Malaysian Physiotherapy Journal (e-ISSN 2821-3718)

ORIGINAL ARTICLE

Comparison Between Different Eccentric Exercises and Static Stretching Exercise on Hamstring Flexibility: A Randomized Controlled Trial

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ABSTRACT

Background and Objective: Hamstring strain is one of the most common sports injuries contributed by lack of hamstring flexibility as one of the injury risks factors. Eccentric training could serve to reduce the risk of hamstring strain by improving hamstring flexibility. However, the effectiveness of different eccentric hamstring exercise in improving hamstring flexibility is still understudied**.** The aim of this study is to compare the effectiveness of eccentric exercises and static stretching exercise on hamstring flexibility of recreational athletes. **Methods:** A randomized controlled trial was carried out to examine the effects of Nordic Hamstring Exercise (NHE) and Sliding Leg Curls (SLC) on hamstring flexibility of recreational athlete for four weeks. Participants with hamstring tightness were classified as sit and reach test score for less than 30cm for males and 33cm for females. Participants were randomly assigned using sequentially numbered, opaque, and sealed envelopes to three equal groups (n = 15 for each group): NHE, SLC and Static Stretching (SS). Assessor was blinded from participants' group assignment. **Results:** A total of 45 recreational athletes (28 male and 17 female), mean age 20.36 ± 1.25 years participated in the study. There was no difference between eccentric hamstring (NHE and SLC) and static stretching exercise in improving hamstring flexibility (p = 0.82). NHE and SLC exercises are equally effective in increasing hamstring flexibility [NHE: $p < 0.0001$, ES = 0.90, 95% CI (4.36, 6.77); SLC: $p < 0.0001$, ES = 0.70, 95% CI (4.26, 6.09)], as to static stretching [SS: $p < 0.0001$, ES = 0.62, 95% CI (3.18, 4.71)]. **Conclusion:** Eccentric hamstring exercises are equally effective as static stretching in improving hamstring muscle flexibility.

Keywords: Nordic hamstring exercise, sliding leg curls, static stretching, hamstring flexibility

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INTRODUCTION

Hamstring strains are common injuries incurred during sporting activities at high school, collegiate, and professional levels and further accentuated by the high injury recurrence rate (Elliott et al. 2011; Kaux et al. 2015; Kay et al. 2017; Mohd Jamali et al. 2021). Majority of hamstring muscle strain occurs in sports that require sprinting and kicking, namely football, basketball, soccer, rugby, and track and field (Liu et al. 2012). While the exact time of the occurrence remains debatable, it is believed that hamstring strains may occur when the hamstring is in eccentric contraction, and elongated position (Liu et al. 2012).

Despite the high incidence of hamstring strains in several popular sports, there are inconsistence findings on the causation, rehabilitation, and prevention of hamstring strains. The ability to design effective rehabilitation and injury prevention programs are hampered by inadequate understanding of the injury causes. Literature reveals complex intrinsic and extrinsic risk factors of hamstring strains, including poor hamstring flexibility, previous history of a hamstring injury, age, muscle fatigue and insufficient warm-up (Ernlund & Vieira 2017; Liu et al. 2012). However, the evidence of hamstring flexibility as a risk of hamstring strains are inconsistent (Mendiguchia et al. 2012; Thacker et al. 2004). The accepted notion is that athletes with poor hamstring flexibility may have shorter optimum hamstring muscle length and are at a greater risk of hamstring strain injury than athletes with normal hamstring flexibility (Liu et al. 2012).

Stretching exercises including static, dynamic, ballistic and proprioceptive neuromuscular facilitation are widely prescribed to increase hamstring flexibility. Among these exercises, static stretching is commonly practiced as it is effective to increase muscle flexibility, safe and easy to perform. However, recent studies have found that static stretching, if not performed properly, may hamper athletic performance (Simic et al. 2013; Winchester et al. 2008). Therefore, other effective alternatives, without the risk of reducing athletic performance, are needed.

A study has suggested eccentric exercise to increase muscle flexibility as it is equally effective to stretching in improving hamstring flexibility (Nelson & Bandy 2004), while increasing eccentric strength. Eccentric strength will allow the muscle to withstand the increase of tension during the late swing phase of sprinting owing to eccentric loading and lengthening of the hamstrings (Van Der Horst et al. 2015). Eccentric hamstring strengthening exercises such as the Nordic Hamstring Exercise (NHE), Sliding Leg Curl (SLC), Romanian deadlift, and hip extension exercise become popular in preventing and rehabilitating hamstring strain. NHE is considered to be one of the most effective eccentric hamstrings strengthening exercises (Arnason et al. 2008; Ernlund & Vieira 2017). However, due to the load transmitted to the knee structure in a kneeling position while performing the exercise, it may be unsuitable for an individual with knee pathology or in the early rehabilitation phase. Unfortunately, the effectiveness of the other hamstring exercises with minimal weight bearing such as SLC is limited.

Although previous studies have reported that eccentric hamstring training increases hamstring flexibility, to the best of our knowledge, no studies have been performed to compare the effects of different eccentric hamstring exercises. Thus, the aim of this study is to compare different eccentric exercises and static stretching exercises on hamstring flexibility. This information is crucial to provide athletes, health care and medical professionals with management options to increase hamstring flexibility in various stages of rehabilitation and hamstring injury prevention programs.

MATERIALS AND METHODS

Study design

This study used a single-blinded, randomized-controlled trial design with pre-test and post-test measurements. Participants were randomly assigned to one of the three groups, which were the intervention groups [Nordic Hamstring Exercise (NHE) or Sliding Leg Curl (SLC)], or the control group static stretching (SS). This study was approved by the institution's ethical review committee (UTAR)(U/SERC/144/2018).

Study setting and duration

Data collection was conducted at Physiotherapy Centre, Universiti Tunku Abdul Rahman, Selangor between October to December 2019.

Participants

The sample size was determined using G*Power 3.1 software, where the power was set at 0.80, alpha at 0.05, effect size at 0.25, and additional of 10% to compensate for drop-out rate, which required a total of 45 participants. The ratio of the group allocation is 1:1:1, therefore, 15 participants were allocated for each group. Inclusion criteria were individuals aged between 18 to 25 years old, who have hamstring tightness, and undertake sports at least once a week for leisure (Rosenbloom 2012). Hamstring tightness was defined as receiving a score less than 30cm in males and 33cm in females in sit-and-reach test (Ayala et al. 2012). To ensure reliability of the results, participants with history of back and lower limbs injury in the previous year were excluded. Participants were informed of the benefits and risks of the investigation prior to signing an approved informed consent document to participate in the study. All participants were subjected to a randomization to one of the three groups. Participants were randomly assigned by an investigator using sequentially numbered, opaque, and sealed envelopes. Each envelope contained a carbon paper and paper with one of the three group code labels. No differences in size or weight could be detected among the envelopes. Participant information was written on the envelopes prior to opening. An audit trail was observed with the transfer of information onto the assignment paper using the carbon paper. Subsequently, the coded sealed opaque envelope was opened.

Outcomes

Hamstring flexibility was assessed using the sit and reach test device (ICC = 0.92) (Ayala et al. 2012). The height, length, and width of this box are 12 inches (30.5 cm) and the length on the top of this box is 20 inches (51.4 cm). Participants sat with legs extended and feet flat against the sit and reach device. Participants stretched forward as far as possible with one hand over the other and fingertips in line and held the end point for two seconds. This process was repeated three times and the average score was used for analysis.

Procedures

Pre-test and post-test measurement of hamstring flexibility were performed using the same procedures by the same assessor. The posttest measurement was conducted two to three days after the final day of the intervention session. The same assessor was blinded from participants' group assignment. For the interventions, the investigator (SYC) delivered the interventions to all the participants.

Interventions

Nordic Hamstring Exercise (NHE)

Participants started in a kneeling position on the mat with their arms in front of their chests and upper bodies straightened. Examiner stabilized the participants' ankles. Participants lowered their bodies down slowly as possible by keeping them straight and fell on their arms, and their chests touched the mat when they could not resist the movement and pushed up immediately with their upper limbs (Mjølsnes et al. 2004). Participants performed three sets of four repetitions of NHE for three non-consecutive days. One-minute rest interval was given between sets. The repetitions were increased by two each week for four weeks.

Sliding Leg Curl (SLC)

Participants started by lying on their backs with one knee bent. Participants lifted their pelvic off the floor and slowly slid the bent knee until it was fully extended.

Participants returned to the starting position and repeated the movement. Participants switched sides (Orishimo & McHugh 2015). Participants performed three sets of four repetitions of SLC for three non-consecutive days. One-minute rest interval was given between sets. The repetitions were increased by two each week for four weeks.

Static Stretching (SS)
Participants stood erect with the left foot planted on the floor and the toes pointing forward. The heel of the foot to be stretched was placed on a knee-high stool with the toes directed toward the ceiling (Nelson & Bandy, 2004). Participants leaned their bodies forward as far as possible until a gentle stretch was felt in the posterior thigh, and this position was maintained for 30 seconds while keeping the knee fully extended. Participants performed five repetitions for each leg for two sets with a one-minute rest interval given between sets. Participants performed three times per week for four weeks.

Data analysis
Descriptive statistics were performed on demographic data including age, height, body weight, and body mass

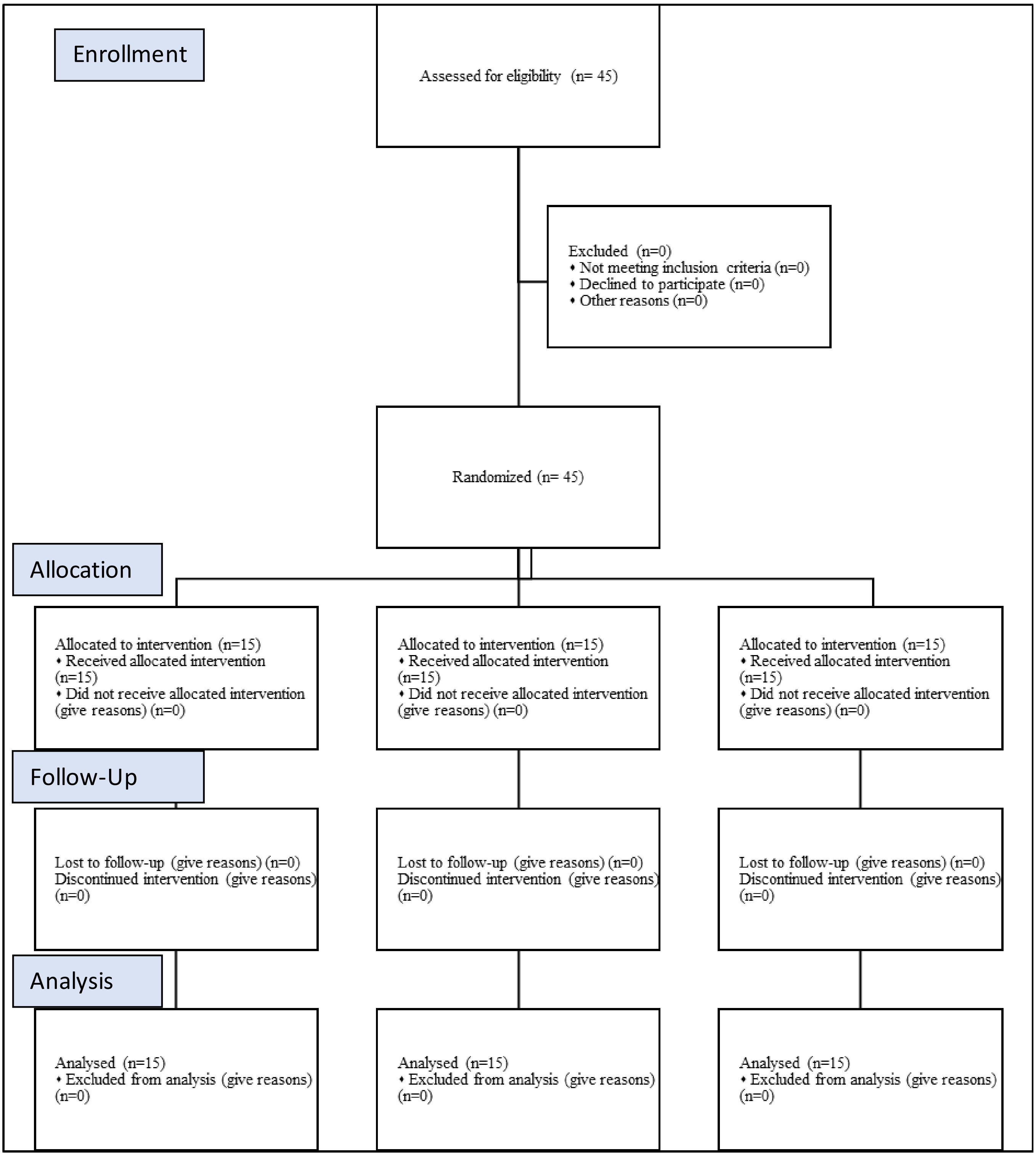

Figure 1: Flow of patients throughout the course of the study

index, and were reported as means (M) and standard deviations (SD). All variables were tested for normality of distribution and met the assumption for the analysis of the variance analyses (one-way and mixed between–within). A one-way analysis of the variance was used to determine the baseline demographic differences and pretest measurements for all variables between the groups. Mixed model analysis of the variance was used to compare the means of the groups to determine whether a significant difference existed. Cohen's d was calculated for pairs with significant differences. Data were analysed using SPSS version 23 (SPSS Inc., Chicago, IL, USA) and the level of significant differences was set at $p < 0.05$.

RESULTS

A total of 45 participants were recruited and included in the analysis (Figure 1). No drop out and important harm occurred. The characteristics are shown in Table I. No group difference between characteristics measures was observed except for age ($p < 0.05$). Majority of the participants were males (n = 28, 62.2%) compared to females (n = 17, 37.8%).

Table I: Participants' anthropometrics measures

Characteristics (n = 45)	NHE (n = 15) M ± SD	SLC (n = 15) M ± SD	SS (n = 15) M ± SD
Age (years)	19.73 ± 1.16	19.93 ± 1.22	21.4 ± 0.51
Height (m)	1.67 ± 0.09	1.68 ± 0.09	1.67 ± 0.08
Weight (kg)	63.53 ± 10.99	70.81 ± 19.96	61.92 ± 15.08
BMI (kg/m²)	22.72 ± 3.26	24.62 ± 5.39	21.91 ± 3.55

The means (SD) of the hamstring flexibility are shown in Table II and Figure 2. Interaction effect between group and time was observed ($F_{2.42} = 3.43$, $p = 0.042$, partial eta squared = 0.14). Time effect was observed ($F_{1.42} = 345.41$, $p < 0.001$, partial eta squared = 0.89) and indicates significant increase in hamstring flexibility following interventions. No significant group difference was observed in hamstring flexibility pre-intervention ($F_{2.42} = 0.075$, $p = 0.93$, partial eta squared = 0.004) and indicates all groups are equally effective in increasing hamstring flexibility. For all groups, differences were observed in hamstring flexibility following interventions [NHE: $p < 0.0001$, ES = 0.90, 95% CI (4.36, 6.77); SLC: $p < 0.0001$, ES = 0.70, 95% CI (4.26, 6.09); SS: $p < 0.0001$, ES = 0.62, 95% CI (3.18, 4.71)].

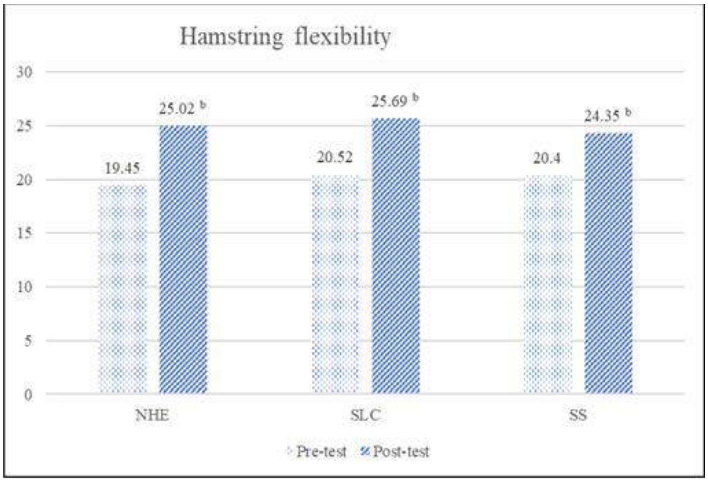

Figure 2: Pre- and post- hamstring flexibility between three groups

DISCUSSION

The aim of this study is to compare the effectiveness of eccentric exercises and static stretching exercise on hamstring flexibility of recreational athletes. After four weeks of intervention, significant improvement in hamstring flexibility was observed in NHE, SLC, and SS with no difference between the three groups. Importantly, this study is the first to report the comparison of different eccentric exercises and static stretching exercise on hamstring flexibility.

Different eccentric hamstring exercises, namely NHE and SLC, effectively increase hamstring flexibility among recreational athletes. The mechanism for the increased hamstring flexibility following NHE and SLC is unclear, however, it could be due to increase in fascicle length contributed by the addition of serial sarcomeres in the muscle fibres (Vogt & Hoppeler 2014), which was observed following other hamstring eccentric exercise i.e. prone hamstring curl (Potier et al. 2009). These changes increase muscle contraction velocity and extensibility, thus allowing more powerful force production at longer muscle lengths, which potentially protect against muscle damage (Vogt & Hoppeler 2014). Increased hamstring flexibility could reduce the risk of hamstring strains especially during sporting activities that imposed high risk of injury to the hamstring such as sprinting (Wan et al. 2017) and kicking (García-Pinillos et al. 2015). On the other hand, fascicle length increases are dependent on the range of lengths used during the intervention (Seymore et al. 2017). The differences in range of motion could lead to a difference in magnitude of architectural changes (Potier et al. 2009).

Table II: Pre and post hamstring flexibility between three groups

Hamstring flexibility (cm)	NHE (n = 15) M ± SD	SLC (n = 15) M ± SD	SS (n = 15) M ± SD	Time effect	Group effect
Pre	19.45 ± 5.91	20.52 ± 7.65	20.40 ± 6.66	< 0.001	0.93
Post	25.02 ± 6.46	25.69 ± 7.17[b]	24.35 ± 6.15		
Difference	5.57 ± 2.17	5.17 ± 1.66	3.95 ± 1.38		
ES	0.90	0.70	0.62		

NHE tends to train on larger knee and hip joint angles, while the SLC tends to train on smaller knee and hip joint angles. However, these effects are not seen in this study.

Significant improvement in hamstring flexibility was also observed in SS, similar to a previous study that found 30 seconds of static stretching, where a slow static stretch facilitates the Golgi tendon organ and produces autogenic inhibition (Davis et al. 2005). With regard to SS chronic effect, a routine program decreases muscle- tendon unit stiffness, but not tendon stiffness, suggesting that SS does not affect the elasticity of tendon structures but affects that of connective tissues in parallel with muscle fibres such as the endomysium, perimysium, and epimysium (Ichihashi et al. 2014). Additionally, a routine SS increases pain thresholds as it modifies the stretch tolerance and inhibits signals from nociceptive fibres by the afferent input from muscles and joints, thus increasing flexibility.

The current study found that eccentric hamstring exercise is equally effective in increasing hamstring flexibility, similar to a previous study by Nelson & Bandy (2004). Although NHE and SLC achieve the same flexibility gains as static stretching, eccentric training offers a more functional option for flexibility training. The multifactorial nature of the hamstrings strain injuries suggests that it is not the sole existence of a single risk factor that leads to injury. NHE and SLC offer both strengthening and flexibility effects. It is believed that after NHE and SLC training, the muscle can generate a greater torque at more extended joint positions, where most damage to the hamstring occurs, further preventing muscle fibre tears that leads to a protection against hamstring strain (Brockett et al. 2001).

When considering the above findings, a few limitations should be taken into account. Firstly, only recreational athlete from 18 to 24 years old were recruited, thus, the findings cannot be generalized to sport-specific athletes of other skill levels, sex or ages. Next, the effects of the eccentric exercises are only limited to four weeks. Further study is needed to determine the effects of different hamstring exercises among sport-specific athletes of other skill levels, gender or ages. Future study should also consider a more extended intervention period.

CONCLUSION

In general, different eccentric exercises such as Nordic Hamstring Exercise and Sliding Leg Curl, and hamstring static stretching effectively improve hamstring muscle flexibility among recreational athletes. The findings provide coaches, athletes, health care and medical professionals with options to effectively increase hamstring flexibility in various stages of rehabilitation and hamstring injury prevention programs.

ACKNOWLEDGEMENTS

The authors would like to thank all individuals who assisted and participated in the experiment.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

FUNDING

This study did not receive any funding.

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