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# Implementing hamstring injury prevention programmes remotely: a randomised proof of concept trial

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## ABSTRACT

**Objectives** This study aimed to (1) compare the effectiveness of a Nordic hamstring exercise (NHE) versus single-leg Romanian deadlift (SLRDL) exercise programme on a hamstring injury risk surrogate; (2) compare the muscle soreness experienced by both exercise programmes; and (3) assess compliance to remote injury prevention exercise protocols through video software.

**Methods** Twenty participants (10 women and 10 men: 21.45±1.6 years; 176±23 cm; 70±10 kg) were randomised into an NHE or SLRDL programme for 6 weeks. Single-leg hamstring bridge (SLHB), a hamstring injury surrogate, was the primary outcome for exercise efficacy. Muscle soreness and exercise adherence were also assessed. Significance was set at p<0.05.

**Results** Both exercises increased SLHB performance resulting in an overall effect (p=0.013) with no effect for group (p=0.470) and no interaction effect (p=0.709), indicating both groups improved but there was no difference in improvement between interventions. There was no difference in muscle soreness between groups (p=0.087). Finally, both groups had 100% adherence to the programme.

**Conclusions** Both the NHE and SLRDL are equally effective in increasing SLHB performance and demonstrate a similar level of muscle soreness. This suggests that SLRDL may be a viable option as a preventative exercise to mitigate the risk of hamstring injury. Finally, implementing injury prevention programmes remotely has the potential to enhance adherence.

### WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The Nordic hamstring exercise (NHE) reduces the risk of hamstring strain injury but adherence to this exercise has been poor.

### WHAT THIS STUDY ADDS

⇒ Conducting an NHE programme remotely resulted in 100% adherence. Furthermore, an alternative exercise, the single-leg Romanian deadlift, also achieved 100% adherence. Additionally, both exercises improved performance on a hamstring strain injury surrogate measure.

### HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This evidence suggests that conducting injury prevention remotely over web-enabled video technology may be a viable alternative to on-site programmes.

## INTRODUCTION

Hamstring injuries continue to be a persistent problem during sporting activities, with little change in incidence rates over time.[1] These injuries account for 24% of all injuries in elite European men's football,[2] with similar hamstring injury rates in females and males in field sports.[3]

The Nordic hamstring exercise (NHE) can reduce hamstring injury incidence by up to 51%.[4] However, this exercise is poorly adopted and adhered to across elite football,[5] as it is deemed to cause muscle soreness.[6] Therefore, the pursuit of potential alternative exercises seems prudent.

The deadlift is a staple of hamstring strengthening routines, and of its variations, the single-leg Romanian deadlift (SLRDL) offers specific benefits. As a single-leg exercise, the SLRDL adds an extra balance requirement by reducing the base of support[7] while also increasing eccentric biceps femoris activation over its bilateral equivalent.[8] Additionally, the SLRDL targets the hamstrings more specifically, as evidenced by a higher ratio of biceps femoris and semitendinosus to erector spinae activation, compared with other deadlift variations.[9] The SLRDL may present an alternative to the NHE.

The progression in internet-based video technology facilitates a potential alternative medium[10] to implement and monitor injury prevention exercises. Routines involving the SLRDL and the NHE are conducive to remote delivery, and the remote setting has the advantage of wider and less costly implementation. It also allows delivery to athletes who live away from their team's location due to education/work or within elite populations, due to international duty. The difficulty of assessing on-site injury-related outcomes may be overcome by using surrogate measures with a relationship to injury that can be assessed remotely to act as a substitute for measuring prospective hamstring strain injuries directly when this is not feasible. An appropriate surrogate measure may be the single-leg hamstring bridge (SLHB) test as it is possible to implement remotely and has been shown to have predictive validity for hamstring strain injury.[11]

Therefore, this study aimed to (1) compare the effectiveness of an NHE versus SLRDL programme on a hamstring injury risk surrogate; (2) compare muscle soreness experienced by both exercise programmes; and (3) assess compliance to remote injury prevention protocols.

## METHODS

### Participants

Twenty individuals (10 women and 10 men) were recruited for this study. We recruited through email and word of mouth. Inclusion criteria consisted of healthy, active men and women, aged between 18 and 25 years. Exclusion criteria comprised a history of hamstring or lower limb injury in the last year, any strength training contraindications or participation in any concurrent lower limb resistance training.

### Study design

All assessments and interventions in this randomised interventional trial were conducted remotely through web-enabled video software (Zoom Video Communication, San Jose, California, USA). Participants were located at a variety of diverse geographical locations throughout the island of Ireland. Participants underwent an initial SLHB test prior to allocation to either NHE or SLRDL, with 50:50 block randomisation used to maintain gender balance. Prior to the SLHB test, participants were familiarised with the exercise technique. Following group allocation, participants were familiarised with their specific exercise prior to commencing their intervention sessions. Participants completed two weekly sessions of their allocated exercise for 6 weeks with increasing volumes to maintain progressive overload (online supplemental material 1).[12 13] The investigators remotely supervised all sessions. Three separate investigators supervised in a crossover fashion, with each supervisor alternating their intervention group on a weekly basis. Delayed-onset muscle soreness (DOMS) values were assessed during each session using a verbal Numerical Rating Scale of 0–10, with the peak weekly value used for analysis.[14] After 6 weeks, participants completed a final SLHB test.

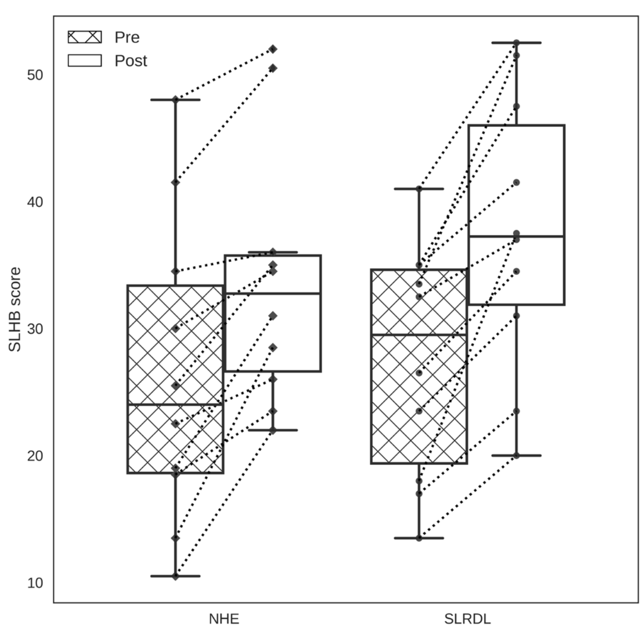


**Figure 1** Single-leg hamstring bridge (SLHB) box plot results for the Nordic hamstring exercise (NHE) and single-leg Romanian deadlift (SLRDL) groups. Pre-intervention results are in hatched grey, while post-intervention results are plain white boxes. Dotted lines represent individual change across time points.

### SLHB test

This test was chosen as it has demonstrated predictive validity for hamstring injury risk,[11] can be monitored remotely and requires minimal equipment.

Participants lay supine with the heel of their foot on a stable surface 60 cm in height. Participants were asked to measure the height of the equipment they would place their heel on (eg, table, desk) to ensure the height was as close to 60 cm as possible. They repeated their post-test using the same equipment. With the test leg in 20° of knee flexion, they crossed their arms over their chest and pushed through their heel to raise the pelvis off the floor and return to the starting position.[11] This was repeated until the subject was unable to continue, and the number of complete repetitions was counted. During the test, verbal feedback was given to ensure that the athlete touched the floor with their pelvis without resting it on the ground, before extending their hip to 0°.[11] Furthermore, verbal feedback was given to ensure controlled and consistent duration of eccentric and concentric phases for each repetition in all participants. Both legs were tested, with starting legs alternated between participants. As the investigator completing the assessment has supervised each group due to crossover supervision of the intervention, blinded assessment was not possible.

### Nordic hamstring exercise

Participants knelt on a soft surface and kept ankles stabilised either through partner assistance or by securing the ankles under a heavy object (eg, large furniture). Participants crossed their arms over their chest with their hips extended and lowered their body, controlling the descent as far as possible until reaching the floor.[15] Those able to control the movement in the final 10–20° were required to hold a weight plate to the chest to ensure intensity.[15 16]

### Single-leg Romanian deadlift

Participants stood erect with their legs–shoulder width apart while holding a weight plate. The non-working leg was lifted slightly above the ground and the stance leg knee flexed to approximately 15°. Participants lowered the plate through hip flexion of the weight-bearing leg, while the non-working leg extended backwards. The weight was lowered until the plate reached the distal tibia[17]; the hips were then extended to return to the starting position. Failure was deemed as a point in the repetition range where participants were unable to maintain technical control or unable to return to the starting position after the lowering phase of the exercise. The resistance was adjusted weekly to ensure failure at the predetermined final repetition. Participants supplied their own weights to ensure consistent overload.

### Statistical analysis

Analysis was conducted using Stata V.16 (StataCorp, Texas, USA). Normal data distribution was determined by the Shapiro-Wilk test. The primary dependent variable was number of completed SLHB repetitions; as there was no statistical difference between limbs, the average score of both legs was used. A two-way (2×2) mixed-model analysis of variance was used to examine the effect of the intervention group (NHE vs SLRDL), time (pre-intervention vs post-intervention) and interaction. Within-group comparisons were analysed using a paired-sample t-test. The secondary dependent variable was DOMS score. A Kruskal-Wallis test assessed the differences between interventional exercises on DOMS. Compliance was assessed through the number of missed supervised training sessions as a percentage. Statistical significance was set at p<0.05. Calculations of sample size were performed a priori. A sample size of 20 participants was deemed sufficient based on an effect size of 1.2, power set at 80% and an alpha level of <0.050.[15]

## RESULTS

### Group characteristics

Twenty individuals (10 women and 10 men: 21.45±1.6 years; 176±23 cm; 70±10 kg) completed this study. All participants exercised recreationally two to three times per week, with 14 of these participating in regional-level competitive sports (Gaelic football, camogie, hurling, soccer). None had any history of hamstring strain injury or any lower limb injury in the previous year. Participants were not participating in any concurrent lower limb resistance training, but otherwise were not asked to alter their normal activity.

### SLHB test

Both groups increased their SLHB score post-intervention (NHE (mean±SD): pre: 26±12 (95% CI: 18 to 35) vs post: 34±10 (95% CI: 27 to 41), Cohen's d=0.67; SLRDL: pre: 28±9 (95% CI: 21 to 34) vs post: 38±11 (95% CI: 30 to 45), Cohen's d=1.00, figure 1) resulting in an overall effect for time (95% CI for SLHB difference by time: 2 to 16, p=0.013). There was no effect for group (95% CI for SLHB difference by group: −5 to 10, p=0.470) and no interaction effect (p=0.709), indicating that both groups improved but there was no difference in improvement between interventions.

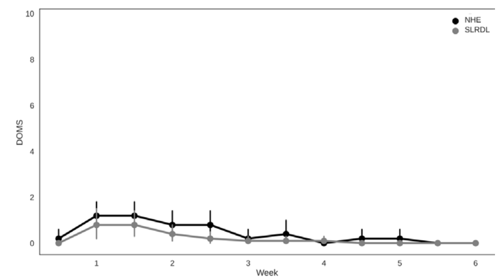


**Figure 2** Weekly delayed-onset muscle soreness (DOMS) results (mean±SD) for the Nordic hamstring exercise (NHE, black) and single-leg Romanian deadlift (SLRDL, grey) groups.

### Delayed-onset muscle soreness

There was no difference between groups for DOMS (p=0.087, figure 2). DOMS decreased weekly in both groups (p<0.001).

### External load

The median external load required for the NHE group was 0 kg (range: 0–5 kg), with only one participant requiring external load, while the median external load for the SLRDL group was 7.5 kg (range: 0–15 kg), with all participants requiring external load.

### Compliance

Neither group had any participant miss a supervised interventional session, resulting in 100% compliance in both groups.

## DISCUSSION

Both the NHE and SLRDL increased hamstring bridge performance, with neither exercise found to be superior. Conducting these exercises remotely resulted in 100% compliance for both interventions.

An improvement in SLHB performance is of significance due to its predictive validity for hamstring injury risk.[11] It has previously been demonstrated that athletes with a lower SLHB score were more likely to sustain a hamstring injury in the following season.[11] The current study represents, to the authors' knowledge, the first evaluation of SLRDL effects on indirect hamstring injury indicators, such as the SLHB. Similar exercises have been compared with NHE previously with no differences being found,[18] in keeping with our results. However, neither the SLRDL or previous alternatives (45° hip extension)[19] have been proven to have direct effects on preventing hamstring injuries.[4 12 13] Considering the relatively higher biceps femoris long head force production during deadlifts compared with the NHE,[18] future trials assessing the preventive effects of these alternative exercises on hamstring injury risk appear warranted.

Despite the repeated demonstration of positive outcomes resulting from NHE programmes, compliance in elite sport remains poor,[5,6] an issue of pertinence given the importance of compliance to the effectiveness of injury prevention.[20] Poor compliance may be linked to a high repetition number prescribed by the seminal randomised control trials in the area,[12,13] but our study adhered to a high-volume prescription and maintained a 100% adherence rate. A second proposed factor causing poor compliance is muscle soreness.[6] However, we observed minimal muscle soreness during both interventions, with no significant difference between them. DOMS experienced during the NHE programme in the current study appears lower than what was reported in previous work with similar dosage[14,19]; whether this is a consequence of the remote delivery remains speculative. The lack of difference in DOMS values suggests that if DOMS is the main reason for avoidance, SLRDL at the current dosage may not result in enhanced compliance over NHE. However, issues of compliance are not restricted to NHE.[21] For all interventions, remote delivery offers benefits including time flexibility and convenience, and may be more cost-effective, notwithstanding possible additional time required of supervising staff, as group delivery of intervention may be precluded by the remote format.[12,13]

## Limitations

Despite the success of the interventions on SLHB and full compliance achieved, the intervention has limitations. Other potentially relevant hamstring injury measures, such as muscle architecture,[22] were not assessed due to the remote delivery of the trial. There were no prospective follow-ups to assess whether intervention improved future hamstring injuries. Comparing ratings of perceived exertion would have allowed a comparison of the intensity of the interventions between groups. Furthermore, blinded assessment would have reduced potential bias. Finally, no performance measures were assessed, despite both exercises previously demonstrating a potential benefit on athletic attributes.[23,24] In elite sport, it may be the ergogenic rather than preventive benefits of an exercise that ultimately result in its inclusion among an athlete's programme.

## Clinical implications

Both the NHE and SLRDL are equally effective in increasing SLHB performance and demonstrate a similar level of muscle soreness. This suggests that SLRDL may be a viable option as a preventative exercise to mitigate the risk of hamstring injury. Finally, implementing injury prevention programmes remotely has the potential to enhance compliance.

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