, in hours, in training and matches (friendly and official) (Raya-González, de Ste Croix, et al., 2020).

Training program

Soccer players belonging to the EG underwent a 14-week training program based on NHE and sprint exercises. The experimental sessions (15–20 min) were conducted immediately after regular soccer training session (75–90 min), supervised by the strength and conditioning staff of the team, providing adequate feedback and cues for exercise and drill execution. The training program was applied one time per week at least 48 hours prior to the official match. A progressive overload adapted to each drill was applied during the intervention (Table 2). Players were familiarized with the training program during the first phase of the competitive season.

Table 2 near here, please

Statistical analysis

Data are presented as mean ± standard deviations (SD). To prove the normality of data distribution and the homogeneity of variances, the Kolmogorov-Smirnov and Levene tests were conducted. Since all analyzed variables had a normal distribution, parametric techniques were applied. Between-group differences at baseline were tested using independent *t*-tests. An analysis of covariance (ANCOVA) was applied to detect the training effects, with baseline measurements entered as covariates. Furthermore, a paired-samples t-test was used to evaluate within-group pre-to-post differences. To examine practical significance, Cohen's effect size (ES) was calculated (Cohen, 1988), and the obtained results were interpreted as follow: trivial < 0.20, small ($0.20 \leq d \leq 0.49$), medium ($0.50 \leq d \leq 0.79$), and large ($d \geq 0.80$). These data were analyzed using the Statistical

Package for Social Sciences (SPSS 25.0, SPSS Inc., Chicago, IL, USA), and the statistical significance was set at $p < 0.05$.

Injury incidence and burden are presented as the number of injuries/1,000 hours of exposure (van Mechelen et al., 1992) and the number of absence days/1,000 hours of exposure (Bahr et al., 2017), respectively, each with 95% confidence intervals (CI). The incidence and burden of injuries were compared for group (i.e., EG and CG) by calculating rate ratios (RR) with a 95% CI and using the Z-test (Kirkwood & Sterne, 2003). These data were analyzed using Microsoft Excel 2011 software (Microsoft, Redmond, WA, USA) and GraphPad Prism v.6.0c (GraphPad Software, La Jolla, CA, USA), and the level of significance was set at $p < 0.05$.

Results

Measures of physical fitness

The changes in physical fitness from pre-to-post intervention for the CG and EG are displayed in Table 3. There were no baseline differences between-groups in any dependent variable. The ANCOVA model revealed between-groups differences in SPR10, SPR20 and SPR30 ($F = 6.48$-13.79; $p = 0.012$-0.001) in favor of the EG, as well as higher decrements in DEC-CODd and DEC-CODnd ($F = 4.62$-5.47; $p = 0.037$-0.024). Pre-to-post training values increased in the EG in SPR20 ($p = 0.016$; ES = -0.56, moderate) and SPR30 ($p = 0.008$; ES = -0.62, moderate), but decreased in DEC-CODd ($p = 0.049$; ES = 0.45, small) and DEC-CODnd ($p = 0.014$; ES = 0.57, moderate). In the CG, pre-to-post performance worsened in CODd ($p = 0.004$; ES = 0.63, moderate).

Table 3 near here, please

Injury incidence and burden

Differences in the injury profile are shown in Figure 2. During the experimental period, Participants in CG suffered 3 hamstring injuries (59 absence days) while EC players suffered 1 hamstring injury (7 days). No significant differences between-groups in incidence was observed (1.42 [CG] vs 0.55 [EG] hamstring injuries/1,000 hours of exposure, RR = 2.60, 95% CI 0.27-24.99, $p = 0.410$), while significant differences in burden were reported (27.87 [CG] vs 3.82 [EG] absence days/1,000 hours of exposure, RR = 7.30, 95% CI 3.34-15.99, $p < 0.001$).

Figure 2 near here, please###

Discussion

The aims of this study were to analyze the effects of a training program based on NHE and sprint exercises on physical performance and injury incidence and burden in U19 soccer players. This is the first investigation to study changes in physical performance and injury incidence and burden through the combination of NHE and sprint exercises in soccer players. The main results were that EG improved sprint capacity (i.e., 20 and 30 m) and reduced their burden compared to the CG. However, EG players did not improve their performance in COD parameters in comparison to CG. These findings partially support our hypothesis, since improvements in COD and a reduction in hamstring injury incidence were not observed.

The applied training program in this study (NHE + sprint exercises) mainly focused on hamstring muscles, so attending to the training specificity principle (Baechle & Earle, 2007), it seems realistic to expect significant improvements observed in the players' 20 and 30 m sprint performance in the EG. These results seem to support those previously reported, although in isolation, since authors such as (Suarez-Arrones et al., 2019; Vicens-Bordas et al., 2020) reported improvements in sprint performance after the application of a training program based on NHE, while (Mendiguchia et al., 2020; Rey et al., 2017) obtained similar results through programming of sprint exercises. However, the improvements obtained in the present study in 10 m sprint performance were not significant, possibly due to the need to train acceleration capacity (i.e., first 10 m in a sprint) through different resistance training methods (Alcaraz et al., 2018). Nevertheless, the between-groups comparison highlights significant improvements for all linear sprint distances in favor of the EG. Therefore, the inclusion of this training program in young soccer players seems to effectively enhance sprint performance in a soccer specific context (Wing, 2018) because it does not interfere with regular soccer training and is applied in an ecological way (i.e., a weekly session and using simple material) (Raya-González et al., 2021). On the other hand, no significant improvements were obtained in COD performance in the EG, in fact, players in this group significantly reduced DEC-CODd and DEC-CODnd performance after 14 weeks of training. This could be related to the specificity of the training for linear sprints, while its transfer to COD performance could be limited (Nimphius et al., 2016). A further justification of this could be because soccer players need to apply high lateral forces on to the ground during COD (Schot et al., 1995), and NHE training used in this protocol does not apply such forces. Therefore, it seems necessary to include tasks that improve lateral forces and the braking action in the COD (Beato et al., 2018), either through developing force with flywheel devices (Raya-González et al., 2021) or through non-linear displacements focused on technique (Hader et al., 2015).

Previous research has proved the efficacy of NHE to reduce risk of suffering hamstring injuries in soccer players (al Attar et al., 2017; van der Horst et al., 2014). From a practical perspective, achieving a reduction in the number of injuries is essential to improve the long-term success of the team (Hägglund et al., 2013) and to reduce economic costs for the club (Gebert et al., 2018). In our study, a lower injury incidence in the EG was observed after the application of the NHE and sprint training program compared to the CG; however, these differences were not significant. Our findings may be explained by the duration of the observation or the sample size of the study, therefore future studies are needed to verify the findings reported in the current research. On the other hand, significant differences have been obtained in the burden, being lower in the EG, which is a positive aspect since this implies a lower impact of injuries on the performance and health of the players (Bahr et al., 2017). These between-groups differences could be because of how NHE and sprint exercises cause adaptation in the hamstring muscles' architecture (Cuthbert et al., 2020; Mendiguchia et al., 2020), specifically on biceps femoris, and the expected increase in strength level of this muscle complex (Seymore et al., 2017), variables which seem to favor less damage to the involved muscles after an injury incident (van Beijsterveldt et al., 2013). However, this is the first study to analyze the effects of a combined NHE + sprint training program on the soccer players' injury profile, so future studies on this topic are needed.

This study presents some limitations that should be considered by practitioners. First, it must be considered that it was applied in a soccer group with specific characteristics, therefore, these results should be taken with caution when applied with other teams, levels or in female soccer players. Secondly, this study was performed with a group of U19 players with limited strength experience, therefore the NHE and sprinting volume used in this study need to be adjusted in soccer players with higher strength training experience.

Lastly, a longer follow-up time would have offered a better view of the impact of the training program on injury incidence in the EG which has been found non-significant in this study, therefore future research is needed to verify the findings reported in this study.

Conclusions

This study reported that the application of a training program based on NHE and sprint exercises is effective in improving sprint performance and reducing injury burden in U19 soccer players. This training program can be easily implemented in soccer because of its low frequency (one session a week) for the duration of 14 weeks. Meanwhile, this program leads to a reduction of some COD parameters, which should be considered by practitioners. On this specific point, the authors of this group suggest to the practitioners to add some specific COD exercises and strength training (e.g., flywheel training) focused on the improvement of braking action, which could be very beneficial for soccer players' performance.

Disclosure of interest

The authors report no conflict of interest.

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Table and figure captions

Figure 1. CONSORT diagram of participant's recruitment, allocation, follow-up and analysis. CG = control group; EG = experimental group.

Figure 2. Between-groups differences in incidence and burden.

CG = control group; EG = experimental group.

* Significant differences ($p < 0.001$).

Table 1. An in-season weekly program for the U-19 soccer teams.

Table 2. Nordic hamstring + sprint training program over 14 weeks.

Table 3. Physical performance before (baseline) and after (post-training) the 14-week intervention period in both groups.