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# A randomised controlled trial of 1- versus 2-day per week formats of Nordic hamstring training on explosive athletic tasks in prepubertal soccer players

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**ABSTRACT**

This randomised controlled trial examined the effect of volume-equated programmes of Nordic hamstring exercise (NHE) training, executed at frequencies of 1- or 2-days per week, on explosive athletic tasks (30 m sprint, 15 m manoeuvrability and standing long jump [SLJ]) in male youth soccer players (mean age: 10.3 ± 0.5 years). Players were divided into an experimental group (n = 31) which was further subdivided into 1-day (n = 16) and 2-days (n = 15) per week training conditions, and a control group (n = 14). There were significant group-by-time interactions for 30-m sprint ($p < 0.001$, $d = 0.6$), SLJ ($p = 0.001$, $d = 1.27$) and 15 m manoeuvrability ($p < 0.001$, $d = 0.61$). The experimental group demonstrated small to moderate effect sizes in 30-m sprint ($d = 0.42$, $p = 0.077$), SLJ ($d = 0.97$, $p < 0.001$) and 15 m manoeuvrability ($d = 0.61$, $p < 0.001$). The control group showed small significant performance decrements or no change in these variables. There were no significant differences between the 1-day and 2-day training groups. In two of the three tests (30 m sprint, SLJ) the 2-day group demonstrated larger effect sizes. The NHE enhances explosive athletic task performance in prepubertal youth soccer players and there may be only small advantages to spreading training over two days instead of one.

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**KEYWORDS**
Eccentric; strength; speed; fatigue; youth

## Introduction

Strength training of the hip extensors is crucial to the development of proficient movement in athletes with the concurrent "triple extension" of the hip, knee and ankle joints a primary characteristic of vital athletic movements such as running, jumping, and changing direction quickly (Lorenz, 2016). The Nordic Hamstring Exercise (NHE) has been shown to be an effective method with which to enhance a number of different metrics, driving positive adaptations in muscle strength (Drury et al., 2020), sprinting speed (Raya-González et al., 2021), change of direction speed (Siddle et al., 2019) and jump height (Váczi et al., 2022) in a variety of young athletic populations. In addition to the performance-enhancing benefits that the NHE offers, it is time-efficient, easy to perform and is a highly practicable exercise with no equipment required for execution, meaning it can be performed in a variety of different sporting settings (Bahr et al., 2015; Petersen et al., 2011). This is highly important in environments in which resistance exercise is delivered to youths with time (Pichardo et al., 2019) and equipment (Drury, Clarke et al., 2021) constraints acting as potential barriers to the carrying out of meaningful training sessions that conform to conventional programming guidelines (Lloyd et al., 2014). However, despite the benefits of the NHE, some doubts have previously been expressed with regard to its use in youth populations due to the exercise's high level of intensity, which can lead to delayed onset muscle soreness (Van Der Horst et al., 2015), and youths' inappropriate preparedness to cope with exposure to the method. This is perhaps one of the reasons why so few investigations have been undertaken in prepubertal youth populations, though a lack of lack of coach supervision or specific support at that stage of development might also contribute to this problem.

While some studies have investigated the effect of the NHE on various markers of strength in male prepubertal youths (Drury et al., 2020; Tansel et al., 2008), to date, to the best of our knowledge, just a single intervention (Hammami et al., 2022) has evaluated the effect of NHE training, albeit combined with other strength exercises, on basic athletic skills such as sprinting and jumping in this population. This is an important gap in the literature to address given the importance of such skills for both health (Han et al., 2018) and sport performance (Myer et al., 2013) in youth populations. Detailing the lack of studies in prepubertal populations, a recent meta-analysis (Moran et al., 2017), focusing on male youth athletes, indicated that such individuals adapted to resistance training to a lower magnitude in comparison to those who had experienced the growth spurt. Indeed, adaptations to resistance training in youth are related to hormonal profiles and development of the musculoskeletal system with lower levels of testosterone, IGF-1 and growth hormone impeding substantial morphological changes prior to puberty (McNarry et al., 2014;

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Moran, Sandercock, Ramírez-Campillo et al., 2018; Moran et al., 2017). This potentially leaves prepubertal youth reliant on fewer pathways of adaptation than more mature individuals (Moran, Sandercock, Ramírez-Campillo et al., 2018), with neural mechanisms, such as enhanced excitation-contraction coupling (Ramsay et al., 1990), more likely to underpin any observed changes in strength due to training. Accordingly, further studies, which clarify the degree to which prepubertal youths might adapt to practically viable resistance training, such as the NHE, are required.

In addition to the above, for youths who wish to partake in sport, available time is often cited as a sizeable constraint to participation (Kuhn et al., 2021). Similarly, time constraints have also been highlighted as a common reason for coaches to forgo adherence to neuromuscular training in youth athletes (Owoeye et al., 2020). Given the importance of resistance training in supporting both the physical (Cohen et al., 2021; Moran, Sandercock, Ramirez-Campillo et al., 2018) and psychosocial development (Collins, Booth, Duncan, Fawkner et al., 2019) of youth, the precise and accurate integration of time-efficient methods into the weekly schedule is of paramount importance. Despite this, to date, the optimal frequency of different types of resistance training remains unknown. In this context, we are aware of just one (Medeiros et al., 2020) study that evaluated the effects of different frequencies of NHE training with Medeiros et al. (Medeiros et al., 2020) finding that only a two day protocol resulted in increased strength of the hamstring muscles in an adult athletic population. However, in this study, the training volumes were not equated between the groups with the 2-day group undertaking twice the amount of work as the participants in the 1-day group, meaning that overall training volume was an uncontrolled confounding variable of the programme design. Furthermore, a recent meta-analysis (Cuthbert et al., 2021) reported no significant differences in muscle strength when well-trained populations were exposed to volume-equated resistance training programmes of different frequencies in the same week. Another meta-analysis by the same group (Cuthbert et al., 2020) revealed that lower volumes of NHE training were equally effective as higher volumes at increasing eccentric hamstring strength, yet only one of the included interventions was conducted in a prepubertal population.

On the basis of the above presented evidence, we sought to determine the effectiveness of NHE training in enhancing performance in explosive athletic tasks (i.e. standing long jump [SLJ], 15 m manoeuvrability and 30 m sprint) in prepubertal youth soccer players. Alongside this aim, in the interests of programming efficiency, we were interested in determining the effect of volume-equated 1- and 2-day per week formats of NHE on the same parameters of explosive athletic performance in these players. We hypothesised that NHE training would result in improved performance in all the dependent variables and that the 1-day format would be just as effective as the 2-day format.

## Materials and methods

The purpose of this randomised controlled trial was to determine the effect of adding eight weeks of NHE training to the regular routine of youth soccer players, examining the effect on performance of explosive athletic tasks. A parallel aim was to evaluate the effect on physical performance of a volume-equated programme executed at frequencies of one or two training sessions per week in different experimental groups. Figure 1 outlines the recruitment process and information on the interventions received. The study was conducted according to the latest version of the Declaration of Helsinki and the protocol was fully approved by the university ethics committee prior to the commencement of any assessments.

### Participants

Forty-five young soccer players, aged between 9.4 and 11.5 years, from the same club which played at the local regional level, took part in this study. Participants' characteristics are shown in Table 1. The players were randomly assigned to two different exercise groups (n = 31) or a control group (n = 14). One experimental group executed NHE training on one day per week (1-day group, n = 16) and the other undertook an identical volume of NHE training which was divided across two days of the week (2-day group, n = 15). All participating players had identical daily school schedules. 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 participant informed consent was obtained after a thorough explanation of the objectives, scope, procedures, risks, and benefits of the study. None of the participating athletes had a history of musculoskeletal, neurological, or orthopaedic disorders that might have impaired their ability to execute the prescribed tasks/tests. The sample size estimation was computed using G*Power software (version 3.1.9.6). We conducted an a *priori* sample size calculation for sprint time based on a similar study from Chaabene et al. (Chaabene et al., 2020). We set a type I error rate of 0.05 and 80% statistical power. The estimated effect size of Cohen's d = 0.78 is based on the effects of NHE on explosive athletic performance in youth athletes over a similar time period. The analysis indicated that seven participants per group would represent a sufficient sample. We recruited at least 14 to each group.

### Procedures

All procedures were performed during the second half of the competitive soccer season (February and March 2022). Before the experiment, all athletes participated in two orientation sessions to familiarise themselves with the experimental procedures and to minimise the learning effect on test performance. Participants undertook the SLJ test, a 30 m sprint and a 15-m manoeuvrability test before and after the eight-week NHE training programme. Procedures followed a general warm-up that consisted of running, callisthenics, and stretching.

### Anthropometrics

Participants' stature and body mass were collected using a wall-mounted stadiometer and electronic scales, respectively. To

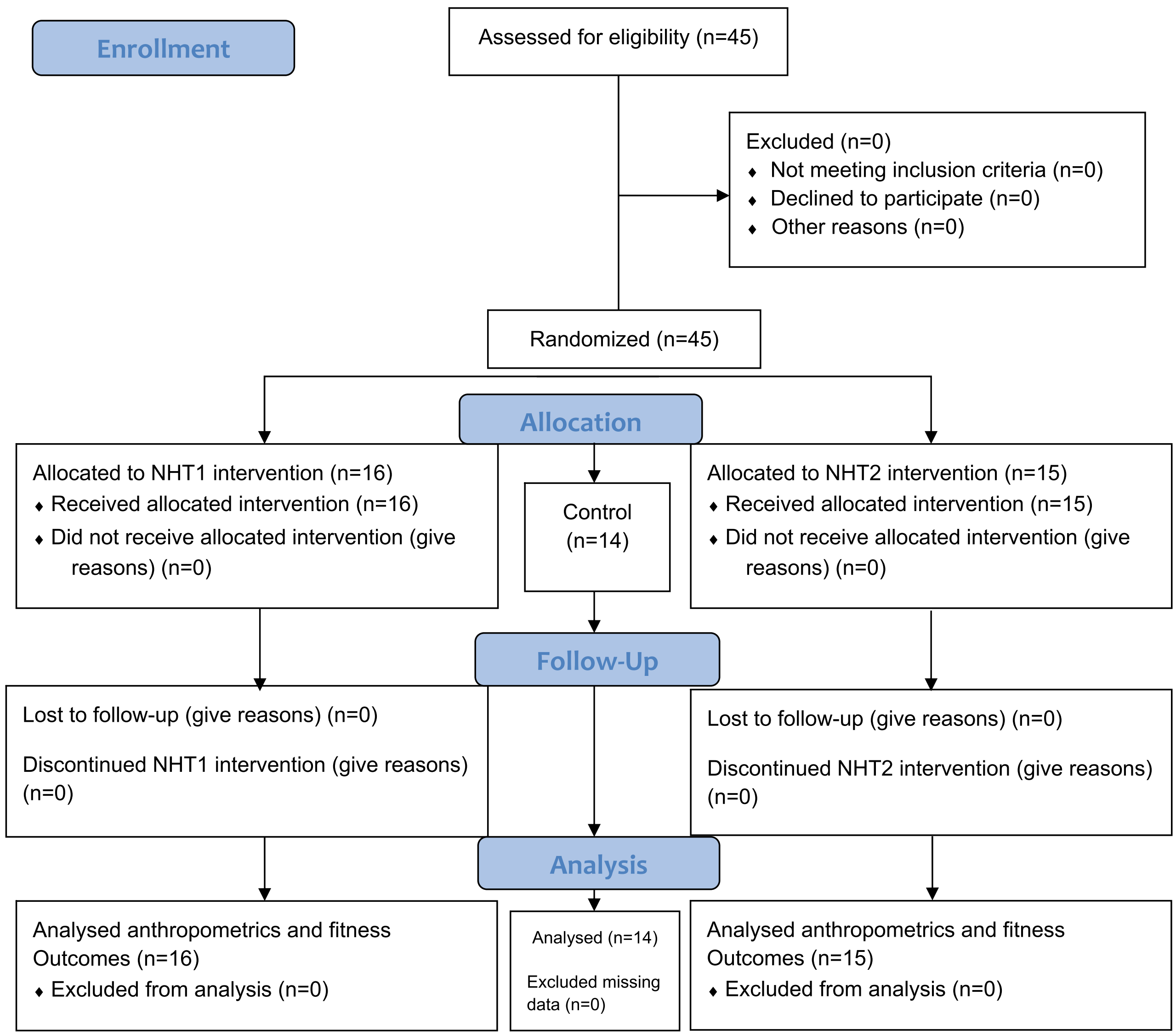


Figure 1. The diagram (The CONSORT: Consolidated Standards of Reporting Trials) includes detailed information on the interventions received.

estimate the maturity status of the participants, a redeveloped version of the maturity offset method was used (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 (PHV = – 7.999994 + (0.0036124 × age × height)). Body mass index was calculated as mass per height squared (kg/m2) with the calculations used to determine body fat percentage using an equation (BF% = 1.51 x BMI – 0.70 x age – 3.6 x sex + 1.4; Deurenberg et al., 1991).

Table 1. Physical characteristics (mean-SD) of the participants.

| | 2-day group | 1-day group | Control group |
|---|---|---|---|
| Age (yrs) | 10.22(0.39) | 10.38(0.57) | 10.41(0.62) |
| Height (cm) | 139.0(5.86) | 140.19(5.92) | 138.07(5.61) |
| Body mass (kg) | 32.63(4.67) | 33.88(5.93) | 32.07(3.30) |
| Maturity offset | −2.87(0.31) | −2.74(0.44) | −2.80(0.50) |
| Body fat | 12.35(3.86) | 12.77(4.12) | 12.47(4.16) |
| Years of experience | 3.33(0.49) | 3.69(0.48) | 3.71(0.47) |

### *Horizontal jump test*

For the SLJ, athletes adopted a bilateral stance just behind the starting line and were instructed to push off vigorously from the ground, jumping forward as far as possible. The distance jumped was measured in centimetres from the start line at take-off to the position of the heel on landing, using a metal tape. Test retest reliability for the SLJ has previously demonstrated excellent reliability (ICC = 0.91, range = 0.83–0.96; Hammami et al., 2016).

### *Sprint tests*

Running speed was evaluated using a 30-m maximal sprint test. Participants sprinted as fast as possible from a stationary standing position located 20 cm behind the first timing gate at the start line. 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 (Chaouachi et al., 2014; Sariati et al., 2021). Participants performed two trials with at least two minutes of rest between each one. The run with the best 30-m time was selected for analysis. Excellent test-retest reliability (ICC = 0.99) has previously been reported for this protocol (Shalfawi et al., 2012).

### Manoeuvrability test

For the 15 m manoeuvrability test, players started by running from a distance of 3 m behind the starting line where the aforementioned timing gates were positioned. The players performed 3-m of straight running before entering a 3-m slalom section marked by three aligned vertically standing poles (1.6 m of height), placed 1.5 m apart. They then cleared a 0.5-m hurdle placed 2-m beyond the third pole. Finally, players ran 7-m to break the second set of timing gates, which stopped the timer (Mujika et al., 2009). Excellent test–retest reliability has been reported for this test, with an ICC value of 0.94 (0.86, 0.97; Chaalali et al., 2016).

### Training programme

The NHE training intervention period lasted for eight weeks. The players were randomly allocated into one of three groups. Every participant was identified by an ID number which was entered into an online randomiser (https://www.randomizer.org/) which arranged the participants into groups. One group executed NHE training on one day per week (1-day group) and the other undertook an identical volume of NHE training which was divided across two days of the week (2-day group), the details of which are in Table 2. Both groups, as well as the control group, executed their usual soccer training activities. The training programme was based on a pooled analysis of previous NHE studies (Cuthbert et al., 2020) and was performed prior to team training, on Tuesdays and Thursdays, to ensure it was executed in a non-fatigued state (Lovell et al., 2018). The NHE was performed by the 1-day group in the first training session of the week and by the 2-day group in the first and second training sessions of the week, with 48 hours between sessions. The NHE was performed as per a previous study in a similar population of youth soccer players (Drury et al., 2020). For performance of the NHE, 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 NHE 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, to prevent hip flexion and lordosis, and aligning the trunk and hips in a neutral position throughout performance. The arms were held around the 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 amount of repetitions. Following completion of the assigned number of repetitions, the participant swapped roles with their partner to repeat the process. This facilitated an inter-set rest of at least one minute (Drury, Peacock et al., 2021).

### Statistical analyses

Statistical analyses were carried out using JASP (version 10.2, University of Amsterdam). Normality and equality of variances for all data were checked with the Shapiro-Wilk and Levene tests respectively. A repeated-measures ANOVA was used to detect statistically significant ($p < 0.05$) changes in the dependent variables with Tukey-adjusted post-hoc tests conducted to identify statistically significant comparisons. In addition to this null hypothesis testing, we also calculated Cohen's *d* effect sizes (ES) which were classified as "trivial" (<0.2) "small" (0.2–0.59), "moderate" (0.6–1.19), "large" (1.2–1.99), or "very large" (>2; Hopkins et al., 2009).

## Results

### Effect of the intervention: experimental groups combined vs. control group

Both groups achieved a 100% attendance rate. After the intervention, our analyses revealed significant group by time interactions for SLJ (df = 1, F = 12.194, $p = 0.001$, $d = 1.27$), 15 m manoeuvrability (df = 1, F = 27.638, $p < 0.001$, $d = 0.61$) and 30 m sprint (df = 1, F = 13.493, $p < 0.001$, $d = 0.60$). In the *post hoc* analyses, the experimental group demonstrated "small" to "moderate" effect sizes representing positive changes in performance. By comparison, the control group experienced a trivial performance increase (SLJ) and statistically significant performance decrements in 15 m manoeuvrability and 30 m sprint. These findings are summarised in Figure 2 and Table 3.

Table 2. Training intervention.

| | Day 1 (sets x repetitions) | | | Day 2 (sets x repetitions) | | |
|---|---|---|---|---|---|---|
| Group | 2-day group | 1-day group | Control | 2-day group | 1-day group | Control |
| Week 1 | 2x5 | 4x5 | Skills | 2x5 | Skills | Skills |
| Week 2 | 2x5 | 4x5 | Skills | 2x5 | Skills | Skills |
| Week 3 | 2x6 | 4x6 | Skills | 2x6 | Skills | Skills |
| Week 4 | 2x6 | 4x6 | Skills | 2x6 | Skills | Skills |
| Week 5 | 3x6 | 6x6 | Skills | 3x6 | Skills | Skills |
| Week 6 | 3x6 | 6x6 | Skills | 3x6 | Skills | Skills |
| Week 7 | 3x8 | 6x8 | Skills | 3x8 | Skills | Skills |
| Week 8 | 3x8 | 6x8 | Skills | 3x8 | Skills | Skills |

Intensity: exercises were performed with maximal effort (intensity: 100%), Rest: 1–2 min between sets.

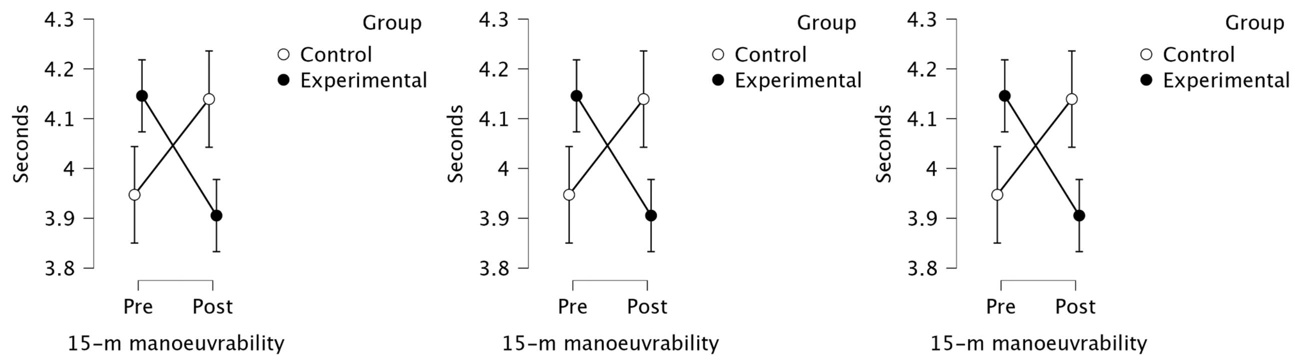


Figure 2. Results of the experimental vs control analysis.

Table 3. Results of the experimental vs control analysis.

| | Group | Baseline (Mean, SD) | | Follow up (Mean, SD) | | d | 95% Confidence interval | Tukey ($p < 0.05$) |
|---|---|---|---|---|---|---|---|---|
| | Control | 5.29 | 0.34 | 5.56 | 0.36 | −0.70 | −1.42 to 0.02 | 0.041 |
| 30 m sprint | Experimental | 5.50 | 0.42 | 5.33 | 0.40 | 0.42 | −0.06 to 0.91 | 0.077 |
| | Control | 3.95 | 0.42 | 4.14 | 0.38 | −0.50 | −1.07 to 0.07 | 0.031 |
| 15 m manoeuvrability | Experimental | 4.15 | 0.43 | 3.91 | 0.37 | 0.61 | 0.24 to 0.97 | <0.001 |
| | Control | 139.6 | 17.9 | 141.1 | 16.4 | 0.13 | −0.42 to 0.67 | 0.922 |
| Standing long jump | Experimental | 145.4 | 13.5 | 160.0 | 13.2 | 0.97 | 0.50 to 1.43 | <0.001 |

### *Intervention comparison: 1-day group vs. 2-day group*

After the intervention, there were no significant differences between the 1-day and 2-day training groups in any of the measured performance variables (Figure 3 and Table 4). In the *post hoc* analyses, both groups experienced significant increases in physical performance in both SLJ and 15 m manoeuvrability, with neither group achieving this in 30 m sprint. The 2-day group was, however, on the threshold of statistical significance with an effect size that far exceeded that of the 1-day group. There was a similar trend for SLJ with the 2-day group achieving a large effect size, relative to the moderate effect observed in the 1-day group.

## Discussion

This randomised controlled trial examined the effect of volume-equated programmes of NHE training, executed at frequencies of 1- or 2-days per week, on explosive athletic tasks (30 m sprint, 15 m manoeuvrability and SLJ) in male youth soccer players. The results of the study show that incorporating the NHE exercise into the training schedule of prepubertal youth soccer players can result in small to moderate increases in the aforementioned explosive athletic tasks. The control group in this study experienced either no significant changes in performance, or significant decreases indicating that its performance worsened over the course of the intervention. Accordingly, the

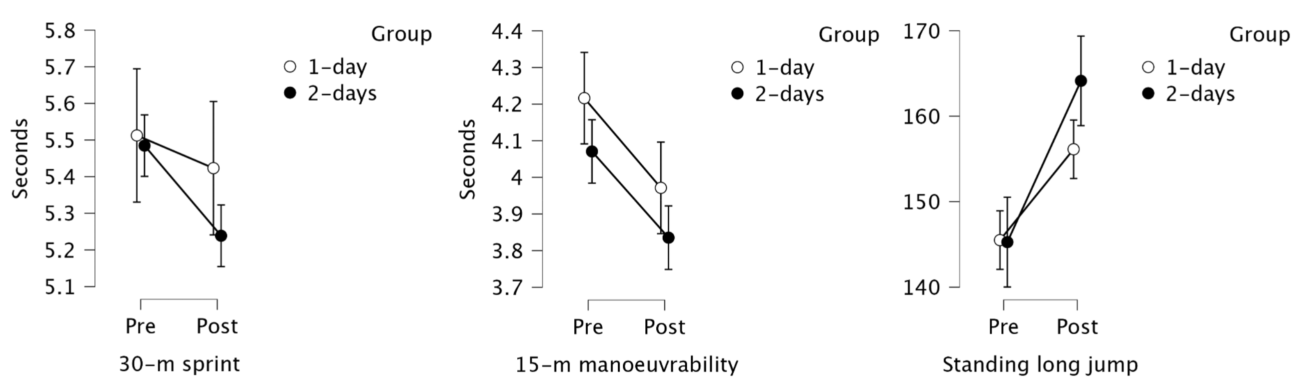


Figure 3. Results of the 1-day vs 2-day analysis.

Table 4. Results of the 1-day vs 2-day analysis.

| | Group | Baseline (Mean, SD) | | Follow up (Mean, SD) | | d | 95% Confidence interval | Tukey ($p < 0.05$) |
|---|---|---|---|---|---|---|---|---|
| 30 m sprint | 1-day group | 5.51 | 0.45 | 5.42 | 0.47 | 0.23 | −0.40 to 0.86 | 0.753 |
| | 2-day group | 5.48 | 0.41 | 5.24 | 0.30 | 0.60 | −0.08 to 1.28 | 0.069 |
| 15 m manoeuvrability | 1-day group | 4.22 | 0.39 | 3.97 | 0.36 | 0.61 | 0.09 to 1.14 | 0.006 |
| | 2-day group | 4.07 | 0.48 | 3.84 | 0.37 | 0.59 | 0.06 to 1.13 | 0.011 |
| Standing long jump | 1-day group | 145.5 | 16.54 | 156.13 | 13.3 | 0.84 | 0.167 to 1.51 | 0.003 |
| | 2-day group | 145.27 | 9.88 | 164.13 | 12.21 | 1.39 | 0.60 to 2.19 | <0.001 |

results of the current study demonstrate that additional training may be required to enhance performance as the playing of a particular sport is not necessarily sufficient to increase important athletic abilities such as sprinting and jumping. In addition to this, the results of the current study show that despite both the 1-day and 2-day groups experiencing similar increases in performance following the study, there was no statistically significant differences between the groups indicating that coaches can interchangeably prescribe both 1- and 2-day formats of NHE training with a view to enhancing explosive athletic performance in young athletes. These results are very important in that they are observed in prepubertal youths for which, to the best of our knowledge, only three previous eccentric training intervention studies (Drury et al., 2020; Hammami et al., 2022; Tansel et al., 2008) have been carried out, thus making definitive conclusions difficult to make in this population.

The positive changes we observed are likely due to a combination of increased fascicle length (Timmins et al., 2016), and eccentric muscle strength which can underpin performance changes in sprints over different distances (Bautista et al., 2021). During execution of the NHE, the bicep femoris muscle has been shown to actively lengthen as hip and knee extension occurs (Raiteri et al., 2021). Consequently, the NHE facilitates replication of the lengthening action of the hamstring muscles during sprinting movements. For example, as sprint speed increases the bicep femoris experiences an increase in musculotendon stretch due to the negative work it performs during the swing phase of the gait cycle (Chumanov et al., 2011). As a result, structural changes such as increased fascicle length that occur following NHE training in male youth athlete (Lacome et al., 2020) may have positive influences on sprint performance. Similarly, it appears that strength adaptations are stimulated by increases in eccentric maximal voluntary contraction force of the hamstrings (as measured during oppositional knee flexion) and enhanced electromyographic activity of the biceps femoris and semitendinosus muscles (Delahunt et al., 2016). It is unclear what combination of these factors may have contributed to the performance increases we observed in the current study and so future work can focus on the relative contributions of these mechanisms.

The implications of our findings are not only important for physical performance in youth, but also to offset the chances of injury which can be caused due to early sport specialisation, a common issue in youth athletes (Bell et al., 2018). Indeed, previous data in young soccer players (under 9 to 14) suggest that as much as 97% of training time is devoted to the specific execution of soccer activities with little time devoted to other forms of programming (Brownlee et al., 2018). Alongside this, it has been demonstrated that as youths mature, they become sequentially less flexible, thus exposing the hamstrings to greater injury risk as a player grows (Daga et al., 2021). It is likely that adaptations such as increased muscle strength and fascicle length can offset the likelihood of injury occurring (Howatson et al., 2007; Hyldahl et al., 2017), enabling a player to meet the often gruelling performance demands of their sport. Indeed, these factors can also act as a form of protection from high volumes of training, with eccentric training providing damage resistance via the repeated bout effect (Howatson et al., 2007; Hyldahl et al., 2017). It has previously been posited that the classification of an individual as an "athlete" at a young age can induce unnecessary competitive pressures and a drift away from the initial and fundamental purposes of sports participation, such as the development of key motor skills (Merkel, 2013). Fundamental movement skills (FMS), such as those tested (i.e. running, jumping) in the current study (Collins, Booth, Duncan, Fawkner et al., 2019), have been suggested to be important for the development of physical capacities such as muscular strength in children (Faigenbaum et al., 2019). In turn, the strengthening of muscles is also effective for the development of FMS with a balanced programme of physical development vital for the overall health of the growing child (Faigenbaum et al., 2019). In this way, the goals of muscle strengthening and development of FMS in children are symbiotic. However, despite these well accepted assertions, contemporary children are less fit than those in previous generations (Faigenbaum et al., 2019) and this is compounded by the recently reported reduction in the time devoted to physical education and activity in both the US (Katzmarzyk et al., 2018) and the UK (DfE does not plan to change curriculum PE requirement, 2019), even prior to the Covid 19 pandemic.

Given the above information, the execution of a simple and effective NHE programme that is easy to coach, and does not require specialist equipment, seems a time-efficient way to underpin the development of FMS in children. A lack of equipment is often cited as a barrier to programming resistance training in youth (Drury, Clarke et al., 2021), however, such equipment is not necessarily required to construct an effective plan. To this end, exercises such as the NHE are a safe and effective way of building eccentric strength in the hamstrings in a prepubertal youth population (Drury et al., 2020). Accordingly, sport coaches and physical education practitioners can incorporate the NHE into the pre-session warm up or main body of a standard training session (Kilding et al., 2008), utilising the exercise to underpin the learning and performance of traditional FMS that should be part of any comprehensive programme of physical preparation for the young athlete (Ryan et al., 2018). Indeed, using the example of an elite academy from England's Premier League, there appear to be few differences between a traditional strength and conditioning programme and a typical approach to developing physical literacy in young children (Duncan et al., 2018). For example, the youth physical development programme of a leading professional club (Ryan et al., 2018) has been focused on the establishment of competence in the execution of FMS such as running and jumping, an approach that shares numerous similarities with other school- and community-based physical literacy programmes detailed in the literature (Duncan et al., 2018; Han et al., 2018). In this way, many of the performance tests that are used to gauge movement skill in a youth soccer academy session can be utilised by practitioners working with so called "non-athletes" in the community and the incorporation of traditional strength and conditioning exercises like the NHE, that are easy to implement, seems a logical step to improving FMS in all youth.

The concept of maturation status must also be discussed in the context of this investigation. Given the lack of studies on NHE in prepubertal youths, we are aware of just one other intervention (Hammami et al., 2022) which investigated the effect of NHE on running speed in young athletes. Hammami et al. (Hammami et al., 2022) reported small to moderate effect sizes following general eccentric hamstring training in pre- and mid-pubertal handball players, observing larger effect sizes and statistical significance in the pre-pubertal group. Those results were in line with the current research and we also observed small to moderate effects in the experimental group. When programming resistance exercise in youth, coaches should consider the degree to which their trainees' adaptability can be affected by their level of physical maturity. Indeed, this can be impacted by an individual's body size with greater mass of the upper torso meaning higher strength levels are required to decelerate that mass in larger youths. It has previously been demonstrated that prepubertal youths may respond to resistance exercise to a lower degree than their mid- and post-pubertal counterparts, thus the incorporation of other effective forms of training is warranted (Moran et al., 2017). A programme of integrative neuromuscular training is recommended from a young age (Myer et al., 2011).

Our study design facilitates a comparison of different weekly configurations of NHE training. On this, the results indicate that there are no significant differences between 1-day per week and 2-days per week formats of volume equated NHE training in prepubertal athletes, though the observed effect sizes did mostly favour the 2-day group. Accordingly, coaches can be confident of achieving performance improvements regardless of whether a 1- or 2-days per week programming format is chosen, though there may be a small practical advantage to adopting the 2-day format. Previously, Hartman et al. (Hartman et al., 2007) suggested no apparent benefit in dividing the training load of young weightlifters across two daily sessions rather than condensing into one. The authors did however suggest a potential protective effect against injury when utilising the more frequent format. It is also interesting to note that delayed onset muscle soreness may be reduced in higher-frequency training protocols (Gomes et al., 2019) and this could potentially result in greater training compliance and, by extension, improved performance. Laterally, a review (Smith & Scarf, 2017) suggested that the performance of highly diverse and disparate tasks such as surgical skill execution and video game playing was of a higher quality when spaced over a number of days rather than being condensed into a single day. Similarly, coaches have previously preferred to adopt a format of higher frequency, presumably to support learning by leveraging the effect of more contextual variety in task execution and to expose athletes to training on a greater number of occasions (Smith & Scarf, 2017; Tribolet et al., 2022). Because of this greater number of exposures, it is suggested that memories of skill execution would be more likely to be recalled in subsequent bouts (Smith & Scarf, 2017), an important factor in the prepubertal athlete in whom the opportunity to acquire and develop skills could be maximised in the years prior to adolescence given the eventual emergence of synaptic pruning (De Graaf-Peters & Hadders-Algra, 2006; Lloyd et al., 2014). As our results are not conclusive in this matter, it cannot necessarily be recommended that a 2-day per week format is more effective than 1-day; however, future investigations may clarify this issue.

There are some limitations to our study that readers must be aware of. Our sample size was relatively small though the presented data can be very useful for inclusion in future meta-analyses on this particular topic. Also, an experimental group of differing maturation status could have been useful in terms of making conclusions as to how effective NHE training can be across the developmental spectrum.

## Conclusion

The results of this study show that NHE training is an effective way to enhance explosive athletic performance in prepubertal athletes. The method is safe, effective, time-efficient and easy to coach meaning that it is accessible to both youth sports coaches and physical education teachers alike. These practitioners can interchangeably programme this exercise in 1-day or 2-days per week formats and can anticipate adaptive responses of a similar magnitude, regardless of their choice. This makes the NHE a highly versatile training method. In implementing the NHE, coaches may consider issues such as the maturation level of the trainee, which can affect the degree of adaptation, as well as the heretofore theoretical learning advantages of programming the exercise in a 2-days per week format.

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## References

Bahr, R., Thorborg, K., & Ekstrand, J. (2015). Evidence-based hamstring injury prevention is not adopted by the majority of Champions League or Norwegian Premier League football teams: The Nordic Hamstring survey. *Br J Sports Med*, *49*(22), 1466–1471. https://doi.org/10.1136/bjsports-2015-094826

Bautista, I. J., Vicente-Mampel, J., Baraja-Vegas, L., Segarra, V., Martín, F., & Van Hooren, B. (2021). The effects of the Nordic hamstring exercise on sprint performance and eccentric knee flexor strength: A systematic review and meta-analysis of intervention studies among team sport players. *J Sci Med Sport*, *24*(9), 931–938. https://doi.org/10.1016/j.jsams.2021.03.009

Bell, D. R., Post, E. G., Biese, K., Bay, C., & Valovich Mcleod, T. (2018). Sport specialization and risk of overuse injuries: A systematic review with meta-analysis. *Pediatrics*, *142*(3), e20180657. https://doi.org/10.1542/peds.2018-0657

Brownlee, T. E., O'Boyle, A., Morgans, R., Morton, J. P., Erskine, R. M., & Drust, B. (2018). Training duration may not be a predisposing factor in potential maladaptations in talent development programmes that promote early specialisation in elite youth soccer. *Int J Sports Sci Coach*, *13*(5), 674–678. https://doi.org/10.1177/1747954117752127

Chaabene, H., Negra, Y., Moran, J., Prieske, O., Sammoud, S., Ramirez-Campillo, R., & Granacher, U. (2020). Effects of an Eccentric Hamstrings Training on Components of Physical Performance in Young Female Handball Players. *Int J Sports Physiol Perform*, *15*(1), 91–97. https://doi.org/10.1123/ijspp.2019-0005

Chaalali, A., Rouissi, M., Chtara, M., Owen, A., Bragazzi, N.L., Moalla, W., Chaouachi, A., Amri, M., & Chamari, K. (2016). Agility training in young elite soccer players: Promising results compared to change of direction drills. *Biol Sport*, *33*(4), 345–351. https://doi.org/10.5604/20831862.1217924

Chaouachi, A., Othman, A. B., Hammami, R., Drinkwater, E. J., & Behm, D. G. (2014). The Combination of Plyometric and Balance Training Improves Sprint and Shuttle Run Performances More Often Than Plyometric-Only Training With Children. *J Strength Cond Res*, *28*(2), 401–412. https://doi.org/10.1519/JSC.0b013e3182987059

Chumanov, E. S., Heiderscheit, B. C., & Thelen, D. G. (2011). Hamstring musculotendon dynamics during stance and swing phases of high speed running. *Med Sci Sport Exerc*, *43*(3), 525–532. https://doi.org/10.1249/MSS.0b013e3181f23fe8

Cohen, D.D., Sandercock, G.R., Camacho, P.A., Otero-Wandurraga, J., Romero, S.M.P., Marín, R.D.P.M., Sierra, C.A.V., Carreño, J., Moran, J., & Lopez-Jaramillo, P. (2021). The SIMAC study: A randomized controlled trial to compare the effects of resistance training and aerobic training on the fitness and body composition of Colombian adolescents. *PLoS One*, *16*(4), e0248110–e0248110. https://doi.org/10.1371/journal.pone.0248110

Collins, H., Booth, J. N., Duncan, A., & Fawkner, S. (2019). The effect of resistance training interventions on fundamental movement skills in youth: A meta-analysis. *Sport Med - Open*, *5*(1), 1–16.

Collins, H., Booth, J. N., Duncan, A., Fawkner, S., & Niven, A. (2019). The Effect of Resistance Training Interventions on 'The Self' in Youth: A Systematic Review and Meta-analysis. *Sport Med - Open*, *5*(1), 1–14. https://doi.org/10.1186/s40798-019-0205-0

Cuthbert, M., Haff, G.G., Arent, S., Ripley, N., McMahon, J. J., Evans, M., & Comfort, P. (2021). Effects of Variations in Resistance Training Frequency on Strength Development in Well-Trained Populations and Implications for In-Season Athlete Training: A Systematic Review and Meta-analysis. *Sport Med*, *51*(9), 1967–1982. https://doi.org/10.1007/s40279-021-01460-7

Cuthbert, M., Ripley, N., McMahon, J., Evans, M., Haff, G., & Comfort, P. (2020). The Effect of Nordic Hamstring Exercise Intervention Volume on Eccentric Strength and Muscle Architecture Adaptations: A Systematic Review and Meta-analyses. *Sport Med*, *50*(1), 83–99. https://doi.org/10.1007/s40279-019-01178-7

Daga, F. A., Panzolini, M., Allois, R., Baseggio, L., & Agostino, S. (2021). Age-Related Differences in Hamstring Flexibility in Prepubertal Soccer Players: An Exploratory Cross-Sectional Study. *Front Psychol*. 1;215. https://doi.org/10.3389/fpsyg.2021.741756

de Graaf-Peters, V. B., & Hadders-Algra, M. (2006). Ontogeny of the human central nervous system: What is happening when? *Early Hum Dev*, *82*(4), 257–266. https://doi.org/10.1016/j.earlhumdev.2005.10.013

Delahunt, E., McGroarty, M., De Vito, G., & Ditroilo, M. (2016). Nordic hamstring exercise training alters knee joint kinematics and hamstring activation patterns in young men. *Eur J Appl Physiol Vol*, *116*, 663–672. https://doi.org/10.1007/s00421-015-3325-3

Deurenberg, P., Weststrate, A., & Seidell, J. (1991). Body mass index as a measure of body fatness: Age- and sex-specific prediction formulas. *Br J Nutr*, *65*(2), 104–114. https://doi.org/10.1079/BJN19910073

DfE does not plan to change curriculum PE requirement. *Youth Sport Trust*. https://www.youthsporttrust.org/news-insight/news/dfe-does-not-plan-to-change-curriculum-pe-requirement. 2019

Drury, B., Clarke, H., Moran, J., Fernandes, J. F. T., Henry, G., & Behm, D. (2021). Eccentric Resistance Training in Youth: A Survey of Perceptions and Current Practices by Strength and Conditioning Coaches. *J Funct Morphol Kinesiol*, *6*(1), 21. https://doi.org/10.3390/jfmk6010021

Drury, B., Green, T., Ramirez-Campillo, R., & Moran, J. (2020). Influence of Maturation Status on Eccentric Hamstring Strength Improvements in Youth Male Soccer Players Following the Nordic Hamstring Exercise. *Int J Sports Physiol Perform*, *15*(7), 990–996. https://doi.org/10.1123/ijspp.2019-0184

Drury, B., Peacock, D., Moran, J., Cone, C., & Campillo, R. R. (2021). Different Interset Rest Intervals During the Nordic Hamstrings Exercise in Young Male Athletes. *J Athl Train*, *56*(9), 952–959. https://doi.org/10.4085/318-20

Duncan, M., Eyre, E., & Oxford, S. (2018). The effects of 10-week integrated neuromuscular training on fundamental movement skills and physical self-efficacy in 6–7-year-old children. *J Strength Cond Res Cond Res*, *32*(12), 3348–3356. https://doi.org/10.1519/JSC.0000000000001859

Faigenbaum, A. D., Rebullido, T. R., Peña, J., & Chulvi-Medrano, I. (2019). Resistance Exercise for the Prevention and Treatment of Pediatric Dynapenia. *J Sci Sport Exerc*, *1*(3), 208–216. https://doi.org/10.1007/s42978-019-00038-0

Gomes, G. K., Franco, C. M., Nunes, P. R. P., & Orsatti, F. L. (2019). High-Frequency Resistance Training Is Not More Effective Than Low-Frequency Resistance Training in Increasing Muscle Mass and Strength in Well-Trained Men. *J Strength Cond Res*, *33*, S130–S139. https://doi.org/10.1519/JSC.0000000000002559

Hammami, R., Chaouachi, A., Makhlouf, I., Granacher, U., & Behm, D. G. (2016). Associations between balance and muscle strength, power performance in male youth athletes of different maturity status. *Pediatr Exerc Sci*, *28*(4), 521–534. https://doi.org/10.1123/pes.2015-0231

Hammami, R., Duncan, M. J., Nebigh, A., Werfelli, H., & Rebai, H. (2022). The Effects of 6 Weeks Eccentric Training on Speed, Dynamic Balance, Muscle Strength, Power, and Lower Limb Asymmetry in Prepubescent Weightlifters. *J Strength Cond Res*, *36*(4), 955–962. https://doi.org/10.1519/JSC.0000000000003598

Han, A., Fu, A., Cobley, S., & Sanders, R. H. (2018). Effectiveness of exercise intervention on improving fundamental movement skills and motor coordination in overweight/obese children and adolescents: A systematic review. *J Sci Med Sport*, *21*(89–102). https://doi.org/10.1016/j.jsams.2017.07.001

Hartman, M. J., Clark, B., Bemben, D. A., Kilgore, J. L., & Bemben, M. G. (2007). Comparisons between twice-daily and once-daily training sessions in male weight lifters. *Int J Sports Physiol Perform*, *2*(76–86). https://doi.org/10.1123/ijspp.2.2.159

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*, *41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Howatson, G., Van Someren, K., & Hortobagyi, T. (2007). Repeated bout effect after maximal eccentric exercise. *Int J Sports Med*, *28*(7), 557–563. https://doi.org/10.1055/s-2007-964866

Hyldahl, R. D., Chen, T. C., & Nosaka, K. (2017). Mechanisms and Mediators of the Skeletal Muscle Repeated Bout Effect. *Exerc Sport Sci Rev*, *45*(1), 24–33. https://doi.org/10.1249/JES.0000000000000095

Katzmarzyk, P. T., Denstel, K. D., Beals, K., Carlson, J., Crouter, S.E., McKenzie, T.L., Pate, R.R., Sisson, S.B., Staiano, A.E., Stanish, H., & Ward, D.S. (2018). Results from the United States 2018 Report Card on Physical Activity for Children and Youth. *J Phys Act Heal*, *15*(s2), S422–S424. https://doi.org/10.1123/jpah.2018-0476

Kilding, A. E., Tunstall, H., & Kuzmic, D. (2008). Suitability of FIFA's "The 11" training programme for young football players–impact on physical performance. *J Sport Sci Med*, *7*(3), 320–326. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3761904/

Kuhn, A. W., Grusky, A. Z., Cash, C. R., Churchwell, A. L., & Diamond, A. B. (2021). Disparities and Inequities in Youth Sports. *Curr Sports Med Rep*, *20*(9), 494–498. https://doi.org/10.1249/JSR.0000000000000881

Lacome, M., Avrillon, S., Cholley, Y., Simpson, B. M. M., Guilhem, G., & Buchheit, M. (2020). Hamstring Eccentric Strengthening Program: Does Training Volume Matter? *Int J Sports Physiol Perform*, *15*(1), 81–90. https://doi.org/10.1123/ijspp.2018-0947

Lloyd, R. S., Faigenbaum, A. D., Stone, M. H., Oliver, J. L., Jeffreys, I., Moody, J. A., Brewer, C., Pierce, K. C., McCambridge, T. M., Howard, R., Herrington, L., Hainline, B., Micheli, L. J., Jaques, R., Kraemer, W. J., McBride, M. G., Best, T. M., Chu, D. A., Alvar, B. A., & Myer, G. D. (2014). Position statement on youth resistance training: The 2014 international consensus. *Br J Sports Med*, *48*(7), 498–505. https://doi.org/10.1136/bjsports-2013-092952

Lorenz, D. (2016). Facilitating Power Development in the Recovering Athlete: Triple Extension in Rehabilitation. *Strength Cond J*, *38*(1), 48–50. https://doi.org/10.1519/SSC.0000000000000192

Lovell, R., Knox, M., Weston, M., Siegler, J. C., Brennan, S., & Marshall, P. W. (2018). Hamstring Injury Prevention in Soccer: Before or After Training? *Scand J Med Sci Sports*, *28*(2), 658–666. https://doi.org/10.1111/sms.12925

McNarry, M., Lloyd, R., Buchheit, M., Williams, C., & Oliver, J. (2014). The BASES Expert Statement on Trainability during Childhood and Adolescence. *Sport Exerc Sci*, *4*, 22–23. https://www.bases.org.uk/imgs/tses_issue_41_p22_p23_childhood842.pdf

Medeiros, T. M., Ribeiro-Alvares, J. B., Fritsch, C. G., Oliveira, G. S., Severo-Silveira, L., Pappas, E., & Baroni, B. M. (2020). Effect of Weekly Training

Frequency With the Nordic Hamstring Exercise on Muscle-Strain Risk Factors in Football Players: A Randomized Trial. *Int J Sports Physiol Perform*, *15*(7), 1026–1033. https://doi.org/10.1123/ijspp.2018-0780

Merkel, D. (2013). Youth sport: Positive and negative impact on young athletes. *Open Access J Sport Med*, *4*, 151–160. https://doi.org/10.2147/OAJSM.S33556

Moore, S. A., McKay, H. A., Macdonald, H., Nettlefold, L., Baxter-Jones, A. D. G., Cameron, N., & Brasher, P. M. A. (2015). Enhancing a Somatic Maturity Prediction Model. *Med Sci Sport Exerc*, *47*(8), 1755–1764. https://doi.org/10.1249/MSS.0000000000000588

Moran, J., Sandercock, G., Ramirez-Campillo, R., Cctc, C., Jjft, F., & Drury, B. (2018). A meta-analysis of resistance training in female youth: Its effect on muscular strength, and shortcomings in the literature. *Sport Med*, *48* (7), 1661–1671. https://doi.org/10.1007/s40279-018-0914-4

Moran, J., Sandercock, G. R. H., Ramírez-Campillo, R., Meylan, C., Collison, J., & Parry, D. A. (2017). A meta-analysis of maturation-related variation in adolescent boy athletes' adaptations to short-term resistance training. *J Sports Sci*, *35*(11), 1041–1051. https://doi.org/10.1080/02640414.2016.1209306

Moran, J., Sandercock, G. R. H., Ramírez-Campillo, R., Wooller, J. J., Logothetis, S., Schoenmakers, P. P. J. M., & Parry, D. A. (2018). Maturation-related differences in adaptations to resistance training in young male swimmers. *J Strength Cond Res*, *32*(1), 139–149. https://doi.org/10.1519/JSC.0000000000001780

Mujika, I., Santisteban, J., Impellizzeri, F. M., & Castagna, C. (2009). Fitness determinants of success in men's and women's football. *J Sports Sci*, *207* (2), 107–114. https://doi.org/10.1080/02640410802428071

Myer, G. D., Faigenbaum, A. D., Ford, K. R., Best, T. M., Bergeron, M. F., & Hewett, T. E. (2011). When to initiate integrative neuromuscular training to reduce sports-related injuries in youth? *Curr Sports Med Rep*, *10*(3), 155–166. https://doi.org/10.1249/JSR.0b013e31821b1442

Myer, G. D., Lloyd, R. S., Brent, J. L., & Faigenbaum, A. D. (2013). How young is too young to start training? *ACSM's Heal Fit J*. https://doi.org/10.1249/FIT.0b013e3182a06c59

Owoeye, O. B., Emery, C. A., Befus, K., Palacios-Derflingher, L., & Pasanen, K. (2020). How much, how often, how well? Adherence to a neuromuscular training warm-up injury prevention program in youth basketball. *J Sports Sci*, *38*(20), 2329–2337. https://doi.org/10.1080/02640414.2020.1782578

Petersen, J., Thorborg, K., Nielsen, M. B., Budtz-Jørgensen, E., & Hölmich, P. (2011). Preventive effect of eccentric training on acute hamstring injuries in men's soccer: A cluster-randomized controlled trial. *Am J Sports Med*, *39*(11), 2296–2303. https://doi.org/10.1177/0363546511419277

Pichardo, A. W., Oliver, J. L., Harrison, C. B., Maulder, P. S., & Lloyd, R. S. (2019). Integrating Resistance Training Into High School Curriculum. *Strength Cond J*, *41*(1), 39–50. https://doi.org/10.1519/SSC.0000000000000412

Raiteri, B. J., Beller, R., & Hahn, D. (2021). Biceps Femoris long head muscle fascicles actively lengthen during the Nordic hamstring exercise. *Front Sport Act Living*, *3*, 136. https://doi.org/10.3389/fspor.2021.669813

Ramsay, J., Blimkie, C., Smith, K., Garner, S., MacDougall, J., & Sale, D. (1990). Strength training effects in prepubescent boys. *Med Sci Sport Exerc*, *22*, 605–614. https://doi.org/10.1249/00005768-199010000-00011

Raya-González, J., Torres Martin, L., Beato, M., Rodríguez-Fernández, A., & Sanchez-Sanchez, J. (2021). The effects of training based on Nordic hamstring and sprint exercises on measures of physical fitness and hamstring injury prevention in U19 male soccer players. *Res Sport Med*, 1–16. https://doi.org/10.1080/15438627.2021.2010206

Ryan, D., Lewin, C., Forsythe, S., & McCall, A. (2018). Developing world-class soccer players: An example of the academy physical development program from an English premier league team. *Strength Cond J*, *40*(3), 2–11. https://doi.org/10.1519/SSC.0000000000000340

Sariati, D., Hammami, R., Zouhal, H., Clark, C. C., Nebigh, A., Chtara, M., & Ounis, O. B. (2021). Improvement of physical performance following a 6 week change-of-direction training program in elite youth soccer players of different maturity levels. *Front Physiol*, 652. https://doi.org/10.3389/fphys.2021.668437

Shalfawi, S. A., Enoksen, E., Tønnessen, E., & Ingebrigtsen, J. (2012). Assessing test-retest reliability of the portable Brower speed trap II testing system. *Kinesiology*, *44*(1), 24–30. https://hrcak.srce.hr/clanak/124403

Siddle, J., Greig, M., Weaver, K., Page, R. M., Harper, D., & Brogden, C. M. (2019). Acute adaptations and subsequent preservation of strength and speed measures following a Nordic hamstring curl intervention: A randomised controlled trial. *J Sports Sci*, *37*(8), 911–920. https://doi.org/10.1080/02640414.2018.1535786

Smith, C. D., & Scarf, D. (2017). Spacing Repetitions Over Long Timescales: A Review and a Reconsolidation Explanation. *Front Psychol*, *8*(962):548. https://doi.org/10.3389/fpsyg.2017.00962

Tansel, R., Salci, Y., Yildirim, A., Kocak, S., & Korkusuz, P. (2008). Effects of eccentric hamstring strength training on lower extremity strength of 10–12 year old male basketball players. *Isokinet Exerc Sci*, *16*(2), 81–85. https://doi.org/10.3233/IES-2008-0300

Timmins, R. G., Ruddy, J. D., Presland, J., Maniar, N., & Williams, M. (2016). Architectural changes of the biceps femoris long head after concentric or eccentric training. *Med Sci Sport Exerc*, *48*(3), 499–508. https://doi.org/10.1249/MSS.0000000000000795

Tribolet, R., Sheehan, W. B., Novak, A. R., Watsford, M. L., & Fransen, J. (2022). How does practice change across the season? A descriptive study of the training structures and practice activities implemented by a professional Australian football team. *Int J Sports Sci Coach*, *17*(1), 63–72. https://doi.org/10.1177/17479541211019829

Váczi, M., Fazekas, G., Pilissy, T., Cselkó, A., Trzaskoma, L., Sebesi, B., & Tihanyi, J. (2022). The effects of eccentric hamstring exercise training in young female handball players. *Eur J Appl Physiol*, *122*, 955–964. https://doi.org/10.1007/s00421-022-04888-5

Van Der Horst, N., Smits, D. W., Petersen, J., Goedhart, E. A., & Backx, F. J. G. (2015). The Preventive Effect of the Nordic Hamstring Exercise on Hamstring Injuries in Amateur Soccer Players: A Randomized Controlled Trial. *Am J Sports Med*, *43*(6), 1316–1323. https://doi.org/10.1177/0363546515574057