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Effects of Different Neurodynamic Mobilization Techniques on Hamstring Flexibility and Functional Performance in Basketball Players

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ABSTRACT

Background: Hamstring tightness is associated with decreased flexibility and increased injury risk in athletes. While passive stretching is widely used, neurodynamic techniques such as slump and straight leg raise (SLR) sliders may offer additional benefits by mobilizing the neural structures and enhancing muscle extensibility.

Objective: To find the effects of different neurodynamic mobilization techniques on hamstring flexibility and functional performance in basketball players.

Methods: Forty-five basketball players were randomly allocated into three groups: passive stretching (PS), passive stretching with a slump slider (PS+SLUMP), and passive stretching with an SLR slider (PS+SLR). Interventions were administered for eight weeks. Outcome variables included hamstring flexibility and functional performance. Within-group changes were analyzed descriptively using a paired t-test, and between-group differences were examined using one-way ANCOVA.

Results: All groups demonstrated improvements in hamstring flexibility from the pre- to post-test. Post-intervention hamstring flexibility values were 23.16 ± 1.43 cm (PS), 23.58 ± 0.99 cm (PS+SLUMP), and 22.79 ± 0.86 cm (PS+SLR), with no significant between-group differences ($F(2, 41) = 0.819$, $p = 0.448$, partial $\eta^2 = 0.038$). Functional performance showed non-significant improvement pre-post in all three groups and between-group differences ($F(2, 41) = 0.787$, $p = 0.462$, partial $\eta^2 = 0.037$).

Conclusion: Neurodynamic mobilization produces additional benefits in improving hamstring flexibility and functional performance in asymptomatic basketball players.

1. Introduction

Hamstring injuries are common in basketball and are the most severe injuries because of time loss during the season (Liu *et al.*, 2012). Hamstring injuries continue to affect performance in players, and inadequate muscle extensibility remains a commonly known factor (Worrell & Perrin, 1992). 3.3% of hamstring injuries have been documented in basketball players (Drakos *et al.*, 2010), and a recurrence rate of 14.6% has been documented over a six-year period in major league basketball (Okoroha *et al.*, 2019). According to literature, commonly known predisposing factors are insufficient warm-up, poor flexibility, muscle imbalance, neural tension, and fatigue (Croisier, 2004). According to a study by Davis *et al.* (2005), inadequate flexibility within the posterior thigh compartment appears to be one of the more commonly accepted causes of hamstring injuries (Davis *et al.*, 2005).

Involvement of neural tissues in hamstring flexibility has been studied in the literature (Méndez-Sánchez *et al.*, 2010). The nerves that get altered in decreased hamstring flexibility include the sciatic, tibial, and common fibular nerves, as evidenced by limited range in straight leg raise (SLR) (Kornberg & Lew, 1989). During daily activities, the sciatic nerve, which innervates the hamstrings, is exposed to constant pressure during prolonged sitting, standing, and other activities, resulting in hamstring tightness (Lew & Briggs, 1997).

In the treatment of musculoskeletal and sports injuries, nervous system mobilization has emerged as a significant treatment. The purpose of treatment using neurodynamic mobilization is to improve the mechanical and physiological function of neural and associated tissues (Cha *et al.*, 2014). Clinical studies have shown that neurogenic symptoms can be resolved by treatment techniques directed at restoring normal neural biomechanics and physiology (Coppieters & Alshami, 2007). Recent evidence indicates that neurodynamic techniques improve hamstring flexibility immediately and in the short-term in individuals with limited hamstring flexibility (Núñez De Arenas-Arroyo *et al.*, 2025).

Neurodynamic mobilization may enhance motor performance by optimizing neuromuscular function, facilitating more efficient muscle fiber recruitment and synchronization during explosive movements (Castellote-Caballero *et al.*, 2013; Parveen *et al.*, 2024). Similarly, Mendez-Sanchez *et al.* (2010) found that there was significant improvement in range of motion of the knee joint following neurodynamic sciatic nerve sliding, which results in improved hamstring flexibility (Méndez-Sánchez *et al.*, 2010).

Stretching is one of the most effective therapeutic ways to improve and maintain hamstring flexibility (Afonso *et al.*, 2021). Different types of stretching that are commonly used are static, ballistic, contract-relax, and neurodynamic stretching (Stephens *et al.*, 2006). Earlier research has focused on stretching techniques like static stretching, ballistic stretching, and plyometric stretching for increasing flexibility and performance. More recently, several studies have reported the short-term effects of neurodynamic mobilization on hamstring flexibility and performance in basketball athletes (Pereira *et al.*, 2021). However, evidence regarding the long-term effects of different neurodynamic sliding techniques, particularly the slump slider and straight leg raise (SLR) slider, remains limited. This study aims to compare the effect of slump and straight leg raise neurodynamic sliding techniques on hamstring flexibility and functional performance in basketball players. We hypothesized that there will be a significant difference in hamstring flexibility and functional performance in basketball players following different neurodynamic mobilization techniques.

2. Methods

2.1. Research Design

The study was designed as a three-arm, parallel-group, randomized clinical trial with an active control group. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (1964) and received ethical approval from the Jamia Hamdard Institutional Ethics Committee (JHIEC). The study was registered with the Clinical Trial Registry-India, CTRI/2024/04/065932. Written informed consent was obtained from all the participants prior to enrolment.

2.2. Participants and Sample Size

Forty-five university-level basketball players were recruited from the sports complex of Jamia Hamdard, New Delhi, based on predefined inclusion and exclusion criteria. Eligible participants were asymptomatic male basketball players aged 18-25 years who had regularly participated in intercollegiate basketball competitions since at least 1 year. Participants were included if they were able to perform sports activities without pain. Participants having a recent injury, recent surgery, or positive neurologic signs or symptoms suggestive of nerve root involvement (diminished upper or lower extremity reflexes, sensation to sharp and dull, or strength) were excluded from the study.

Sample size was calculated using G*Power software based on the F-test for ANOVA. Using an effect size of 0.5 for hamstring flexibility tested in the present study, an alpha level of 0.05, and a power of 0.90, the required sample size was estimated to be 45 participants.

2.3. Intervention

Participants in Experimental Group 1 received passive stretching combined with slump neurodynamic sliding (PS+SLUMP). Experimental Group 2 performed passive stretching along with straight leg raise (PS+SLR) neurodynamic sliding. The Control Group received only passive stretching (PS). All participants underwent the intervention three times per week for a duration of eight weeks.

2.3.1. Static Stretching

All participants underwent an identical static stretching protocol. Each stretch was performed bilaterally for the targeted muscle groups with a hold duration of 20 seconds and a rest interval of 60 seconds for 6 repetitions for each muscle group.

- **Hamstring muscles:** Participants assumed a supine position with the lower limb fully extended. Using one therapist's hand placed on the heel, the participants passively elevated the limb while maintaining knee extension until the stretch was perceived (Baechle & Earle, 2008).
- **Lumbar muscles:** Participants lay in the supine position with the contralateral knee slightly bent, and the participant flexed the hip and knee of one lower limb and drew it toward the chest (Baechle & Earle, 2008).
- **Piriformis muscle:** Participants adopted a supine position and placed one ankle over the contralateral

knee. The contralateral thigh was then pulled toward the chest until a stretch was perceived in the piriformis muscle (Baechle & Earle, 2008).

- **Hip flexors:** Participants adopted the lunge position and gradually extended the hip of the trailing limb until the stretch was felt (Baechle & Earle, 2008).
- **Stretching of quadriceps:** Participants were in a standing position, flexed one knee, and grasped the ipsilateral forefoot, bringing the heel toward the gluteal region until the stretch was perceived in the quadriceps muscle group (Baechle & Earle, 2008).

2.3.2. Slump Neurodynamic Sliding

For the slump neurodynamic sliding technique, participants were seated at the edge of a plinth while cervical, thoracic, and lumbar flexions were maintained with assistance from the therapist. This technique involved applying mechanical stress to the nervous system at one end while simultaneously releasing it at the other, followed by reversal of the movement sequence. The therapist passively performed a sequence of knee flexion with ankle plantarflexion, followed by knee extension with ankle dorsiflexion in a continuous rhythmic manner for 60 seconds, with a 30-second rest interval between repetitions for 3 repetitions (Sahasrabuddhe & Sadawarte, 2022). Passive stretching was maintained for a duration of 20 seconds with a 60-second rest interval for 6 repetitions.

2.3.3. SLR Neurodynamic Sliding

In the SLR neurodynamic sliding technique, the participants were positioned supine. The therapist passively moved the limb into hip flexion with ankle plantarflexion, followed by hip extension combined with ankle dorsiflexion, maintaining a sliding mechanism of the neural tissue for 60 seconds, with a 30-second rest interval between repetitions for 3 repetitions (Sahasrabuddhe & Sadawarte, 2022). Passive stretching was maintained for a duration of 20 seconds with a 60-second rest interval for 6 repetitions.

2.4. Outcome Variables

2.4.1. Hamstring Flexibility

The sit and reach test was used to measure hamstring flexibility (Baltaci *et al.*, 2003). In this test participants were instructed to sit on a flat surface barefoot with their legs extended in front of the body and toes pointing upward. The feet were placed slightly apart with the sole against the base of the step. Participants then placed one hand over the other and then reached forward as far as possible. At the point of greatest reach of the participants, the therapist measured the distance reached by the fingertips in centimeters. The best of three trials was recorded. The therapist ensured that the knees of the participants stayed extended.

2.4.2. Functional Performance

It was assessed by the estimation of vertical jump height. This outcome measure demonstrated excellent reliability with intra-class correlation coefficients ranging from 0.93 to 0.97 (Sattler *et al.*, 2012). Participants assumed a bipedal stance with their hands positioned on their hips and were instructed to perform the highest possible jump. Standardized verbal encouragement was provided throughout testing to ensure maximal effort. Three valid trials were recorded for each participant with a minimum rest interval of 1 minute between consecutive jumps (Sattler *et al.*, 2012). The best of the three trials was recorded.

2.5. Randomization and Blinding

All participants were randomly divided into the three groups, having 15 participants in each group using simple random distribution. The three intervention groups were the Experimental 1 Group (PS + SLUMP), the Experimental 2 Group (PS + SLR), and the Control Group (PS). This was a single-blinded study in which only the participants were blinded about the intervention group they were allocated to.

3. Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 23. Descriptive statistics were expressed as mean ± standard deviation. Normality of the data was assessed using the Shapiro-Wilk test. Since most of the data were normally distributed, within-group differences pre- to post-differences were assessed using paired-sample t-tests. Between groups, differences in anthropometric measures and outcome measures were analyzed using one-way ANOVA at baseline. If significant differences were found at baseline, ANCOVA was used to measure differences of pre- and post-data between the groups. ANCOVA was selected because it allows comparison while controlling for potential confounding effects of baseline differences. The null hypothesis stated that there would be no significant difference in post-intervention hamstring flexibility and functional performance among the three intervention groups. A p-value < 0.05 was considered statistically significant.

4. Results

A total of 45 basketball players were randomly divided into the three equal groups. All the participants were comparable at the baseline for outcome variables with no significant differences (Table 1). Figure 1 shows participants flow chart.

Table 1: Baseline Characteristics

	PS	PS+SLUMP	PS+SLR	p- value
Age (year)	23.87±2.7	24.60±1.88	24.73±1.53	0.48
Weight (kg)	74.27±9.11	62.27±5.36	64.13±3.94	0.00*
Height (cm)	177.33±5.31	168.33±5.55	163.47±3.60	0.00*
BMI (kg/m2)	23.54±2.64	21.94±1.16	23.93±1.21	0.01*
Hamstring Flexibility (cm)	21.94±1.05	22.49±0.90	21.69±0.71	0.05
Functional Performance (cm)	36.53±6.76	38.80±4.64	39.40±3.91	0.29

Note: Values are presented as mean ± standard deviation, BMI- Body mass index.

4.1. Sit-and-Reach Test (Hamstring Flexibility)

All three groups showed significant improvements in hamstring flexibility after the 8 weeks of intervention. The PS+SLUMP group showed significant improvement from 22.49 ± 0.90 cm to 23.58 ± 0.99 cm, $p < 0.01$; the PS+SLR group significantly improved from 21.69 ± 0.71 cm to 22.79 ± 0.86 cm, $p < 0.01$; and the PS group significantly improved from 21.94 ± 1.05 cm to 23.16 ± 1.43 cm, $p < 0.01$ (Table 2).

No significant difference between groups was observed ($F(2, 41) = 0.819$, $p = 0.448$, partial $\eta^2 = 0.038$) with ANCOVA taking BMI as a covariate.

4.2. Vertical Jump Test (Functional Performance)

No significant improvements were observed in functional performance after the 8 weeks of intervention in any groups. However, improvements were seen within the PS+SLUMP group, which improved from 38.80 ± 4.64 to 39.80 ± 3.93 cm, $p = 0.09$; the PS+SLR group, which improved from 39.40 ± 3.91 cm to 39.47 ± 3.31 cm, $p = 0.89$; and the PS group, which improved from 36.53 ± 6.76 to 37.07 ± 6.67 cm, $p = 0.37$ (Table 2).

No significant difference between groups was observed ($F(2, 41) = 0.787$, $p = 0.462$, partial $\eta^2 = 0.037$) with ANCOVA taking BMI as a covariate.

Table 2: Comparison of Hamstring Flexibility and Functional Performance Across Groups Before and After Intervention

	PS			PS+SLUMP			PS+SLR		
	Pre	post	p- value	Pre	Post	p-value	Pre	Post	p- value
Hamstring Flexibility (cm)	21.94± 1.05	23.16± 1.43	<0.01*	22.49± 0.9	23.58± 0.99	<0.01*	21.69± 0.71	22.79± 0.86	<0.01*
Functional Performance (cm)	36.53± 6.76	37.07± 6.67	0.37	38.80± 4.64	39.80± 3.93	0.09	39.40± 3.91	39.47± 3.31	0.89

Note: Values are presented as mean ± standard deviation.

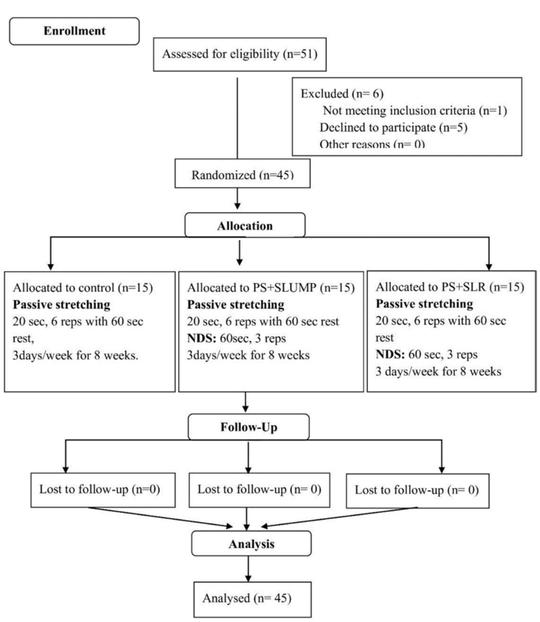

Figure 1: Participants Flow Chart

5. Discussion

The present study compared the effects of slump and SLR neurodynamic sliding techniques on hamstring flexibility and functional performance in basketball players. The main finding was that all three groups (PS, PS+SLUMP, and PS+SLR) showed significant improvement in hamstring flexibility after an 8-week intervention period. However, no significant between-group differences were observed in hamstring flexibility. Functional performance showed non-significant improvements after the intervention.

The finding of this study is consistent with the previous literature, which showed both slump and SLR position sliders appear to effectively address neural tightness, thereby enhancing flexibility when combined with passive stretching. This is supported by Castellote-Caballero *et al.*, who reported significant short-term improvements in hamstring flexibility following neurodynamic sliding compared to no intervention in healthy male soccer players (Castellote-Caballero *et al.*, 2013). Similarly, Parveen *et al.* demonstrated that neural sliders and tensioners, when used as an adjunct to passive stretching, significantly improved knee extension in healthy individuals (Parveen *et al.*, 2024). However, the addition of SLUMP or SLR sliders did not produce a statistically superior outcome compared with stretching alone. It may be due to the fact that the intervention chosen in the control group also targets tightness of all the large muscles, including hamstrings. Secondly, participants in this study were asymptomatic and without any neurological symptom.

The present study also explored the effect of neurodynamic mobilization on functional performance in basketball players. The findings suggest that neurodynamic mobilization does not significantly influence performance outcomes measured by vertical jump height. One possible explanation is that improvement in flexibility alone may not be sufficient to produce measurable changes in explosive performance. Vertical jump encompasses great action, which demands muscle power, strength, and contraction coordination of many muscles, such as quadriceps, hamstrings, and triceps surae. Vertical jump performance requires coordinated activation of different muscle groups (Wilmore *et al.*, 2008). The effects of neurodynamic mobilization may be more noticeable in simple or isolated tasks rather than in activities requiring complex and multi-joint activities.

The lack of significant findings between the groups in the present study may also be due to the control intervention, which showed minimal effects of short-duration stretching on hamstring flexibility and jump performance as reported in a previous study (Perrier *et al.*, 2011). Also, more advanced techniques like isokinetic dynamometry or electromyography can give deeper insights.

The present study contributes valuable evidence to the emerging literature on the effects of neurodynamic mobilization on hamstring flexibility and functional performance. However, it also points to the need for more research to better understand the mechanisms behind these effects and to determine the extent to which neurodynamic mobilization can influence motor control, neuromuscular function, and athletic performance.

6. Limitations of the Study

The present study has several limitations. First, the sample size was relatively small, which may have limited the ability to detect subtle changes between the groups. Second, the participants were asymptomatic basketball players, which may limit the generalizability of the findings to injured athletes. Third, functional performance was assessed using only the vertical jump test.

7. Conclusion

Neurodynamic mobilization techniques used in this study showed significant improvements with both passive stretching alone and combined with neurodynamic sliders in hamstring flexibility and non-significant improvements in functional performance in basketball players. However, neither intervention showed significantly superior improvement than others in hamstring flexibility and functional performance.

Passive stretching remains an effective intervention for improving hamstring flexibility in asymptomatic basketball players. Neurodynamic mobilization may have a role in athletes with neural mechanosensitivity, low back pain, or hamstring-related disorders. Future research can include long-term follow-up assessments to determine whether neurodynamic mobilization influences the maintenance of flexibility and recurrence of hamstring injuries or long-term athletic performance. Also, additional outcome measures such as speed, agility, muscle stiffness, EMG activity, and injury incidence can be taken by researchers.

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Authorship Contribution

Zainul Abdeen: Methodology, Data curation, Experimentation, Investigation, Formal Analysis, Writing – Original Draft; Deepika Singla: Conceptualization, Visualization, Validation, Formal Analysis, Project administration, Resources, Methodology, Writing- Review & Editing; Tasneem Zafar: Software, Data Curation, Validation, Formal Analysis, Project administration, Writing – Review & Editing.

Ethical Approval

Ethical approval was obtained from the Institutional Ethical Committee of Jamia Hamdard (Ref No.: 12/23 (01/11/23)).

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Declarations

The authors declare that the manuscript is original, has not been published previously, and is not under consideration for publication elsewhere. All sources of information used in this study have been appropriately acknowledged and cited.

Data Availability Statement

Authors declare that the data supporting the conclusions of this study can be obtained upon request from the corresponding author, (Singla, D). The data are not publicly accessible due to information that may compromise the privacy of research participants.

Human and Animal Rights

No animals were used in this research. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee.

Figure Permission

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AI Disclosure Statement

The authors declare that no artificial intelligence (AI) tools were used in the writing, analysis, or preparation of this manuscript.

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