Original Article

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Effectiveness of the Muscle Energy Technique versus Neurodynamic Sliding on Hamstring Flexibility and Balance among Athletes

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Abstract:

Objective: Muscle energy technique (MET) and neurodynamic sliding (NDS) are effective in improving hamstring flexibility. However, there is a dearth of information on the efficacy of these techniques for improving balance and regarding which is superior. Therefore, the purpose of the study was to compare the effects of MET with NDS on improving hamstring flexibility and balance among athletes.

Material and Methods: A pre-test and post-test experimental study design with a total of 90 participants (30 cricketers, 30 football players, 30 runners) with unilateral hamstring tightness were randomly assigned to Group MET (n=30), Group NDS (n=30), Group MHP (moist heat pack) (n=30). PSLR (passive straight leg raising), AKE (active knee extension), SST (stork stand test), and mSEBT (modified star excursion balance test) were recorded at baseline and post-intervention.

Results: Paired t-test for pre- and post-test comparisons of all the groups showed significant improvement (p-value=0.000) in all the outcomes. One-way ANOVA for between-group comparisons showed significant differences for PSLR (p-value=0.000), AKE (p-value=0.000), SST (p-value=0.018), mSEBT reach distance [anterior (p-value=0.000), postero-medial (p-value=0.001), and postero-lateral (p-value=0.001)], mSEBT normalized scores [anterior (p-value=0.002), postero-medial (p-value=0.002), and postero-lateral direction (p-value=0.002)], and mSEBT composite scores (p-value=0.002). Level of significance was set at 95%.

Conclusion: MET showed a significant increase in hamstring flexibility; therefore, it is preferred to NDS for increasing hamstring flexibility among athletes. Additionally, MET and NDS are equally effective at improving static and dynamic balance among athletes, as both resulted in comparable outcomes.

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Introduction

The prevalence and incidence of hamstring injuries are widely recognized, especially in football[1], athletics[2], and cricket[3]. For both professional and amateur athletes, hamstring injuries are a substantial source of disability and impairment, as they can result in decreased athletic performance, loss of training and competition time, increased financial burden for rehabilitation, and delayed return to play, impairing the athlete's perceived quality of life[2]. Various risk factors, including inadequate warm-up, poor flexibility, muscular imbalances, neural tension leading to altered neurodynamics, fatigue, prior injuries to hamstrings, and inadequate rehabilitation, have been suggested in the literature, leading to hamstring injuries[2-5]. Despite the devastating effects of hamstring injuries in sports, the best ways to prevent them are still unknown, and the frequency of such injuries has increased recently[6].

Flexibility and balance are important aspects of physical fitness and rehabilitation, and therefore considered vital for normal biomechanical functioning and optimal function in sports[7]. Mobility and balance are linked with hamstring tightness due to its effect on range of motion and pelvic stability[8-10]. The roles of detecting body position and maintaining balance are carried out by the intrafusal fibre, golgi tendon organ, and other proprioceptors. Any variations in the muscle tendon's unit size, stiffness, and muscle activation influence the afferent proprioception (ability to perceive) and efferent muscle activation (ability to respond). This initiates the corresponding muscle responses, eventually influencing the proprioception, altering balance[11-13].

MET is a gentle, non-invasive, and safe therapeutic manual therapy technique that involves the patient's muscle contracting (isometric and/or isotonic contraction) voluntarily in a precisely controlled direction and at changing intensities in opposition to a distinctly executed counter-force applied by the practitioner[14,15]. The physiological mechanisms proposed to account for the changes in muscle or myofascial extensibility produced by MET include reflex relaxation (including golgi tendon response), changes in viscoelastic properties, and changes to stretch tolerance[14,16]. MET can be used to mobilise an immobile joint and stretch tight muscles and fascia[14-16].

The neurodynamic sliding technique alternates between the combined motions of a minimum of two joints, lengthening the nerve bed at one joint, thereby causing tension in the nerves, while concurrently shortening the nerve bed at an adjacent joint, thereby releasing tension in the nerves[17]. This results in a decrease in the neural tissue's mechanosensitivity[18].

There is evidence that both MET[15,16] and NDS[19,20] are effective in improving hamstring flexibility. To date, no study has investigated the comparative efficacy of these two techniques for improving hamstring flexibility. Also, there is a dearth of information in the scientific literature on the efficacy of these techniques regarding improving balance. Therefore, the aim of the study was to compare the effectiveness of the Muscle Energy Technique versus Neurodynamic Sliding on hamstring flexibility and balance among athletes.

Material and Methods

Study design

A pre-post experimental study design was used for the study. The sample design used was convenience sampling, or non-probability sampling. This was a single-

blind study, as the subjects were unaware of the intervention while the therapist was aware of the intervention being given to the subject. The study was accorded ethical approval by the Independent Ethical Committee of the Indian Fertility Society, Approval No. F.1/IEC/IFS/2021No.01, and registered on the Clinical Trials Registry- India (CTRI/2022/02/039977). The study was carried out in accordance with the Declaration of Helsinki (2017).

Sample size calculation

The sample size was determined as "n=90" using G-Power 3.1.9.4 Software with a significance level of 5%, power (1-β) of 95%.

Participants

Ninety participants comprising 86 males and 4 females (30 cricketers, 30 football players, and 30 runners) from Delhi-NCR sports stadiums were recruited for the study. Participants were included if they met the following criteria: unilateral hamstring tightness, as assessed by SLR (≤80 degrees), age between 18 and 30 years, and the ability to read English[5]. The participants with a history of hamstring injury within the last 12 months, low-back pain in the past 6 months, significant backache, major trauma or fracture of the lower limb/ lumbar spine in the past 6 months, disparity in leg length, diagnosed cases or symptoms of conditions including PIVD, spondylolisthesis, spinal stenosis, cancer, inflammation, spinal or lower limb/spinal deformity were excluded from the study[21].

Equipment used

Universal goniometer, hydrocollator unit, stabilizing belt, couch, towel, stopwatch, measuring tape, micropore tape, marker, paper, and pen.

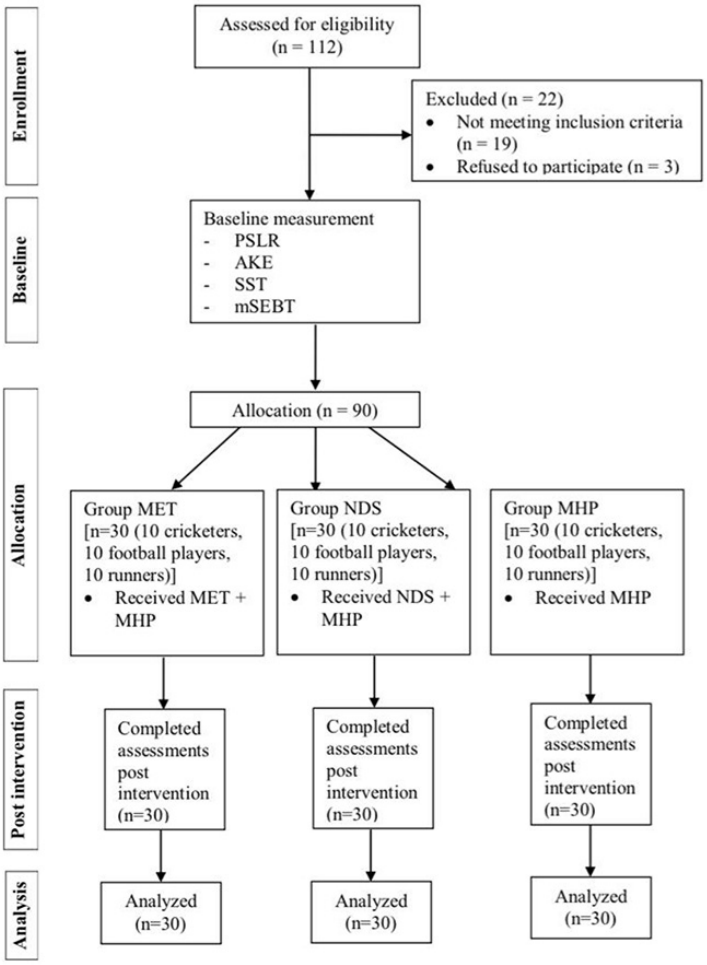
Procedure

After explaining the study details, individuals who expressed their willingness to participate were confirmed for recruitment if eligible based on the inclusion and exclusion criteria. After which, volunteers (n=90) signed the informed consent, protecting their rights. Furthermore, they completed the Physical Activity Readiness Questionnaire (PAR-Q); descriptive data and baseline measurements were obtained. The participants were assigned randomly to Group MET {n=30 (10 cricketers, 10 football players, 10 athletics)}, or Group NDS {n=30 (10 cricketers, 10 football players, 10 athletics)}, or Group MHP {n=30 (10 cricketers, 10 football players, 10 runners)}. Flow of participants is shown in the CONSORT diagram (Figure 1).

Interventions

Group MET (muscle energy technique+moist heat pack) received 15 minutes of moist heat therapy for the hamstring, followed by MET. In the muscle energy technique group, the post-isometric relaxation (PIR) principle was used for the intervention. The subject was positioned supine, with the non-treated leg straight on the examination table. The treated leg was flexed at both the hip and knee, then straightened until the restriction barrier was found [Figure 2(a)]. At this barrier, isometric contraction (20% of available strength) was applied against resistance [Figure 2(b)]. Post 7-10 seconds of isometric contraction, the leg was straightened at the knee towards its new barrier. This slight stretch was held for up to 30 seconds [Figure 2(c)]. In total, 3 sets of MET were performed[14].

Group NDS (neurodynamic sliding+moist heat pack) received 15 minutes of moist heat therapy for the hamstring, followed by NDS. For performing neurodynamic sliding, the subject was positioned supine, with their cervical and thoracic spine in the flexion position, supported by a pillow. Dynamically, simultaneous hip and knee flexion with ankle dorsiflexion [Figure 3(a)] was alternated with simultaneous hip and knee extension with ankle plantar flexion [Figure 3(b)]. This combination of motions was carried out for 180 seconds[5].



PSLR=passive straight leg raising, AKE=active knee extension, SST=stork stand test, mSEBT=modified star excursion balance test, MET=Muscle energy technique, NDS=neurodynamic sliding, MHP=moist heat pack

Figure 1 CONSORT flowchart of participants

Group MHP (moist heat pack) received moist heat therapy only. A large hot pack removed from a hydrocollator unit (preheated at 72 degrees C) and placed in a single layer of towel was applied to the hamstring for 15 min. Additional layers of toweling were added as needed for subject comfort.

Outcome measures

Outcomes were measured at baseline and post-intervention.

Measurement of hamstring flexibility

Passive straight leg raising

The subject was positioned supine on an examination table. The goniometer had been placed to measure the

Figure 2 Application of Muscle energy technique. 2(a). The treated leg was flexed at both the hip and knee and then straightened by the therapist until the restriction barrier was identified. 2(b). Isometric contraction (20% of available strength) for 7–10 sec against resistance was introduced at this barrier. 2(c). Leg was straightened at the knee towards its new barrier. This slight stretch was held for up to 30 seconds

Figure 3 Application of Neurodynamic sliding technique 3(a). Hip and knee flexion with ankle dorsiflexion.3(b).Hip and knee extension with ankle plantar flexion.

angle of hip flexion (axis – on the greater trochanter of the femur; moving arm – directed towards the lateral condyle of the femur; stationary arm – parallel to the examination table). The examiner lifted one of the subject's legs by the ankle, keeping the knee straight and the ankle in a neutral position, while the other leg remained flat on the table. The leg was lifted until the subject first experienced discomfort or resistance was felt in the hamstring, and the degree of hip flexion was noted by a second examiner[5,21]. The average of three measurements was obtained. Passive SLR has demonstrated high interobserver reliability [0.94–0.96][5,21].

Active knee extension

The subject was positioned supine with the ipsilateral hip and knee flexed to 90 degrees by the examiner. The contralateral lower extremity was stabilized on the examination table. The goniometer had been placed to measure the angle of knee extension (axis – on the knee joint axis over the lateral joint line; moving arm – directed towards the lateral malleolus; stationary arm – directed towards the greater trochanter). The subject actively extended their knee, and the angle of knee extension was recorded when the subject reached their maximum extension or felt a significant stretch in the hamstrings[22]. The average of three measurements was obtained. The intratester reliability of the active knee extension test has been reported to be 0.99[22].

Measurement of balance

Stork stand test

The subject was positioned standing barefoot on a flat surface with their hands placed on their hips. They were instructed to lift one leg, bending the knee and placing the foot against the inner thigh of the standing leg. The heel of the stance limb was raised. The examiner used a stopwatch to time how long the subject could hold the stance[7,23]. The best of three attempts was recorded as the final score (duration in seconds). Ability to hold the position for <10 sec indicated poor balance; 10–24 sec, fair; 25–39 sec, average; 40–50 sec, good; >50 sec, excellent. It is a valid and reliable tool [test–retest reliability (r=0.87)][7,23].

Modified star excursion balance test

Before conducting the mSEBT test, the length of the lower limb was measured. With the subject in the supine-lying position, using a cloth measuring tape, the distance from the anterior superior iliac spine to the most distal aspect of the medial malleolus was obtained. A "Y" was made on the ground using an adhesive micropore tape. Three lines of "Y" were made using a goniometer, with an angle of 90 degrees between the posterior lines and 135 degrees between the posterior and anterior lines. The subject was positioned at the centre of a 'Y' marked on the floor, standing on one leg with hands on hips. The other leg was free to move and reach in the anterior, posteromedial, and posterolateral directions. The subject reached with the swing limb as far as possible along each line without losing balance and returned to the starting position. The maximum distance reached in each direction was measured (average of three measurements was obtained) and scores were calculated[24,25]. It is a valid and reliable tool[24] with an intra and interrater reliability from good to excellent (intraclass correlation coefficient ranging from 0.87 to 0.94)[25].

Statistical analysis

The SPSS software, Version 21 (IBM Corp., Armonk, NY, USA) was used for all statistical analyses. The normality of the data distribution was checked using the Shapiro-Wilk test, which showed the data were normally distributed (p-value>0.05). The mean±S.D. for each variable was described using descriptive statistics. The demographic characteristics and the baseline criterion measures were compared among the three groups at study entry by one-way analysis of variance (ANOVA). Paired t-test was used for significance testing for within-group analysis. One-way ANOVA was used for significance testing for between-

group analysis, followed by POST HOC ANALYSES – BONFERRONI for the difference between the two groups. Level of significance was set at 95% or p-value<0.05, to be considered statistically significant.

Results

The demographic characteristics of all 90 subjects (86 males and 4 females) at baseline showed no difference (Table 1). No significant differences (p-value>0.05) were seen at baseline for PSLR, AKE, SST, and for mSEBT reach distance [anterior, postero-medial, postero-lateral], mSEBT normalized scores [anterior, postero-medial, and postero-lateral], and mSEBT composite scores between groups MET, NDS, and MHP (Table 2).

Pre- and post-test comparisons using a paired t-test for groups MET, NDS, and MHP showed a significant improvement (p-value=0.000) in all the outcomes (Table 3). Between-group comparisons using One-way ANOVA (Table 4) showed significant differences (p-value<0.05) for PSLR, AKE, SST, and for mSEBT reach distance [anterior, postero-medial, postero-lateral], mSEBT normalized scores [anterior, postero-medial, and postero-lateral], and mSEBT composite scores. Results of the post-hoc tests for determining the significant difference between groups are shown in Table 4.

Table 1 Participant characteristics at baseline for group MET, NDS & MHP

Characteristics	MET	NDS	MHP	F-value	p-value
	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.		
AGE (years)	20.73± 3.50	19.97± 2.34	21.63±4.11	1.81	0.17^{NS}
BMI (kg/m^2)	21.93±2.01	21.19±2.07	21.56±1.71	1.08	0.342^{NS}
LL (cm)	90.64±6.27	89.43±4.15	89.63±5.08	0.463	0.631^{NS}

MET=muscle energy technique, NDS=Neurodynamic slding; MHP=moist heat pack, S.D.=standard deviation, BMI=body mass index, kg=kilogram, m^2=metre square, LL=limb length of lower limb, cm=centimeter, ^{NS}=indicates no significant difference at 0.05 level

Table 2 Variable characteristics at baseline for group MET, NDS & MHP

Dependent Variables	MET (Mean±S.D.)	NDS (Mean±S.D.)	MHP (Mean±S.D.)	F-value	p-value
PSLR	72.73±4.42	71.57±5.78	73.13±5.35	0.73	0.484^{NS}
AKE	28.27±3.28	30.57±4.44	28.37±4.57	2.96	0.057^{NS}
SST	14.27±7.35	14.80±7.96	13.23±5.95	0.37	0.689^{NS}
mSEBT_AN	112.13±10.28	111.27±8.86	114.33±9.68	0.81	0.449^{NS}
mSEBT_PM	106.47±10.97	108.8±10.06	110.13±9.00	1.03	0.363^{NS}
mSEBT_PL	104.63±9.41	106.3±9.10	108.60±9.59	1.36	0.263^{NS}
mSEBT_NS_AN	123.78±8.49	124.71±11.89	127.89±12.42	1.14	0.325^{NS}
mSEBT_NS_PM	117.50±9.32	121.98±13.32	123.15±11.13	2.06	0.133^{NS}
mSEBT_NS_PL	115.50±7.73	119.12±11.69	121.52±12.58	2.33	0.104^{NS}
mSEBT_CS	118.93±7.92	121.94±12.02	124.19±11.75	1.81	0.169^{NS}

MET=muscle energy technique, NDS=Neurodynamic slding, MHP=moist heat pack, ^{NS}=indicates no significant difference at 0.05 level, S.D.=standard deviation, PSLR=passive straight leg raising, AKE=active knee extension, SST=Stork stand test, mSEBT_AN=mSEBT reach distance in anterior direction, mSEBT_PM=mSEBTreach distance in postero-medial direction, mSEBT_PL=mSEBT reach distance in postero-lateral direction, mSEBT_NS_AN=mSEBT normalized score in anterior direction, mSEBT_NS_PM=mSEBT test normalized score in postero-medial direction, mSEBT_NS_PL=mSEBT normalized score in postero-lateral direction, mSEBT_CS=mSEBT composite score

Table 3 Within group analysis for group MET, NDS & MHP

Dependent Variables	MET		NDS		MHP		p-value
	Pre-test (Mean±S.D.)	Post-test (Mean±S.D.)	Pre-test (Mean±S.D.)	Post-test (Mean±S.D.)	Pre-test (Mean±S.D.)	Post-test (Mean±S.D.)	
PSLR	72.73 ± 4.42	89.50 ± 3.68	71.57 ± 5.78	85.63±4.79	73.13±5.35	79.50 ±4.69	0.00*
AKE	28.27±3.28	18.50±2.66	30.57±4.44	21.40±4.45	28.37±4.57	24.57±4.36	0.00*
SST	14.27±7.35	18.17±7.10	14.80±7.96	18.00±7.53	13.23±5.95	13.67±5.65	0.00*
mSEBT_AN	112.13±10.28	126±9.64	111.27±8.86	124.43±8.30	114.33±9.68	116.36±10.16	0.00*
mSEBT_PM	106.47±10.97	119.87±10.17	108.8±10.06	120.57±9.57	110.13±9.00	111.80±9.49	0.00*
mSEBT_PL	104.63±9.41	117.83±9.42	106.3±9.10	118.9±8.86	108.60±9.59	110.23±9.89	0.00*
mSEBT_NS_AN	123.78±8.49	139.16±7.84	124.71±11.89	139.55±11.59	127.89±12.42	130.16±12.84	0.00*
mSEBT_NS_PM	117.50±9.32	132.37±8.62	121.98±13.32	135.16±13.09	123.15±11.13	125.01±11.64	0.00*
mSEBT_NS_PL	115.50±7.73	130.10±7.33	119.12±11.69	133.24±11.76	121.52±12.58	123.33±12.79	0.00*
mSEBT_CS	118.93±7.92	133.87±7.34	121.94±12.02	135.95±11.89	124.19±11.75	126.16±12.13	0.00*

MET=muscle energy technique, NDS=Neurodynamic slding, MHP=moist heat pack, *=indicates p value significant at 0.05 level, S.D.=standard deviation, PSLR=passive straight leg raising, AKE=active knee extension, SST=stork stand test, mSEBT_AN=mSEBT reach distance in anterior direction, mSEBT_PM=mSEBT reach distance in postero-medial direction, mSEBT_PL=mSEBT reach distance in postero-lateral direction, mSEBT_NS_AN=mSEBT normalized score in anterior direction, mSEBT_NS_PM=mSEBT test normalized score in postero-medial direction, mSEBT_NS_PL=mSEBT normalized score in postero-lateral direction, mSEBT_CS=mSEBT composite score

Table 4 One way ANOVA and Post hoc analysis for between group comparisons post intervention

Dependent Variables	MET (Mean±S.D.)	NDS (Mean±S.D.)	MHP (Mean±S.D.)	F-value	p-value	Post hoc analysis – Bonferroni test p-value		
						MET vs MHP	NDS vs MHP	MET vs NDS
PSLR	89.50±3.68	85.63 ± 4.79	79.50 ± 4.69	39.13	0.001*	0.000*	0.000*	0.003*
AKE	18.50±2.66	21.40±4.45	24.57±4.36	18.04	0.001*	0.000*	0.007*	0.015*
SST	18.17±7.10	18.00±7.53	13.67±5.65	4.21	0.018*	0.037*	0.047*	1^{NS}
mSEBT_AN	126±9.64	124.43±8.30	116.36±10.16	9.07	0.001*	0.000*	0.004*	1^{NS}
mSEBT_PM	119.87±10.17	120.57±9.57	111.80±9.49	7.49	0.001*	0.006*	0.002*	1^{NS}
mSEBT_PL	117.83±9.42	118.9±8.86	110.23±9.89	7.58	0.001*	0.007*	0.002*	1^{NS}
mSEBT_NS_AN	139.16±7.84	139.55±11.59	130.16±12.84	6.96	0.002*	0.006*	0.004*	1^{NS}
mSEBT_NS_PM	132.37±8.62	135.16±13.09	125.01±11.64	6.49	0.002*	0.04*	0.002*	1^{NS}
mSEBT_NS_PL	130.10±7.33	133.24±11.76	123.33±12.79	6.49	0.002*	0.05*	0.002*	0.801^{NS}
mSEBT_CS	133.87±7.34	135.95±11.89	126.16±12.13	6.99	0.002*	0.019*	0.002*	1^{NS}

MET=muscle energy technique, NDS=Neurodynamic slding, MHP=Moist heat pack, *=indicates p value significant at 0.05 level, ^{NS}=indicates no significant difference at 0.05 level, S.D.=standard deviation, PSLR=passive straight leg raising, AKE=active knee extension, SST=stork stand test, mSEBT_AN=mSEBT reach distance in anterior direction, mSEBT_PM – mSEBT reach distance in postero-medial direction, mSEBT_PL=mSEBT reach distance in postero-lateral direction, mSEBT_NS_AN=mSEBT normalized score in anterior direction, mSEBT_NS_PM=mSEBT test normalized score in postero-medial direction, mSEBT_NS_PL=mSEBT normalized score in postero-lateral direction, mSEBT_CS=mSEBT composite score

Discussion

The results of this study demonstrated that MET was significantly (p-value<0.05) better than NDS in increasing hamstring flexibility, and both MET and NDS were significantly (p-value<0.05) better at increasing hamstring flexibility compared to the MHP group. Additionally, there was no statistically significant difference (p-value>0.05) between MET and NDS in improving static and dynamic

balance, and both MET and NDS were significantly better (p–value<0.05) at improving the static and dynamic balance compared to the MHP group.

Previous studies have reported improvements in hamstring flexibility after the application of MET among futsal players[26], football players[27], and athletes[28]. A systematic review and meta–analysis conducted on the efficacy of MET to improve hamstring flexibility reported that MET was more efficient for improving the flexibility of hamstrings compared to stretching or no treatment, as it combines isometric contraction with stretching[15].

The reason for the increase in the flexibility of hamstrings in the MET group is due to the changes in muscle elasticity[14,16]. Reflex muscle relaxation after muscle contraction has been postulated to occur due to GTO activation, which inhibits the muscle from creating any force. Further, it is hypothesised that passive tension reductions of a comparable magnitude occur during both muscle stretching and contraction, indicating the viscoelastic stress relaxation of MTU[14,16]. During an isometric contraction, the connective tissues must lengthen to offset the shortening of the contractile elements, if a muscle is to maintain its length. A combination of stretching and isometric contractions, as used in MET, activates the proprioceptors and mechanoreceptors in the muscles and joints, which might decrease pain perception, hence permitting more muscular elongation[14].

Previous studies have reported improvements in hamstring flexibility after the application of neurodynamic sliding among elderly populations[29], healthy adults[8], soccer players[1], and male football players[30]. A systematic review[19] reported that neurodynamic treatment was more effective in improving hamstrings flexibility compared with no intervention and other techniques.

The reason for the increase in hamstring flexibility in the NDS group is due to the changes in neurodynamics. Tension is induced into the neural system when neurodynamics are applied. The sciatic nerve is lengthened by the axonal transport system after it has been shortened by the influence of hamstring flexibility and the nearby associated structures[31]. Following nerve and muscle elongation, muscular performance improves[32]. NDS alters the extraneural interface and facilitates the sciatic nerve's linear excursion. This may minimize the adhesions, limiting the excursions of the neural tissue, which reduces the neural mechanosensitivity and improves the viscoelasticity of the neural tissue, leading to an increase in the mobility of the hamstrings[17,18].

The possible reason for the significant results in the MET group for improving the flexibility of hamstrings could be attributed to the fact that MET involves a combination of contractions and stretches[14], which may be more efficient than neurodynamic sliding alone at causing viscoelastic change. This is because higher forces may result in enhanced passive extensibility and viscoelastic change, hence resulting in more flexibility.

Increases in flexibility in the MHP group could be attributed to the reflexive reduction in muscle tone brought on by the application of heat. Heat is an effective adjunct to stretching maneuvers and should be the treatment of choice for increasing the range of motion in a clinical or sporting setting[33] because of its effect on the properties of connective tissue: increased collagen extensibility, reduced muscle spasm, decreased joint stiffness, pain relief, changes in metabolism, nerve transmission, hemodynamics, and mechanical properties[33,34]. As the connective tissue temperature rises, the connective tissue's resistance to stretch decreases, which further facilitates an increase in soft tissue extensibility, causing less tissue damage compared with a similar stretch force at lower temperatures[34].

There is a dearth of information on the efficacy of MET or NDS for improving the balance of lower limbs in the scientific literature. Results of the present study are in accordance with the previous studies done on

hamstrings, where MET improved balance among collegiate students[35]and young adults[9], and NDS improved balance among the elderly population[29] and adults[8].

Improvements in both static and dynamic balance in the MET and NDS groups are attributed to increased proprioceptive inputs through joint mechanoreceptor stimulation[12,13,36]. MET acts on joint mechanoreceptors and proprioceptors, modifying the target joint's motor programming by influencing the descending pathways[16]. Similarly, NDS is believed to demonstrate peripheral nerve responses that include increased pain pressure thresholds, decreased nerve stiffness, and stimulation of joint mechanoreceptors by dynamic alteration in joint motion as performed in NDS, which further facilitates nerve function[37].

The hamstring is considered a crucial muscle in order to maintain balance and posture while standing. Previous studies found that postural balance is enhanced as a result of increased hamstring flexibility[29,38]. The fascia transmits the force of stretching to distant joints, and therefore, it is hypothesized that the range of motion of distant joints may be increased by maneuvers that lengthen the hamstrings. As a result, pelvic and spinal muscles are stabilized and normal posture is restored, thereby improving static balance[39].

In order to overcome balance disturbances, a stiffer MTU might enable a force-dependent, fast response, while an optimal level of MTU might enable energy absorption so that the centre of mass stays within the base of support[40]. Furthermore, a compliant MTU would deliver tension to the GTO slower than a stiffer MTU, delaying muscle tension detection by GTO. Alterations in the length and elasticity of the MTU can impact afferent responses to variations in the length of the muscle and tension[11]. The perception of the intrafusal stretch receptors could also be affected by changes in increased length and decreased stiffness of MTU. As a result, changes in muscle compliance brought on by stretching or similar maneuvers may have an impact on both the muscle's afferent input to the central nervous system and its ability to produce muscle output to counteract unplanned perturbations in balance[11]. Consequently, a more compliant MTU system may be partly responsible for potential improvements in balance by enabling the creation of force or absorption of energy over longer muscle lengths[40].

Limitations

Firstly, athletes 18-30 years of age were recruited for the study. Thus, the results cannot be generalized to all age groups. Secondly, only the immediate effects were investigated. Thirdly, only cricket, football, and athletics were considered for the recruitment of athletes. Lastly, few females volunteered for the study. Therefore, the findings cannot be generalized to both genders.

Clinical implications of the study

This study adds to the literature on the use of MET and NDS to make evidence-based decisions on the appropriate use of either mode of treatment for improving hamstring flexibility and balance of the lower limb. Collaboration with sports teams and guiding them to implement the evidence-based treatment protocols will help society benefit in terms of optimal athletic performance, less injury risk, less financial burden due to injury, and further recognition of the physiotherapy profession. In today's sports scenarios, where the majority of the athletes are likewise trained and conditioned, following evidence-based treatment protocols will help gain a competitive advantage over those following more conventional protocols.

Conclusion

The muscle energy technique and neurodynamic sliding are effective in increasing hamstring flexibility and both static and dynamic balance among athletes. However, MET showed significant increases in hamstring flexibility; therefore, MET is preferred to NDS for increasing hamstring

flexibility among athletes. Additionally, MET and NDS are equally effective in increasing static and dynamic balance among athletes, as both resulted in comparable outcomes.

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Conflict of interest

There are no potential conflicts of interest in the development and publication of this article.

References

1. Castellote-Caballero Y, Valenza MC, Martín-Martín L, Cabrera-Martos I, Puentedura EJ, Fernandez-de-Las-Penas C. Effects of a neurodynamic sliding technique on hamstring flexibility in healthy male soccer players. A pilot study. Phys Ther Sport 2013;14:156-62.
2. Silvers-Granelli HJ, Cohen M, Espregueira-Mendes J, Mandelbaum B. Hamstring muscle injury in the athlete: state of the art. J ISAKOS 2021;6:170-81.
3. Jerome A, Gharote G, Pardeshi T, Jeyabalan K. Prevalence of muscle strain among cricketers-an observational study. Res J Science Tech 2018;10:211-6.
4. Bahr R, Holme I. Risk factors for sports injuries—a methodological approach. Br J Sports Med 2003;37:384-92.
5. Castellote-Caballero Y, Valenza MC, Puentedura EJ, Fernández-de-las-Peñas C, Alburquerque-Sendín F. Immediate effects of neurodynamic sliding versus muscle stretching on hamstring flexibility in subjects with short hamstring syndrome. J Sports Med 2014:1-8.
6. Haddad FS, Paton BM, Plastow R, Wilson MG. Basics must improve to reduce the burden of hamstring muscle injuries. Br J Sports Med 2023;57:252-3.
7. Peterson DD. Periodic fitness testing: Not just for athletes anymore. Strength Cond J 2018;40:60-76.
8. Park J, Cha J, Kim H, Asakawa Y. Immediate effects of a neurodynamic sciatic nerve sliding technique on hamstring flexibility and postural balance in healthy adults. Phys Ther Rehabil Sci 2014;3:38-42.
9. Ruparelia H, Patel S. Immediate effect of muscle energy technique (MET) and positional release therapy (PRT) on SLR90^0-90^0, ankle dorsiflexion range and Y-balance test—an experimental study. Int J Health Sci Res 2019;9:53-8.
10. Shah C. The effect of hamstring and calf tightness on static, dynamic balance and mobility-a correlation study. Indian J Physiother Occup Ther 2013;7:17-22.
11. Behm DG, Bambury A, Cahill F, Power K. Effect of acute static stretching on force, balance, reaction time, and movement time. Med Sci Sports Exerc 2004;36:1397-402.
12. Filipa A, Byrnes R, Paterno MV, Myer GD, Hewett TE. Neuromuscular training improves performance on the star excursion balance test in young female athletes. J Orthop Sports Phys Ther 2010;40:551-8.
13. Lim KI, Nam HC, Jung KS. Effects on hamstring muscle extensibility, muscle activity, and balance of different stretching techniques. J Phys Ther Sci 2014;26:209-13.
14. Chaitow L. Muscle energy techniques. 3rd ed. London: Churchill Livingstone; 2006:1-187.
15. Kang YH, Ha WB, Geum JH, et al. Effect of muscle energy technique on hamstring flexibility: systematic review and meta-analysis. Healthcare 2023;11:1089.
16. Thomas E, Cavallaro AR, Mani D, Bianco A, Palma A. The efficacy of muscle energy techniques in symptomatic and asymptomatic subjects: a systematic review. Chiropr Man Ther 2019;27:1-8.
17. Coppieters MW, Butler DS. Do 'sliders' slide and 'tensioners' tension? An analysis of neurodynamic techniques and considerations regarding their application. Manual Therapy 2007;13:213-21.
18. Basson A, Olivier B, Ellis R, Coppieters M, Stewart A, Mudzi W. The effectiveness of neural mobilization for neuromusculoskeletal

conditions: a systematic review and meta-analysis. J Orthop Sports Phys Ther 2017;47:593-615.
19. Lopez LL, Torres JR, Rubio AO, Sanchez IT, Martos IC, Valenza MC.Effects of neurodynamic treatment on hamstrings flexibility: A systematic review and meta-analysis. Phys Ther Sport 2019;40:244-50.
20. Macias CH, Hernandez VP, Seguín LM. A systematic review of the efficacy of neural mobilisation in sport: a tool for the neural tension assessment. J Bodyw Mov Ther 2024;24:1409-16.
21. Babu VK, Akalwadi A, Kumar SN, Mahendrabhai UM. Immediate effect Of neurodynamic sliding technique versus mulligan bent leg raise technique on hamstring flexibility in asymptomatic individuals. Int J Physiother 2015;2:658-66.
22. Norris CM, Matthews M. Inter-tester reliability of a self-monitored active knee extension test. J Bodyw Mov Ther 2005;9:256-9.
23. Castillo-Rodríguez A, Onetti-Onetti W, Sousa Mendes R, Luis Chinchilla-Minguet J. Relationship between leg strength and balance and lean body mass. Benefits for active aging. Sustainability 2020;12:2380-9.
24. Onofrei RR, Amaricai E, Petroman R, Suciu O. Relative and absolute within-session reliability of the modified Star Excursion Balance Test in healthy elite athletes. Peer J 2019;7:e6999.
25. Van Lieshout R, Reijneveld EA, Van Den Berg SM, et al. Reproducibility of the modified star excursion balance test composite and specific reach direction scores. Int J Sports Phys Ther 2016;11:356-65.
26. Sundaram SS. The effect of muscle energy technique on flexibility of hamstring muscle in futsal players. MOHE 2020;9:35-44.
27. Adkitte R, Rane SG, Yeole U, Nandi B, Gawali P. Effect of muscle energy technique on flexibility of hamstring muscle in Indian national football players. Saudi J Sports Med 2016;16:28-31.
28. Rojhani-Shirazi Z, Salimifard MR, Barzintaj F. Comparison of the effects of static stretching and muscle energy technique on Hamstring flexibility, pain, and function in athletes with Patellofemoral pain. J Adv Pharm Educ Res 2021;11:33-8.
29. Roy S, Kaur S, Koley S. Effect of neurodynamic sliding technique on bilateral hamstring flexibility and balance in normal elderly population. Int J Yogic Hum Mov Sports Sci 2021;6:26-9.
30. Areeudomwong P, Oatyimprai K, Pathumb S. A randomised, placebo-controlled trial of neurodynamic sliders on hamstring responses in footballers with hamstring tightness. Malays J Med Sci 2016;23:60-9.
31. Webright WG, Randolph BJ, Perrin DH. Comparison of nonballistic active knee extension in neural slump position and static stretch techniques on hamstring flexibility. J Orthop Sports Phys Ther 1997;26:7-13.
32. Coutinho EL, DeLuca C, Salvini TF, Vidal BC. Bouts of passive stretching after immobilization of the rat soleus muscle increase collagen macromolecular organization and muscle fiber area. Connect Tissue Res 2006;47:278-86.
33. Bleakley CM, Costello JT. Do thermal agents affect range of movement and mechanical properties in soft tissues? A systematic review. Arch Phys Med Rehabil 2013;94:149-63.
34. Lentell G, Hetherington T, Eagan J, Morgan M. The use of thermal agents to influence the effectiveness of a low-load prolonged stretch. J Orthop Sports Phys Ther 1992;16:200-7.
35. Chawdi M, Shah DN. Effect of muscle energy technique vs retro-walking on hamstring flexibility and dynamic balance in young college going students-a comparative study. Int J Health Sci Res 2022;12:14-20.
36. Ghaffarinejad F, Taghizadeh S, Mohammadi F. Effect of static stretching of muscles surrounding the knee on knee joint position sense. Br J Sports Med 2007;41:684-7.
37. Martins C, Pereira R, Fernandes I, et al. Neural gliding and neural tensioning differently impact flexibility, heat and pressure pain thresholds in asymptomatic subjects: A randomized, parallel and double-blind study. Phys Ther Sport 2019;36:101-9.
38. Anandhi D, Nivethika S. Effectiveness of retrowalking on hamstring tightness and dynamic balance in young collegiate students. Int J Yoga Physiother Phys Educ 2018;3:197-201.
39. Hyong IH, Kang JH. The immediate effects of passive hamstring stretching exercises on the cervical spine range of motion and balance. J Phys Ther Sci 2013;25:113-6.
40. Behm DG, Kay AD, Trajano GS, Blazevich AJ. Mechanisms underlying performance impairments following prolonged static stretching without a comprehensive warm-up. Eur J Appl Physiol 2021;121:67-94.