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Effects of low volume of Nordic hamstring exercise training performed during the warm-up on sprint and change of direction performance in highly trained youth male soccer players

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Abstract

Background: While there is ample evidence on the effects of Nordic hamstring training (NHT) on physical fitness in youth athletes, less is known about the ef-fectiveness of different volumes of this type of training. Accordingly, this study aimed to examine the effects of 8 weeks of low-volume Nordic hamstring training (LNHT) performed during the warm-up, on sprints (5, 10, and 20-m) and change of direction (CoD) with (15-m CoD Ball) and without (15-m without Ball) the ball in young male soccer players in highly trained male youth soccer players.

Methods: Twenty-eight male youth soccer players, aged 13 to 14 years, were randomly assigned to LNHT (n= 14) or a control group (CON, n= 14). The eight-week NMT included low Nordic exercises with 3 sets of 4 repetitions. The CG performed a soccer-specific warm-up. Training was performed during the warm-up with similar training volumes between groups.

Pre-, and post-training, tests were conducted to assess sprint (5, 10, and 20-m) and change of direction (CoD) with (15-m CoD Ball) and without (15-m without Ball) the ball.
Results: Findings showed significant group-by-time interactions for all 5 ($F_{1,26}$=.77, P =.38, Pη2 =.029), 10 ($F_{1,26}$=2.7, P =.11, Pη2 =.095) and 20-m sprint ($F_{1,26}$=14.9, P =.001, Pη2 =.364) and CoD with ($F_{1,26}$=12.9, P =.001, Pη2 =.332) and without the ball ($F_{1,26}$=24.1, P =.001, Pη2 =.481) tests. There were significant pre-post changes for all tested variables (all P<0.005) in favor of LNHT but not CG.
Conclusions: In conclusion, LNHT was a mean tool for improving CoD speed and sprint performance. Due to the importance of CoD and short accelerations for overall competitive performance in soccer, our results suggest that young players should perform LNHT as part of their warm-up soccer training if the goal is to improve sprint and CoD performance.

Keywords: Eccentric exercise, football, young, neuromuscular adaptation, resistance training.

1. Introduction

Youth soccer players can also increase their speed and change-of-direction (CoD) performance by executing the Nordic hamstring exercise (HHE) in the preseason (Hammami et al., 2021, Amundsen et al., 2022, Van Dyk et al., 2018). However, the duration of 8 to 13 weeks and high training volumes (2–3 sessions per week, up to 30 repetitions per session) of these programs reduce the chance of their implementation (Fuller, 2019; Muntean et al., 2023).

The NHE was first introduced with 700 repetitions across 10 weeks, which resulted in better hamstring strength than the concentric group (hamstring curl). However, this high-volume exercise is probably the reason for high Delayed Onset Muscle Soreness (DOMS) and low compliance (Bahr et al., 2015). Research showed that high and low-volume protocols effectively increase strength and reduce injuries (Van Dyk et al., 2018; Rosu et al., 2024). Three sets of three repetitions, three times per week is considered the lowest Nordic hamstring protocol (Cuthbert et al., 2020). However, a program of shorter duration and with lower training volume can facilitate implementation in the busy training and match schedules of elite teams. Still, it may attenuate the effects as there is a dose-response relationship between strength gain and training volume (Ralston et al., 2017).

Evidence suggests that the lowest dose of NHE required to enhance athletes' performance is yet to be found (Empuaji et al., 2023, Cuthbert et al., 2020). The low eccentric nature of the NHE provides a stimulus, whereby the myosin heads are already attached to actin and forced to detach by the lengthening of the cross bridges, incurring muscle damage (Franchi et al., 2017). Hence, regarding the maximal eccentric effort, a high level of NHT volume may influence compliance rates (Cuthbert et al., 2020).

Furthermore, the hamstrings work eccentrically to decelerate the forward movement of the foot and the leg in the late forward swing phase of the running cycle (Chaabene et al., 2020, Mjølsnes et al., 2004). In addition, when sprinting and changing direction tasks, the deceleration phase shortens, requiring a higher eccentric activation of the hamstrings to compensate for the forward momentum, and the forces that influence the hamstrings may then cause tearing in the muscle-tendon unit (Roche et al., 2018). The low volume during the NHT exercise will subsequently facilitate a more efficient transfer of torques through the kinetic chain during sprint CoD tasks (Chaabene et al., 2018, de Hoyo et al., 2015). Further, the intervention outlined by Mjølsnes et al. (2004) includes high volumes, with participants performing 700 NHE across 10 weeks, and the combi-nation of high volume and high occurrence of DOMS could be one of the reasons why the same 10-week NHE intervention given to 50 UEFA Champions League clubs has presented a compliance rate as low as 16.7% (Bahr et al., 2015). Although a minimum dosage has yet to be identified, it is important to compare how various volumes that have been used during interventions affect the hamstrings, to improve sprint and CoD performance in youth soccer players. NHE is widely used in the soccer warm-up, likely due to its practicality as a field-based exercise that requires no equipment. However, this was described as ineffective in some cases due to the infrequency of use and lack of motivation from the coaches (Cuthbert et al., 2020).

Therefore, this study aimed to identify the effects of 8-weeks of a low-volume Nordic hamstring training program on linear sprint (5, 10, and 20 m) and CoD performance without the ball (CoDWB) and with the ball (CoDB) in youth soccer players. In previous studies (Cuthbert et al., 2020, Franchi et al., 2017, Van Dyk et al., 2018), we hypothesized that training-induced adaptation is more pronounced when performing a low volume of NHE compared to a control group of youth soccer players.

2. Materials and Methods

2.1. Study Design

2.1.1. Participants

Before the start of the study, participants were given a letter that included written information about the experimental procedure with a parental consent request. Parental and subject informed consent was obtained after a thorough explanation of the objectives, scope, procedures, risks, and benefits of the study which was conducted according to the latest version of the Declaration of Helsinki. Before the experimental testing, the protocol was fully approved by the Local Ethics Committee of the National Centre of Medicine and Science of Sports of Tunis (CNMSS-LR09SEP01) before the commencement of the procedure.

The sample size estimation was computed using G*Power software (version 3.1.9.6) (De Bernardo et al., 2022) with a type I error rate of 0.05 and 80% statistical power. The estimated effect size of Cohen's f = 0.40 is based on a similar study from Chaabene et al. (2018) on the effects of NHE on physical fitness in youth athletes, over a similar period. The analysis indicated that 14 participants per group would represent a sufficient sample. Thus, 28 male youth soccer players, aged 13-14 years took part in this study. Participants' characteristics are shown in Table 1 (see results section). Participants were randomly assigned to one of one experimental group (LNHT, n=14) or a control group (CON, n=14). Figure 1 outlines the recruitment process and information on the interventions received.

All participating players came from families of similar socio-economic backgrounds and had identical daily school schedules. Inclusion and exclusion criteria were defined a priori. Inclusion criteria comprised 100% adherence for both groups in terms of exercise session attendance and not

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having a history of musculoskeletal, neurological, or orthopedic disorders that might have impaired their ability to execute the prescribed tasks/tests. All players were uninjured during the study period. Exclusion criteria involved taking any dietary supplements during the study time and participating in additional non-team training.

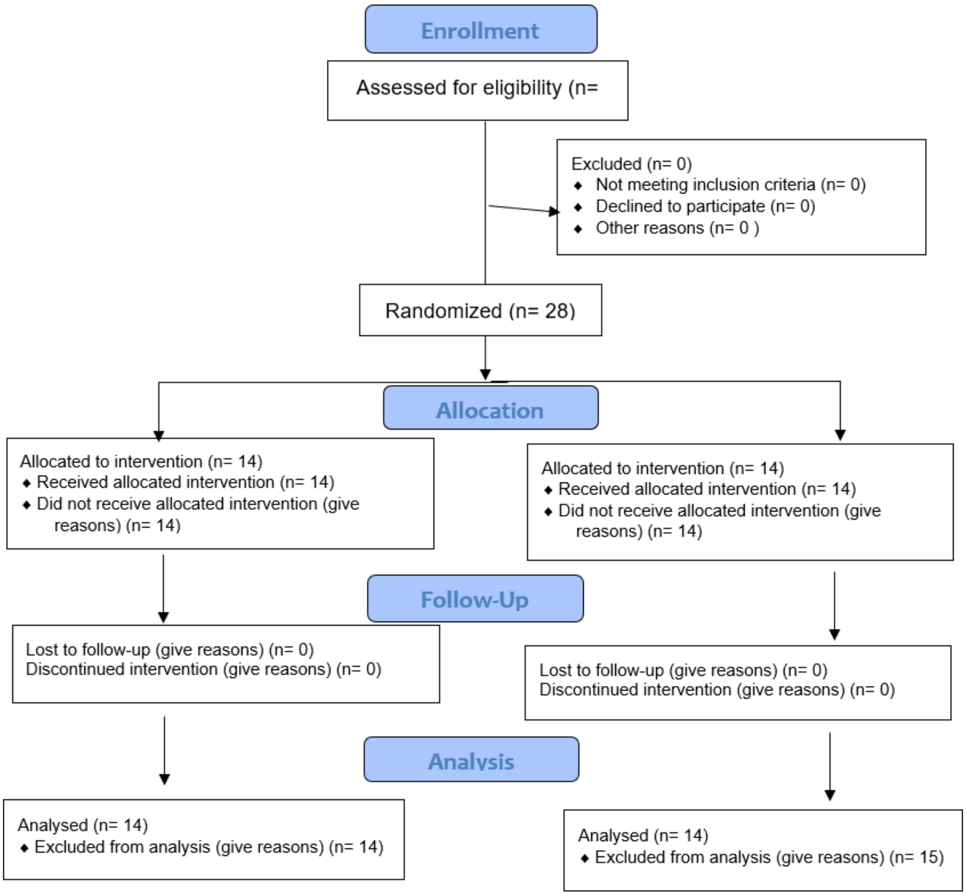


Figure 1. CONSORT Flow Diagram

2.2. Procedures

Field tests were carried out on third-generation synthetic soccer turf, at the same time of day (between 5 p.m. and 7 p.m.) and under similar environmental conditions (temperature: 19–23 °C, humidity: 50–60%, wind speed: ≤2 m/s). All participants were encouraged to perform at maximum effort throughout the test. All procedures were performed during the second half of the competitive soccer season (February and March 2021). Before the experiment, all players participated in two orientation sessions to familiarize themselves with the experimental procedures to minimize the learning effect of testing. All participants had the same daily school and soccer training team-training schedules. They all had been playing soccer regularly three times a week (i.e., ~90 minutes per session), with a match played during the weekend, for more than 3 years. Participants undertook a sprint, and COD tests before and after the eight-week NHE training programme. Procedures followed a general warm-up that consisted of running, calisthenics, and stretching. Each player's body height and mass were collected respectively. The sum of skinfolds (biceps, triceps, sub-scapular, and supra-iliac) was also assessed. Body fat measurements were conducted according to Deurenberg et al. (1990) and the maturity offset was estimated according to Moore et al. (2015).

2.2.1. Linear sprint tests

Running speed was evaluated using 5-m and 20-m sprint tests. Participants sprinted as fast as possible from a stationary standing start position located 20 cm behind the first timing gate. The start stance was consistent for each participant. Time was automatically recorded using photocell gates (Brower Timing Systems, Salt Lake City, Utah, USA, 195 accuracy of 0.01 s) placed 0.4-m above the ground. Participants performed two trials with at least two minutes of rest between each one. The run with the best of 5, 10, and 20-m time was selected for analysis.

2.2.2. Change-of-direction tests

For the 15 m-CoD test, players departed running 3 m behind the initial set of gates. Players performed 3 m of straight running, entered a 3-m slalom section marked by three aligned sticks (1.6 m of height) placed 1.5 m apart, and then cleared a 0.5-m hurdle placed 2. m beyond the third stick. Finally, players ran 7 m to break the second set of photocell gates, which stopped the timer (Mujika et al., 2009). Excellent test-retest reliability has been reported for this COD test, with an ICC value of 0.93 (0.86, 0.97) (Sariati et al., 2021).

2.2.3. Skinfolds, body fat measurements, and maturity offset

Anthropometric measurements were carried out indoors and in the morning (between 9 a.m. and 10 a.m.) and under similar environmental conditions (temperature: 19–23 °C, humidity: 50–60%). During assessment, participants were asked to be naked with panties and with an empty stomach. Athletes' body height and mass were collected using a wall-mounted stadiometer (Florham Park, NJ) and an electronic scale (Baty International, West Sussex, England), respectively. The sum of skinfolds was assessed using Harpenden's skinfold calipers. Body measurements were conducted according to Deurenberg et al. (1990) who reported similar prediction errors between adults and adolescents. Afterward, biological maturity was evaluated non-invasively using chronological age and body height as input parameters for a regression equation to subsequently predict the maturity offset (Moore et al., 2015). This assessment is a non-invasive and practical method of predicting years from peak height velocity (PHV) as a measure of maturity offset using height and age as variables. Thus, the following equation was used: PHV = 27.999994 + [0.0036124 3 age 3 height] (Moore et al. (2015).

2.3. Training programme

The LNHT exercise program intervention period lasted 8 weeks. The players were randomly allocated into one experimental group which undertook a low volume of NHE training

(LNHT) in addition to their usual soccer training. The training program was based on a pooled analysis of previous NHT studies (Cuthbert et al., 2020, Drury et al., 2020).

The LNHT was undertaken for eight weeks with two weekly sessions, each lasting 15 minutes. LNHT was implemented in the warm-up of a soccer-specific training session and included Nordic exercises with 3 sets and 4 repetitions each and a rest of 60–120 s between sets and exercises (Drury et al., 2020). LNHT exercises were conducted on the soccer pitch.

The CG performed 15 minutes of ball-passing drills as part of the warm-up. The subsequent soccer-specific training sessions were identical for all 2 groups. Accordingly, training volume (i.e., total training exposure) was similar between groups. Qualified coaches and experienced sports scientists supervised the intervention groups. For the performance of the LNHT, participants were instructed to kneel on the ground with their ankles secured in place by a partner who orientated their weight downwards to prevent any movement of the joint. The participant who was executing the NHT was positioned such that the ankles were perpendicular to the lower leg. To execute the exercise, the participant gradually lowered the upper body, attempting to resist the downward movement by contracting the hamstring and gluteal muscles and aligning the trunk and hips in a neutral position throughout the performance. The arms were held around their chest and flexed at the elbow joints such that the palms of the hands were facing the shoulder joints. Participants were allowed to use their arms in the final stages of the movement to buffer the fall as their upper body approached the ground. From there, they ascended back to the start position using their arms before repeating to complete the assigned number of repetitions. Following completion of this, the participant swapped roles with their partner to repeat the process. This facilitated an inter-set rest of at least one minute (Drury et al., 2021).

2.4. Statistical analyses

Data are presented as group mean values and standard deviations (SD). After data normality was confirmed using the Shapiro-Wilk test, a MANOVA was applied to detect baseline between-group differences. To examine any differences pre to post between NHT and Con groups, a 2 (time) way repeated measures ANOVA was employed with time (pre to post) as the subject's factor and group (NHT vs CON) as between-subject factors. Where any significant differences were found, Bonferroni post-hoc pairwise comparisons were used to determine where the difference lay. Partial eta squared (Pη2) was used as a measure of effect size. Within-group Cohen's d effect sizes (Pη2) were also calculated using the equation: Pη2 = (mean post − mean pre-) / mean SD. ES can be classified as small ($0.00 < d < 0.49$), moderate ($0.50 \leq d < 0.80$), and large ($d > 0.80$) (Hopkins, 2009). The IBM Statistical Package for Social Sciences (SPSS, version 28, IBM Corp, Armonk, NY, USA) was used for all analyses.

3. Results

All players from the intervention groups completed the study according to the prescribed protocol. Participants attended all training sessions, and no training- or test-related injuries were reported. Adherence rate was 100% across all groups and none reported any training- or test-related injury. No significant differences in anthropometric characteristics were found between the control and intervention groups (Table 1).

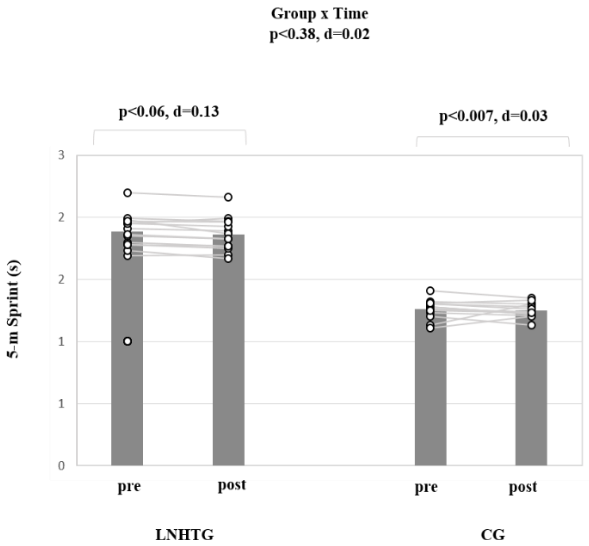
Table 1. Anthropometric characteristics (Mean±SD) per groups at baseline.

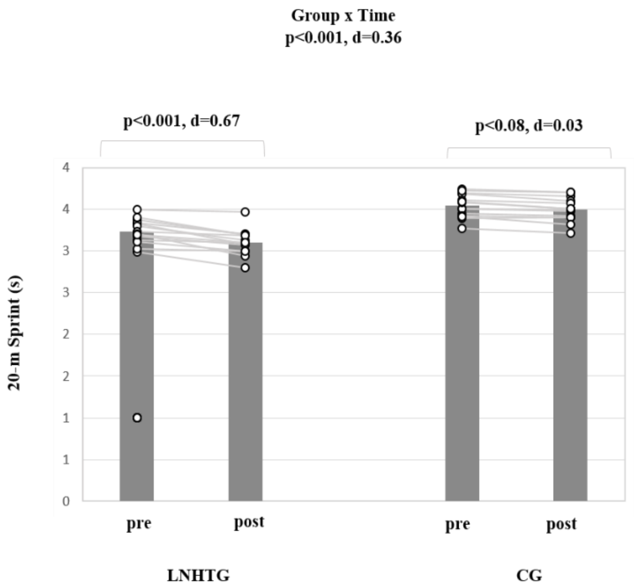
Variables	LNHT (n=14)	CON (n=14)	*p*-value
Age (y)	13.7 (.31)	13.6 (.34)	.450
Height (cm)	160.4 (8.8)	155.5 (7.8)	.138
BM (kg)	49.9 (8.9)	45.3 (6.2)	.121
BF (°/°)	8.7 (4.2)	9.7 5.9	.32
MO (y)	-2.31 (0.65)	-2.20 (2.6)	.78
APHV (y)	13.6 (.41)	13.5 (.46)	.302

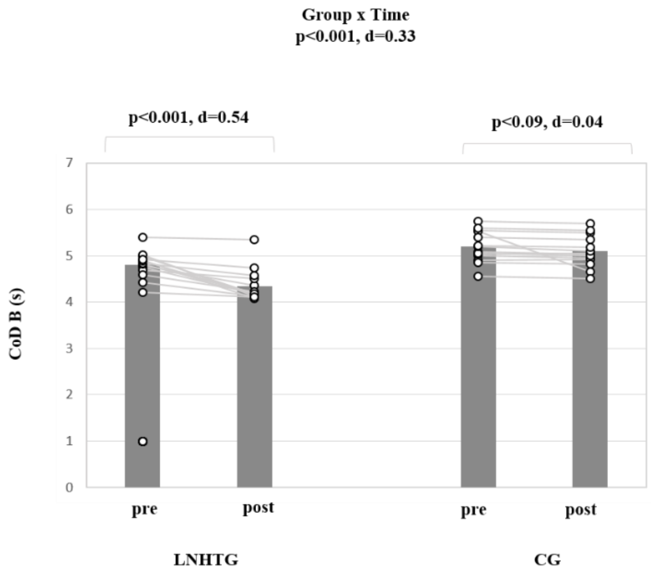
Note: Table presented as mean±standard deviation. LNHT: low volume of the nordic hamstring training group; BM: body mass; BF: body fat; MO: maturity offset; APHV: age at peak height velocity.

Linear sprint time

For 5m sprint time there was no significant main effect for time (F1,26=3.9, P =.06, Pη2 =.133) or time x group interaction (F1,26=.77, P =.38, Pη2 =.029) (Figure 2). There was however a significant main effect for the group (F1,26=19.1, P =.001, Pη2 =.423). Bonferroni pairwise post-hoc comparisons indicated that the LNHT group had a significantly quicker 5m sprint time (1.15 ± .06) compared to the CON group (1.25 ± .06).




Group x Time
p<0.001, d=0.36
p<0.001, d=0.67
p<0.08, d=0.03
20-m Sprint (s)
4
4
3
3
2
2
1
1
0
pre
post
pre
post
LNHTG
CG


Group x Time
p<0.001, d=0.33
p<0.001, d=0.54
p<0.09, d=0.04
CoD B (s)
7
6
5
4
3
2
1
0
pre
post
pre
post
LNHTG
CG

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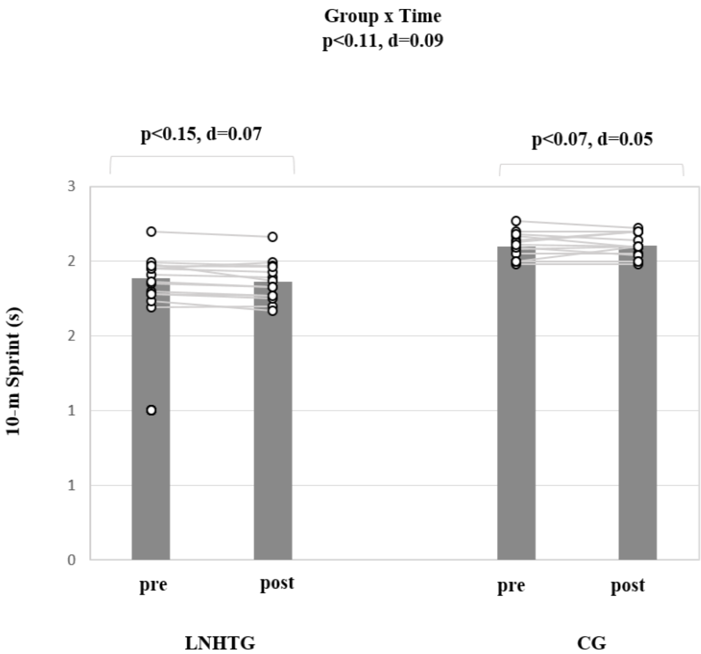

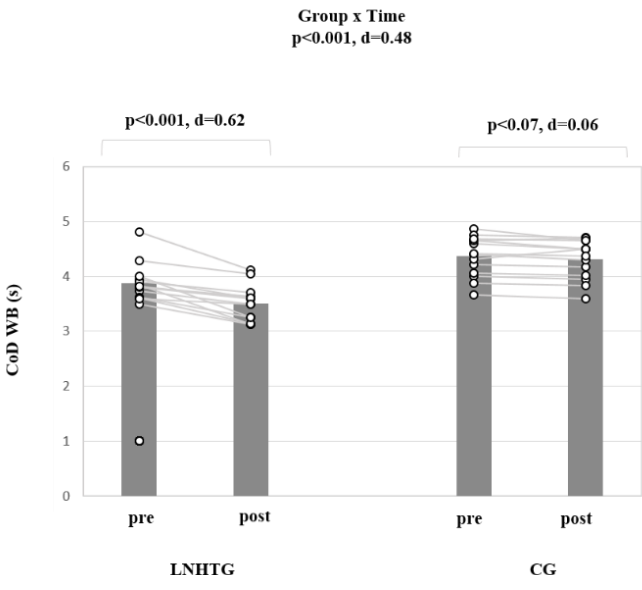

Figure 2. Individual and mean pre- and post-testing data of the 5-m sprint time by LNHT and CON; LNHT: low volume of the nordic hamsting training group; CON: control training group; Pη2: effect size.

Similar findings were demonstrated for 10m sprint time where there was no significant main effect for time (F1,26=2.2, P =.15, Pη2 =.077) or time x group interaction (F1,26=2.7, P =.11, Pη2 =.095). There was however a significant main effect for the group (F1,26=29.6, P =.001, Pη2 =.533). Bonferroni pairwise post-hoc comparisons indicated that the LNHT group had a significantly quicker 5m sprint time (1.87 ± .05) compared to the CON group (2.1 ± .07).
For 20m sprint time, there was a significant main effect for time (F1,26=54.9, P =.001, Pη2 =.679) and group (F1,26=41.3, P =.001, Pη2 =.614). There was also a significant time x group interaction (F1,26=14.9, P =.001, Pη2 =.364). Bonferroni posthoc pairwise comparisons indicated that the LNHT group was significantly faster than CON at both pre and post (both P = .001) but that the magnitude of change was significantly greater for the LNHT group (Δ =.124) compared to the CON group (Δ =.041).

Table 2 Effects of different nordic hamstring training volumes (Low vs Con) on linear sprint time in youth soccer players.

Variable	Time	LNHT	CON	ANOVA Group	Time	Group×time
5 m (s)	**Pre**	1.17 (.05)	1.26 (.07)	.001	.06	.388
	Post	1.14 (.06)	1.25 (.05)			
10 m (s)	**Pre**	1.88 (.13)	2.1 (.08)	.001	.153	.111
	Post	1.86 (.13)	2.10 (.08)			
20 m (s)	**Pre**	3.23 (.14)	3.52 (.14)	.001	.001	.001
	Post	3.10 (.15)	3.51 (.14)			

Mean ± standard deviation. * Significant difference ($p < 0.001$); LNHT: low volume of the nordic hamstring training group.

Change of direction outcomes and skill index

For a change of direction without the ball, there was a significant main effect for time (F1,26=42.3, P =.001, Pη2 =.620) and group (F1,26=26.7, P =.001, Pη2 =.507). There was also a significant time x group interaction (F1,26=24.1, P =.001, Pη2 =.481). Bonferroni post-hoc pairwise comparisons indicated that the LNHT group had significantly faster change of direction times than CON at both pre and post (both P = .001) but that the magnitude of change was significantly greater for the LNHT group (Δ =.36) compared to the CON group (Δ =.006). A similar outcome was observed for a change of direction with the ball. There was a significant main effect for time (F1,26=31.5, P =.001, Pη2 =.548) and group (F1,26=4.5, P =.001, Pη2 =.492). There was also a significant time x group interaction (F1,26=12.9, P =.001, Pη2 =.332). Bonferroni post-hoc pairwise comparisons indicated that the LNHT group had significantly faster change of direction times than CON at both pre and post (both P = .001) but that the magnitude of change was significantly greater for the LNHT group (Δ =.45) compared to the CON group (Δ =.1).

Table 3. Effects of different nordic hamstrining volumes (High, Moderate and Low) on change-of-direction outcomes and Skill Index in youth soccer players.

Variable	Time	LNHT	CON	Group	Time	Group×time
		ANOVA				
CoDWB	Pre	3.87 (.33)	4.36 (.36)	.001	.001	.001
	Post	3.51 (.31)	4.31 (.35)			
CoDB	Pre	4.79 (.27)	5.19 (.33)	.001	.001	.001
	Post	4.34 (.34)	5.09 (.33)			

Mean ± standard deviation. * Significant difference ($p \leq 0.05$); LNHT: low volume of the nordic hamstring training group; CoDWB: change of direction test without the ball; CoDB: change-of-direction test with the ball.

Recognizing that APHV may have confounded the results data were also made for each dependent variable using APHV as a covariate. This did not change the outcomes of the results and APHV was not significant as a covariate in any of these analyses.

4. Discussion

The purpose of this study was to identify the effect of LNHT on changes in linear sprint and CoD performance in youth soccer players. The main finding was that the evidence-based low-volume prescription can produce large-to-very improvements in sprint and CoD performance over 8 weeks in comparison to a control group. Youth soccer players had to train for at least 8 weeks to improve their sprint and CoD performance. Our main finding is in line with previous studies that have compared different volumes of the NHE (Amundsen et al., 2022, Siddle et al., 2022, Suarez-Arrones et al., 2019).

Similar consistent improvement to linear sprint performance was observed, following the LNHT in youth soccer players. This finding aligns with the other studies that examined the effects of different volumes of eccentric training in a pediatric population (Amundsen et al., 2022, Siddle et al., 2022, Suarez-Arrones et al., 2019). Hammami et al. (2021) demonstrated that both 10- (0.73 %, ES= 0.07) and 30-m (5.74 %, ES: 0.79) sprint performance improved in both pre and post-pubertal groups compared with the control in youth handball players. Chaabene et al. (2020) obtained performance improvements in 5-, 10-, and 20-m sprint times (effect size = 0.68–0.82) after 8 weeks of NHE in young female European handball players. The hamstrings work eccentrically to decelerate the forward movement of the foot and the leg in the late forward swing phase of the running cycle (Chaabene et al., 2020, Mjølsnes et al., 2004). When sprinting, the deceleration phase shortens, requiring a higher eccentric activation of the hamstrings to compensate for the forward momentum, and the forces that influence the hamstrings may then cause tearing in the muscle-tendon unit (Roche et al., 2018). The adaptive processes obtained after eccentric training regimens may contribute to improved hamstring activation during the late swing phase, which prepares the muscles to exert an optimal hip extensor moment during ground contact. Furthermore, Hamstring muscle strength is a key contributor to sprinting with concurrent gains in speed identified post-LNHT interventions further supporting this association (Suarez-Arrones et al., 2019; Timmins et al., 2021). As such, the low volume stimulus adopted within the current study in addition to other factors such as the intervention duration and extraneous variables including match and training load (Mendiguchia et al., 2020) may have been sufficient to elicit sprint changes within this study population. These findings further highlight the need for future research, as playing status may influence data interpretation with potential implications for subsequent program design (Medeiros et al., 2020).

The present results indicated that LNHE was more effective for improvement in CoD performance compared to a control group. In addition, all groups had significant improvement from pre to post-training in CoD Performance. These findings are consistent with previous research highlighting a 2.7–5.5% decrease in COD time following low-volume NHT (Siddle et al., 2022), isolated (Siddle et al., 2019), and combined NHT programs (Tous-Fajardo et al., 2016) in sub-elite and elite male youth soccer players. Rapid change of direction is vital for success in soccer, with players required to perform directional and speed changes that impose high metabolic and mechanical load demands (Tous-Fajardo et al., 2016). When braking, eccentric strength helps to maintain hip extensor torque, assists dynamic knee and trunk stabilization, and contributes to the storage and utilization of elastic energy during the final foot contact of COD tasks (Dos Santos et al., 2017). This is in contrast to linear sprinting, where concentric muscle actions of the lower limbs have been identified as the primary agonists (Johnson & Buckley, 2001). It should be noted that COD tasks are commonplace in popular soccer training methods such as small-sided games. Due to these aforementioned facts, strength and conditioning professionals may consider the low volume of the NHT as a more specific modality to train the deceleration and stabilization of the hips and knees during CoD and sprint tasks in youth soccer players.

The present study is not without limitations. The duration of the protocol, training volume, and methodology of exercise should be noted before making direct comparisons with the literature of a similar nature, as improvements associated with the LNHT are largely mode and intensity-specific (Lacome et al., 2019), as such findings should not be generalized beyond the current population. Future research is required to determine whether manipulation of intervention duration, exercise mode in the form of assisted vs unassisted LNHT and training volume would provide more beneficial improvements in both performance and structural adaptations in elite youth soccer populations, with implications for performance and injury risk.

5. Conclusions

Youth soccer players performing a low-volume nordic hamstring program during the preseason improve linear sprint and CoD performance to a greater extent than the control group. Performing a low-volume programme is probably more feasible and likely to be adopted in a real-world context as such, our findings have important implications for future implementation of the Nordic hamstring exercise among youth soccer players. Allowing youth players to get better at the exercise by keeping the training volume consistent, to allow them to slowly produce force over a greater range of motion, seems to be the most effective way of producing the desired adaptations. As CoD and sprint performance in soccer are directly related to both, success in competition, the results of the present study should therefore be translated into regular soccer training to benefit from success in competition. Coaches should be mindful of the results of the present study when working with youth soccer players in eccentric strength training settings. From a practical standpoint, the positive effects of low NHT exercises were more evident. Therefore, a low NHT exercise appears to be more valuable as a workout (training) and potentially reduces the risk of injuries if the objective is to CoD performance in youth soccer players.

Availability of Data and Materials

Data are available for research purposes upon reasonable request to the corresponding author.

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Conflict of Interest

The authors declare no conflict of interest.

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