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The effects of Sprint Training and the Nordic Hamstring

Exercise on eccentric hamstring strength and sprint performance

in adolescent athletes.

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ABSTRACT

BACKGROUND: Hamstring Strain Injuries (HSI) are among the most common injuries in field based team sports with a high speed running component. The implementation of the Nordic Hamstring Exercise (NHE) is a well documented method of improving eccentric hamstring strength to mitigate the risk of HSI occurrence. Sprint training is specific to the injury mechanism and is thought to activate the hamstrings through maximal eccentric contractions. The purpose of this study was to compare the effects of sprint training and the NHE on eccentric hamstring strength and sprint performance.

METHODS: Twenty-eight participants (Mean $\pm$ SD age = 16.21 $\pm$ 1.34 years; height = 1.75m $\pm$ 0.10m; body mass = 68.5kg $\pm$ 12.1kg) completed an eccentric hamstring strength assessment and 40m sprint to assess acceleration and maximum speed. Participants were randomly allocated to either a NHE training or sprint training group. Two sessions per week for four-weeks of training was performed with baseline testing procedures repeated in the week following the intervention. Perceptions of soreness were recorded following the warm-up in each training session.

RESULTS: Both the NHE (effect size = 0.39, $p < 0.05$) and sprint training (effect size = 0.29, $p < 0.05$) groups displayed significant gains in eccentric hamstring strength. The NHE group reported trivial improvements in sprint performance, whilst the sprint training group experienced a moderate improvement, specifically in maximum speed (ES = 0.83 Moderate). Sprint training also produced greater perceptions of soreness than the NHE following a four-week training intervention, specifically before the start of the last session ($p < 0.05$).

CONCLUSIONS: These findings indicate that sprint training had a beneficial effect for both eccentric hamstring strength and sprint performance, whilst also producing greater soreness than the NHE following the final training session. It was concluded that a four-week block of maximum speed training may have both an injury prevention and performance enhancement benefit.

Key words: resistance training, hamstring muscles, athletic performance, running, sports medicine

Introduction

Hamstring Strain Injuries (HSI) are common among junior and senior athletes participating in field-based, team sports with a high speed running component^{1, 2}. Throughout the 2012 Australian Football League (AFL) season, HSI costs each club an average of A\$245,842³ whilst in the 2015 season, each club lost 19.1 games to HSI⁴. In addition, the cost of HSI to all clubs in the English Premier League was £34,628,000⁵. High speed running is identified as the most common mechanism for HSI, particularly in the Biceps Femoris Long Head^{6, 7}. This injury has been identified to occur during the late swing and early stance phases of the running gait cycle, at which time the hamstrings are heavily eccentrically loaded^{2, 8, 9}.

Eccentric strength of the hamstrings is a modifiable risk factor for HSI^{10, 11}. Athletes with lower eccentric strength have been shown to be more likely to experience a HSI compared to those with greater eccentric strength^{11, 12}. A 2014 study¹⁴ reported that professional Australian football players with an eccentric hamstring strength score of less than 279 N were 4.3% more likely to experience a HSI. However, for every 10 N increase, the risk of HSI decreases by 6.3%, indicating that increasing eccentric hamstring strength may have a prophylactic effect¹⁴.

Currently the Nordic Hamstring Exercise (NHE) is at the forefront of injury prevention practices due to the benefits of increased eccentric strength and reduced incidence of HSI^{1, 11, 15-18}. The protective effect of the NHE has been previously demonstrated in male participants, when the training protocol achieved a 96% compliance rate¹⁷. In addition, a separate field-based study¹⁵ was completed with elite soccer players. The NHE intervention was shown to be 65% effective in reducing HSI among participants who were compliant with the program, however the overall compliance rate with the NHE was reported at 48%. This suggests that compliance with the exercise could be a barrier to effective injury prevention. This is further supported by a study¹⁹ reporting that the NHE has the greatest protective effect when compliance with the exercise is high amongst athletes. Pre-conceived ideas of high muscle soreness have been shown to be a factor influencing compliance with the NHE. Therefore, uptake of the exercise among lesser trained athletes has been shown to be lower than in elite athletes^{15, 19, 20}.

There is an association between a spike in high levels of high speed running and increased risk of HSI⁶, however, the risk is more likely to increase when high levels of sprint training are introduced to individuals with an inconsistent sprint training history over the previous two years²¹. Furthermore, sprint training has been previously shown to improve sprint performance for both junior and senior athletes^{22, 23}. Specifically, the improvements occur in two speed qualities; acceleration and maximum speed²⁴. Sprint training has been previously shown as an effective method of improving the acceleration capabilities of field sport athletes²². In addition, manipulating the starting position from walking to jogging has been shown to improve maximum speed capabilities over 30 m²³. Sprinting has been shown to maximally activate the hamstrings^{7, 25} therefore, sprint training may provide adequate load to the hamstrings to provide specific adaptations such as an increase in eccentric hamstring strength and potentially protect the hamstrings from injury.

Previously, sprinting was shown to be the most common mechanism for HSI, and currently there is very little literature to support sprint training as a method of injury prevention for HSI's, that is not already a part of multi-dimensional approach¹⁴. Therefore, the aim of this study was to compare the effects of both the NHE and sprint training on eccentric hamstring strength and sprint performance in an adolescent athlete population. Since sprint training may overload the hamstrings, it was hypothesised that a progressively overloaded sprint training program would provide sufficient stimulus to induce positive adaptations, which would increase the eccentric strength to similar levels of the NHE and decrease the risk of HSI.

Materials and methods

To compare the effects of two different training interventions (NHE Eccentric Training vs. Sprint Training) on eccentric hamstring strength and sprint performance, a randomised, parallel training study with repeated measures was conducted. Participants completed two weeks of familiarisation, one week of pre-testing, four weeks of training and one week of post-testing. Independent variables were the types of training, whilst the dependent variables were eccentric hamstring strength, hamstring soreness ratings as well as acceleration and maximum speed measures.

Thirty-five adolescent athletes were recruited, with 28 participants completing the study (Mean $\pm$ SD age = 16.21 $\pm$ 1.34 years; height = 1.75m $\pm$ 0.10m; weight = 68.5kg $\pm$ 12.1kg; age range = 14 – 18 years; male = 23, female = 5). Participants were randomly allocated to two training groups, maintaining a gender balance between boys and girls in each group. Prior to training, there were trivial to small differences between groups for age, height, body mass, eccentric strength and sprint performance, but none of these were statistically significant ($p > 0.05$). All participants were student athletes in a secondary school specialist sports program competing in the sports of Australian Football (AF), Soccer, Cricket, Baseball and Field Hockey. Aside from training associated with the study, participants also completed two additional resistance training sessions and two sport-specific technical and tactical sessions per week. Resistance training sessions performed adjacent to the study consisted of self-myofascial release, squat variations, barbell rows, Romanian deadlifts, single leg squats, as well core exercises such as supine holds and prone walks. Resistance training sessions were completed following the exercises performed as a part of the study (sprinting or the NHE), or on a separate day, allowing at least 24 hours before the next intervention session of sprinting or the NHE. The participants were fully informed about the study procedures before the start of the study, and informed consent was obtained from both subjects and their parents or legal guardians with the approval of the University's Human Research Ethics Committee.

None of the subjects had completed the eccentric hamstring strength assessment protocol prior to the current investigation and few were familiar with the sprint testing protocol, so four familiarisation sessions took place before the testing period to minimise any learning effect²⁶. Sprint familiarisation was completed following a standardised warm up (Table 1) and occurred over 40 m. This was completed inside on the school basketball courts. Participants practiced the starting position for two repetitions at 95% of perceived maximum effort (PME) for the first two sessions and two repetitions at 98% PME for the last two sessions. Participants were instructed to start with their preferred foot forward with opposing arm raised in the air to avoid premature starting of the timing system. Subjects were required to be in a stationary position and could not rock to gain any momentum prior to starting. Familiarisation for the eccentric hamstring strength assessment consisted of two

sets of three repetitions. The first set was performed sub-maximally with intensity increasing with each repetition (70%, 80% and 90% PME). Following a one-min rest, subjects completed three maximal voluntary contractions.

Table 1 here

All testing occurred on the same day in a climate-controlled indoor setting (approximately 20°C). Subjects reported for testing following a minimum of a 48-hour period post-competition from their sport. Sprint performance testing was completed before the eccentric hamstring strength test to prevent fatigue from the eccentric hamstring strength test influencing sprint performance measures.

The 40 m sprint was measured using Fusion Sports Smart Speed Pro timing gates (Fusion Sports, QLD). Timing gates were positioned at the start, 10 m, 30 m and 40 m stages of the test. During testing, subjects completed the standardised warm-up before completing a 40 m sprint warm up (Table 1). Following a three-minute rest, participants completed their first of two trials, a three-minute rest and then completed the final trial. Subjects were reminded to maintain the start position and to ensure they sprinted through the last timing gate. The best 0-10 m time was interpreted to represent acceleration, whilst the 30-40 m time was used as an estimate of maximum speed²⁷. The best 10 m time and 30-40 m time was retained for analysis.

Eccentric hamstring strength was tested with a NordBord (Vald Performance, QLD). The NordBord assessment replicates the NHE^{10, 11}, however instead of someone holding the participants ankles, the device uses hooks attached to force transducers to hold the participant in place, whilst producing a force reading in N for each leg. The corresponding knee position was recorded to ensure participants would be in the correct position to apply force vertically through the hooks mounted to force transducers. As both legs are assessed independently, a force reading was obtained for both legs. To obtain an overall score of the subject's eccentric hamstring strength, the mean of the left and right value was used for statistical analysis.

Subjects had a five-minute break following the sprint performance assessment before completing a standardised warm-up consisting of three repetitions of increasing intensity (70%, 80% and 90% perceived maximal effort) (Table 1). Following a one-min rest, the subjects completed a set of three maximum effort repetitions²⁰. Participants were instructed to maintain a straight line from shoulder through to the knee whilst keeping hands at chest level to brace for when they reach the point of failure for the exercise. Subjects were also instructed to control the contraction for as long as possible²⁸. The best trial (average of left and right limbs) was retained for analysis.

The training interventions took place at the school gymnasium, basketball stadium and athletics track. Participants completed two sessions per week for the four-week period (Table 2). Participants were required to complete at least seven sessions in order to be a part of the results for the study. These exercises took place after subjects completed the other training as a part of their school program, which was modified to accommodate for the training interventions without producing an excessive load. Programming of the NHE followed recommendations of previous studies to include its implementation at the end of training sessions^{18, 20}. Participants were required to complete training sessions on non-consecutive days²². Soreness ratings were taken prior to completing each training session but after completing the warm-up. Participants were asked “How sore do you feel in your hamstrings?” and rated their soreness on a 10-point Likert Scale (1=No Soreness, 3 = Minimal Soreness, 5 = Moderate Soreness, 8 = Very Sore, 10 = Extremely Sore).

Table 2 here

The programming variables for NHE training utilized was based on previous research that has reported positive results^{15, 17, 29, 30} to produce a progressively overloaded four-week training program. Participants were given three minute rests between sets of the NHE²⁹. For the sprint training, the four-week intervention was modified to accommodate for a maximum speed focus²⁷. The three-minute rest between efforts has been used previously to provide an adequate recovery^{23, 31} in studies with a performance increase.

Intra-class correlations (ICC) were calculated to determine the reliability of testing measures. To investigate the differences between training interventions on eccentric

hamstring strength and sprint performance, a one-way analysis of variance (ANOVA) was used with repeated measurements. Paired t-tests were used to determine differences between means for outcome variables. Independent t-tests were used to investigate the differences in soreness between groups. The level for significance was set at $p \leq 0.05$. ANOVA, ICC's, paired and independent sample t-tests were conducted using SPSS statistics, version 24.0 (SPSS, Inc., Chicago, IL, USA.). Hopkins effect sizes were calculated, with 0.0 – 0.19 considered a ‘trivial’ effect size, 0.2 – 0.59 considered a “small” effect size and 0.6 – 1.19 considered a “moderate” effect size³².

Results

The average training compliance for the eight sessions was 7.93 sessions for the NHE training group whilst the sprint training group report a compliance of 7.75 sessions. A post-hoc power calculation was completed to determine statistical power as 0.77 (G*Power, Version 3.1). ICC's were calculated for reliability of testing measures between pre-testing trials for the 0-10m (0.88), 30-40m (0.99) and NordBord (0.96), with all values deemed acceptable.

Table 3 here

Both the eccentric and sprint training groups experienced small, yet significant ($p < 0.05$) gains in eccentric hamstring strength. The magnitude of change for the eccentric group (9.8%) was slightly greater than that of the sprint group (6.2%) (Table 3), but there was no significant group by time interaction ($p = 0.37$). Neither of the training groups experienced any statistically significant gains in acceleration performance (effect size = trivial). Eccentric training produced no change in maximum speed, however the sprint group produced a moderate 8.6% gain ($p = 0.10$). However, the group by time interaction for maximum speed did not reach statistical significance ($p = 0.08$).

Prior to the training interventions, sprint training and eccentric training were not significantly different in hamstring soreness (Figure 1). The eccentric training group experienced a moderate increase (effect size = 0.99), followed by a moderate decrease (effect size = 0.65) and then maintained this level for the rest of the training sessions. Sprint training showed a series of small and trivial increases that progressively increased the level

of soreness. Sprint training was found to produce significantly ($p = 0.03$) more soreness after the eighth session than the eccentric training group.

Figure 1 here

Discussion

This is the first study to provide detail of the influence of sprint training on eccentric hamstring strength and sprinting performance in direct comparison to the NHE. Sprint training appeared to produce enough exercise stimulus to produce a gain in eccentric hamstring strength amongst the adolescent athlete population. Whilst the eccentric training produced a bigger gain in eccentric hamstring strength, this improvement was not significantly more than the sprint group, suggesting that sprint training could be an alternative or complementary to the NHE in an athletic training program. The results from this study also indicated that sprint training did not produce a statistically significant gain in maximum speed, however the moderate effect size (0.83) suggests there may have been a practical performance benefit. The study also showed that the NHE incurred no change on either sprint performance measure, as expected.

Both training interventions produced significant increases in eccentric hamstring strength (Table 3). As previously stated, the NHE is proven method of increasing the eccentric strength of the hamstrings, therefore lowering the risk of HSI^{13, 15, 17, 18, 28, 29}. This study demonstrates that a four-week period is sufficient to develop improvements from the NHE in adolescent athletes, which is a shorter timeframe than previously executed programs that last six weeks or longer^{15, 17, 28}. This suggests therefore, that injury prevention benefits can be seen in as little as four weeks due to the increase in eccentric strength¹³. Sprint training was hypothesised to improve eccentric hamstring strength due to the high amount of eccentric loading it places on the hamstring muscle group^{7, 25}, specifically through the late swing and early stance of running gait phase⁹. This was supported by the findings of this study (Table 3), potentially as result of the progressive overloading of the hamstring muscles throughout the four-week training intervention. The gains in mean hamstring eccentric strength were slightly larger in the eccentric training group, potentially due to the specificity of the training method. Whilst considering this, the sprint group did have an average 19.7 N

increase in eccentric strength, which under the guidance of previous research suggests that injury risk would decline^{11, 13, 29}.

Acceleration (0-10 metre speed) did not improve for either group. The aim of the training program was to load the hamstrings eccentrically and this is known to occur during maximal speed sprinting^{7, 8, 25}. Therefore, the lack of change in acceleration may be as a result of less hamstring muscle activation during the first few steps of sprinting (acceleration phase). This result supports the hypothesis that the NHE does not improve sprint performance. Modifying the sprint starting position from standing to jogging decreases the emphasis on acceleration, and focused the training more towards maximum speed as seen by the moderate size increase (ES = 0.83) in the sprint training group. The variations of walking and jogging were used to achieve a higher maximum speed in each repetition^{23, 33}, whilst the majority of the training program was conducted over distances of 30m to provide sufficient time and space to achieve the required muscle stimulus. The 30m distance also replicates the sprinting demands of field-based sports, with the intention of the training program to transfer better to sports performance. The NHE showed no effect, and supported the expected outcome that the slow, non-specific eccentric contraction would not contribute to a maximum speed improvement.

Soreness from eccentric exercises was previously shown to be high and a potential barrier to the implementation of the NHE for injury prevention¹⁹. Previously, scales for rating perceived soreness which have been used³⁴⁻³⁶ have been smaller. The different points from 1 – 10 were designed to determine differences in soreness that may not have been detected by a smaller scale (e.g. 1 – 5). However, the results of this study show soreness to be significantly less following the eighth session of the NHE compared to that of sprint training ($p = 0.03$, ES = 0.93). Following an initial moderate increase (ES = 0.99) and moderate decrease (ES = 0.65), participants appeared to adapt to the stimulus without excessive soreness, a phenomenon that has been previously documented^{37, 38}. Sprint training produced steady increases along the four-week timeline (Figure 1). This could be because, unlike the NHE, sprinting is a high impact, movement with rapid, repeat contractions and high angular velocity of the knee and hip³⁹. Therefore, implementation of sprint training as an injury prevention measure may require careful monitoring of training load^{6, 21} to ensure both the protective and performance effects without elevating the injury risk.

There is currently no research to indicate that sprint training by itself is directly responsible for an increase in eccentric hamstring strength. Sprint training participants cannot attribute their gains in eccentric strength directly to the intervention, due to the other resistance training they completed. Participants performed exercises such as Romanian deadlifts, which have previously been shown to improve hamstring strength¹⁶. Previous studies have incorporated the Nordic curl on top of normal training loads with no reported effect on the intervention^{18,40}. The additional strengthening exercises such as the Romanian deadlift were performed prior to the study, with the key focus of these programs to learn and reinforce good technique. The overall workload for these sessions was low, as athletes completed between 2-4 sets of 5-10 repetitions for these exercises at a sub-maximal load. As both groups were completing the additional resistance training prior to the study commencing, the impact of continuing the training program on either the sprint training or NHE training groups was expected to be minimal.

In addition, the high baseline eccentric hamstring strength levels of the participants in both groups might be further evidence of the influence of training on eccentric strength. However, improving sprinting technique to be more efficient by increasing forward lean and reducing upper body rotation has been shown to produce strength gains from sprint training²². This provides more merit to the notion that sprinting can increase eccentric strength. Soreness measures may have been influenced by outside training and competition influence³⁶, however as this is a normal week to week workload, athletes would be conditioned to this stimulus and this would not be expected to influence soreness ratings significantly. One potential limitation may also be that the maximum speed measurement for the sprint training group was very similar to that of the eccentric training group post-intervention. This could be explained by the sprint group having a lower maximum speed to begin with, hence the moderate effect size gain. This study places training interventions in the context of a short mesocycle of training; four weeks, an idea applicable to the adolescent athletes involved in the study. Nevertheless, improvements in eccentric strength were reported to be similar between the NHE and sprint training, suggesting further research into specific sprint training should be investigated.

Conclusions

The findings from this study indicate that sprint training may be an effective method of improving eccentric hamstring strength and therefore an injury prevention method in adolescent, field-based, team sport athletes, whilst also providing a performance benefit. However, this study also indicates that sprint training produces more soreness following a training session than the NHE, suggesting the application requires a careful balance between sufficient stimulus and excessive soreness. It could be further hypothesised that sprint training could be used either in conjunction with or as an alternative to the NHE in a multifaceted injury prevention program.

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NOTES

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TABLES

Table I.— *Warm-up Protocol*

Activity	Prescription
Jogging	4 minutes.
Leg Swings:	
Anterior-Posterior	30s each leg.
Medio-Lateral	30s each leg.
High Knees (Knee to Chest)	Performed over 20m
Glute Kicks (Heel to Glute)	Performed over 20m
Walking Arabesque (Single Leg RDL)	Performed over 20m
Walking Lunge	Performed over 20m
Test Specific Skills – 40m Sprint	
Run-Through from Starting Position: 70%, 80%, 95% of PME	40m with walking recovery.
Test Specific Skills – Eccentric Hamstring Assessment	
Partial Repetitions: 70%, 80%, 90% of PME	Completed as a set of the exercise.

PME – Perceived Maximum Exertion

Table II. - *Eccentric and sprint training programs*

	Eccentric Training Group	Sprint Training Group
Familiarisation 1	1 x 1 x 70%, 80%, 90% 3-minute rest 1 x 3 x 100%	2 x 40 metres x 95% 3-minute rest
Familiarisation 2	1 x 1 x 70%, 80%, 90% 3-minute rest 1 x 3 x 100%	2 x 40 metres x 95% 3-minute rest
Familiarisation 3	1 x 1 x 70%, 80%, 90% 3-minute rest 1 x 3 x 100%	2 x 40 metres x 98% 3-minute rest
Familiarisation 4	1 x 1 x 70%, 80%, 90% 3-minute rest 1 x 3 x 100%	2 x 40 metres x 98% 3-minute rest
Week 1.1	2 x 5 x 100% effort 3-minute rest	6 x 30 metres ⁺ x 100% effort 3-minute rest
Week 1.2	2 x 5 x 100% 3-minute rest	6 x 40 metres [*] x 100% 3-minute rest
Week 2.1	3 x 4 x 100% 3-minute rest	7 x 30 metres ⁺ x 100% 3-minute rest
Week 2.2	3 x 4 x 100% 3-minute rest	7 x 40 metres [*] x 100% 3-minute rest
Week 3.1	3 x 5 x 100% 3-minute rest	8 x 30 metres ⁺⁺ x 100% 3-minute rest
Week 3.2	3 x 5 x 100% 3-minute rest	8 x 40 metres [*] x 100% 3-minute rest
Week 4.1	3 x 6 x 100% 3-minute rest	10 x 30 metres ⁺⁺ x 100% 3-minute rest
Week 4.2	3 x 6 x 100% 3-minute rest	10 x 40 metres ⁺ x 100% 3-minute rest

* standing start, ⁺walking start, ⁺⁺jogging start

Table 3. Mean eccentric hamstring strength, acceleration and maximum speed ($\pm$ SD) before and after training interventions.

	Eccentric Training					Sprint Training				
	Pre	Post	% Change	<i>p</i>	Effect Size	Pre	Post	% Change	<i>p</i>	Effect Size
Eccentric Hamstring Strength (N)	329.0 $\pm$ 75.8	361.1 $\pm$ 89.4	9.8%	0.01 ⁺	0.39 (Small)	315.4 $\pm$ 74.8	335.1 $\pm$ 74.7	6.2%	0.01 ⁺	0.26 (Small)
Eccentric Hamstring Strength Left (N)	320.0 $\pm$ 79.0	364.4 $\pm$ 99.5	13.9%	0.01 ⁺	0.49 (Small)	307.8 $\pm$ 81.2	334.3 $\pm$ 89.7	8.6%	0.08	0.31 (Small)
Eccentric Hamstring Strength Right (N)	338.3 $\pm$ 74.0	357.7 $\pm$ 86.7	5.7%	0.10	0.24 (Small)	323.0 $\pm$ 81.2	336.0 $\pm$ 77.0	4.0%	0.01 ⁺	0.16 (Trivial)
Acceleration (0-10m) (Seconds)	1.97 $\pm$ 0.13	1.95 $\pm$ 0.15	1%	0.36	-0.14 (Trivial)	1.95 $\pm$ 0.15	1.95 $\pm$ 0.15	0%	0.86	0 (Trivial)
Max Speed (30-40m) (Seconds)	1.27 $\pm$ 0.11	1.27 $\pm$ 0.12	0%	0.42	0 (Trivial)	1.39 $\pm$ 0.27	1.27 $\pm$ 0.14	8.6%	0.10	-0.83 (Moderate)

⁺ = significant on a $p \leq 0.05$ level.

TITLES OF FIGURES

Figure 1.— *Mean (SD) hamstring soreness ratings for each training intervention*